Hero or Villain?
Insider Selling through Stock Repurchase Programs*

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Abstract

Contrary to value-maximizing repurchases signaling stock undervaluation, there is evidence that firms also repurchase overvalued stock and insider-selling is correlated with repurchases. We examine signaling through repurchases with strategic insider selling. Informed insiders can coordinate repurchases to manipulate prices with their stock sales and increase their wealth at the expense of uninformed shareholders both when the stock is undervalued or overvalued. By increasing benefits from repurchase announcements, insider-selling amplifies the incentives of good firms to separate and those of bad firms to mimic. Our analysis is consistent with observed variation in announcement returns of repurchases, and generates novel empirical predictions.

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1 Introduction

Over the last four decades, financial markets have experienced dramatic growth in stock repurchase programs (Grullon and Michaely 2002; Skinner 2008; Farre-Mensa et al. 2014). [1] Based on empirical findings of positive announcement and long-run returns for repurchase programs, a long-standing literature argues that firms repurchase *undervalued* stock.[2] From this perspective, repurchases increase market efficiency by correcting security mispricing by signaling stock undervaluation. However, there is growing evidence that appears at odds with this view of share repurchase programs. In particular, the empirical literature finds that firms also repurchase *overvalued* stock and hence potentially interfere with market corrections to eliminate mispricing (Edmans, Fang and Huang 2022). Moreover, recent studies document that both short- and long-term returns following open-market program announcements have decreased over time and even become insignificant (Ikenberry, Lakonishok and Vermaelen 2000; Obernberger 2014; Fu and Huang 2016; Lee et al. 2020). It is thus apparent that signaling by share purchases and their relation to market efficiency need reconsideration. Our study attempts to fill this gap in the literature.

Our analysis builds on substantial evidence that insider *selling* plays an important role in firms' decisions to set up a repurchase program as well as in its execution: Insider trading is correlated with both stock repurchase announcements (Kahle 2002; Babenko 2009) and firms' actual repurchases (Bonaime and Ryngaert 2013; Ben-Rephael et al. 2014; Moore 2020; Edmans et al. 2022). But insiders are informed agents who are in a position to strategically set repurchase policy to enhance the value of their shareholdings in the firm: either through repurchasing under-valued shares (Brennan and Thakor 1990) or by repurchasing over-valued shares while simultaneously selling vesting equity.[3] Thus, both information signaling and manager-shareholder agency conflicts can influence the design and timing of share repurchase programs.

We develop a framework that considers signaling through repurchase programs in the presence of strategic insider selling by (personal) wealth-maximizing managers. We thus examine share repurchases in the realistic setting of information signaling and shareholder-manager agency conflicts. We show that informed insiders can increase their wealth at the expense of uninformed shareholders

[1] Indeed, this trend is still continuing: In 2023, S&P 500 companies spent $800 billion on stock repurchases, up from about $560 billion in 2020 (See S&P Global, March 18, 2024).

[2] This literature includes Vermaelen (1981), Dann (1981), Ofer and Thakor (1987), Chowdry and Nanda (1994), Lucas and McDonald 1998), McNally (1999), Oded (2005), Babenko, Tserlukevich and Vedrashko (2012), and Kumar, Langberg, Oded and Sivaramakrishnan (2017).

[3] While, in general, trade based on private information is legally forbidden, the law protects firms from being sued when they repurchase their shares if they follow benign guidelines under the Safe Harbor Act (1982). These guidelines were further softened in 2002 (see https://www.sec.gov/rules/final/33-8335.htm).

by repurchasing shares *both* when the stock is undervalued or overvalued by strategically timing their sales to coincide with overvaluation states. By increasing benefits from repurchase announcements, insider-selling amplifies the incentives of managers of good firms to separate and those of bad firms to mimic. Insider-selling can thus both increase price efficiency by supporting signaling or dampen efficiency by disallowing separation, depending on salient firm characteristics (identified by our framework). To our knowledge, we are the first to offer a unified framework to explain: observed repurchase of overvalued securities; correlation of insider trading with corporate repurchases; and weak (or insignificant) announcement effects of repurchases because of possible unraveling of signaling equilibria.

More specifically, our study focuses on the effects of strategic insider selling on the existence and likelihood of signaling by repurchase programs. Intuitively, signaling can unravel because insiders can sell their shares at a higher price by having the firm support the stock price through repurchases, thereby increasing the incentives of low value firms to mimic high value firms. We therefore address the following questions: Does signaling by repurchases still survive in the presence of strategic insider selling? Does insider selling increase market efficiency by encouraging firms to set up repurchase programs and thereby signal value-relevant information? Or does insider selling dampen efficiency by enabling coordinated trading and repurchases that confound signaling?

We focus on open market programs which account for the vast majority of all repurchases.[4] We start with the benchmark case of signaling with stock repurchases when (informed) insiders control the decision to announce a repurchase program and subsequently control the execution of the (announced) program contingent on future outcomes, but cannot trade their own shares during the execution phase. For simplicity, we consider a two-types setup where the firm can be a high value ("good") firm or a low value ("bad") firm; and, at the outset, the firm-type is known only to the insiders but is unknown to the public. Here, we characterize how the existence of a signaling/pooling equilibrium depends on the cost of repurchasing (versus benefit from not repurchasing). We show that in this case, for a signaling equilibrium to hold, the value-difference (or variance) must be high enough to deter the bad-type firm from mimicking the good-type firm. Moreover, the cost of announcing the repurchase program must be low enough so that the good type will find it worthwhile. In sum, the likelihood of a signaling equilibrium through repurchases

[4]In an open market program, the firm announces its intention to repurchase shares, following which it is allowed—but is not committed to—repurchase shares in the financial markets over time at its discretion. Firms can also repurchase their shares via tender offers, and privately negotiated repurchases. However open market programs account for more than 95% of stock repurchase. See, for example, Banyi et al. (2008), and Peyer and Vermaelen (2009).

increases with the firm's liquidity and with its value uncertainty (to enable good firms to benefit from strategic repurchases).

We then allow insiders to sell their own shares and coordinate the sale of their shares with the firm's repurchase activity. We focus on insider sales and also realistically limit the extent of possible selling. This is motivated by the empirical evidence on insider selling (Bonaime and Ryngaert 2013; Ben-Raphael et al. 2014; Cziraki and Gider 2021).[5] Here, we show that allowing insiders to trade has an ambiguous impact on the existence of a repurchase signaling equilibrium. Insider trading may enable the existence of a signaling equilibrium when such an equilibrium does not exist in the benchmark case, but it may also rule out the existence of a signaling equilibrium when such an equilibrium exists in the benchmark case.

To explicate further, insider trading increases the benefits from announcing a repurchase program because—as we show—the wealth transfers from uninformed insiders to informed insiders increase when the latter can trade their own shares strategically in coordination with the firm's repurchase activity. Because of the increase in benefit from announcing repurchases with insider trading, managers of good type firms may optimally announce even though they would not in the absence of insider trading. On the other hand, insider trading also increases the benefit to managers of bad-type firms from mimicking—or pooling with—good-type firms. Hence, insiders of bad-type firms may announce even when—absent insider trading—it would not be in their interest to mimic good-type firms. In particular, if the cost of announcing a repurchase program is sufficiently high, then a non-announcement pooling equilibrium exists; and if this cost is sufficiently low, a pooling equilibrium in which both firms announce a repurchase program also exists. The latter outcome is of particular interest from the viewpoint of explaining empirical findings in the literature (mentioned above) of weak or insignificant announcement effects.

Overall, our analysis implies that while stock repurchases result in wealth transfers from uninformed to informed shareholders, in the absence of insider trading they (repurchases) can serve as a signaling instrument and thereby increase transparency and reduce information asymmetry. However, allowing insiders to trade their own shares when firms repurchase shares not only increases wealth transfers from the uninformed to the informed but may either enhance or reduce the ability

[5] Empirically, insiders' sales are much more common than buys. In particular, managers and employees get compensated with shares and tend to sell them close to the time the shares vest. Moreover, sales are less likely to trigger lawsuits than purchases. This is because if you sell on a regular basis, it is easier to claim no use of private information if you sell when the firm is repurchasing than if you buy when the firm is repurchasing. This is also because buying is taking action, while refraining from selling is not. Lastly, the benefits from coordinating repurchases with sales are higher than with buys. This is because if insiders sell when the firm is buying, the firm is helping them sell, but if they buy when the firm is buying they competing against the firm.

of stock repurchases to serve as a signaling instrument. These theoretical results are consistent with existing empirical evidence that insiders time their trading with firms' repurchase activity. Our findings are also consistent with evidence that there is substantial variation in announcement returns following repurchase programs, and that these returns have decreased significantly over the years (see literature review below).

In addition, our model generates novel empirical predictions. It predicts, for example, that repurchase program announcement returns will be negatively related to insider trading. Similarly, announcement returns will be positively related to information asymmetry, liquidity, and insider ownership. The results also have implications for regulators: In particular, insider trading should be especially carefully scrutinized after repurchase program announcements.

The remainder of this paper is organized as follows: Section 2 reviews related literature. Section 3 presents the model and Section 4 analyses the benchmark case with only repurchases and no insider trade. Section 5 introduces insider trading and demonstrates the existence of a signaling equilibrium with repurchase and insider trading. Section 6 investigates the existence of pooling equilibria with repurchase and insider trading. Section 7 provides a discussion of the announcement effect of a repurchase program and its implications for price efficiency. Section 8 concludes.

2 Related literature

The frictions most of the theoretical literature about stock repurchases build on are information asymmetry, taxes, and agency costs of free cash.[6] Our paper belongs to the first group, and we here review this literature. As we noted above, building on information asymmetry, the signaling literature suggests that good firms initiate stock repurchases in order to distinguish themselves from less valuable firms. Closely related are models that build on asymmetric information to motivate using repurchases to transfer wealth from uninformed outsiders to informed insiders (e.g. Brennan and Thakor 1990; Chowdhry and Nanda 1994; Oded 2009). The wealth transfers associated with repurchases are used in Bond and Zhang (2016) to build a signaling model. Guthrie (2017) builds on these wealth transfers to show that at firms with poor governance, repurchases that harm shareholder occur, while at firms with good governance some value-enhancing repurchases do not occur, where the problem and its cost to shareholders is positively related to the number of employee stock options. But these papers do not consider strategic insider selling by self-interested managers.

[6] Other motivatios suggested that are less relevant to our paper include inflating EPS, price support, influencing liquidity, and offsetting dilution from stock and option compensation.

Also building on information asymmetry, several theoretical papers model the wealth transfers that informed insiders' trades engender. They build trade-offs between the cost to uninformed investors in the form of the wealth transfers and benefits to these investors that insider trading engender from value enhancement through monitoring (Maug 1995; Kahn and Winton 1998; Noe 2002), improvements in firm investment choice (Leland 1992; Bernhardt, Hollifield and Hughson 1995), or in risk sharing among investors that insider trading engender (Bhattacharya and Nicodano 2001). These models, however, do not consider stock repurchases.

To our knowledge, the only theoretical investigations in the literature that consider both share repurchases and insider trading are in Buffa and Nicodano (2008) and in Babenko et al. (2012). Buffa and Nicodano (2008) show that non-enforcement of insider trading regulations can increase investment in the stock and enhance welfare. This is because enforcement leads to informed trading by the firm through the repurchase program, exacerbates the adverse selection problem, and reduces uninformed investors' incentives to invest in the stock. While in Buffa and Nicodano (2008) the repurchase program and insider trading are substitutes—the repurchase program is a superior (that is, coordinated) form of insider trading that intensifies adverse selection—we emphasize the ability of insiders to leverage the repurchase program to enhance insider trading. This leads to different conclusions regarding the implications of insider trading on firm's repurchase behavior. For example, our model can explain why a firm might repurchase *over-valued* shares while in the former this is not possible on the equilibrium path. Furthermore, we consider heterogeneity among firm types and show that insider trading can either undermine or support the signaling role of repurchase plan announcement. Meanwhile, in Babenko et al. (2012), informed insiders can only *buy* shares on their own account and can subsequently decide to repurchase on behalf of the firm. Their analysis implies that insider purchases should be positively related to announcement returns. In contrast, we focus on the interaction of insider sales and repurchase programs and generate implications and predictions that are distinct from Babenko et al. (2012).

In considering private information (on firm value) jointly with agency conflicts (due to strategic insider selling), our paper is related to the long-standing, growing literature on *generalized agency* that examines constrained-efficient outcomes in the joint presence of hidden information and hidden actions (Myerson 1982; Faynzilberg and Kumar 1997, 2000; Castro-Pires et al. 2024). While this literature focuses on analysis of optimal incentive mechanisms in general agency settings, we examine the interaction of private information and agency conflicts in an empirically and institutionally important context, namely, corporate payout policy and insider trading. In doing so, our analysis helps explain and reconcile existing empirical evidence and generates novel refutable predictions.

Empirical support for the signaling hypothesis is reported in different venues. Some document positive announcement returns following repurchase program announcements (e.g., Vermaelen 1981; Comment and Jarrell 1991; Grullon and Michaely 2002). Other studies show improved long-run performance following program announcement (Ikenberry, Lakonishok and Vermaelen 1995; Peyer and Vermaelen 2009). Grullon and Michaely (2004) suggest repurchases signal risk reduction. Massa, Rehman and Vermaelen (2007) empirically show that firms mimic their counterparts that announce repurchases so as not to be seen as economically inferior. They do this by showing that in non-concentrated industries, announcing firms perform better.

Bhattacharya and Daouk (2002) report world wide evidence that insider trading laws enforcement is weak and does not significantly enhance company value. Their interpretation is that insider trading laws do not alleviate adverse selection losses caused to investors in the stock market by insider trading. Cziraki and Gider (2021) provide empirical evidence on the significance of informed insider trading and the associated wealth transfers to these insiders.

There are several empirical papers documenting the correlation between stock repurchase and insider stock and option compensation. These include, for example, Jolls (1998), Fenn and Liang (2001), Kahle (2002), and Weisbenner (2004). Bonaime and Ryngaert (2013) find that insiders' stock buying increase in repurchase quarters, and net insider stock buying are positively associated with post-repurchase abnormal returns. These papers suggest several explanations for the correlation they find. One is that equity compensation aligns managerial interests with maximizing shareholder value and hence they tend to disburse more free cash (through repurchases or dividends). Another is that because dividends dilute the value of insider shares, they prefer repurchases over dividends.

As we mentioned above, while empirical findings of positive short- and long-term abnormal returns following repurchase program announcements support the signaling hypothesis, recent studies find that the repurchase program announcement return has decreased over time (Grullon and Michaely 2004) and has become insignificant (Ikenberry, Lakonishok and Vermaelen 2000; Guest et al. 2022). Similarly, long-run stock returns following open-market program announcements have decreased and become insignificant (Obernberger 2014; Fu and Huang, 2016; Lee, Park and Pearson 2020). This decline is consistent with our model's prediction that allowing for insider sale of shares will result in lower program announcement return. Other papers suggest that insider purchases prior to repurchase announcements add credibility to the undervaluation signal (Babenko et al.

2012; Cziraki et al. 2021) as do high prior repurchase plan completion rates (Bonaime 2012; Ota, Kawase and Lau 2019).

3 The Model

We consider an all-equity financed and financially constrained firm. There are three dates indexed by $t = 0, 1, 2$. All agents are risk neutral, the interest rate is zero, and there are no taxes or transaction costs. For simplicity and without loss of generality we normalize the number of shares outstanding N at $t = 0$ to one ($N = 1$). A fraction β of the shares is held by insiders, where $\beta \in (0, 1)$, and the rest $1 - \beta$ is held by outside shareholders. We assume that insiders control the firm and set its financial policy to maximize their long-term wealth.

There are two types of firms $\theta \in \{G, B\}$, *good* and *bad*. The good type G has random cash flows x realized at time $t = 1$ of $H + \Delta$ or $L + \Delta$ with equal probabilities, and the bad type B has random cash flows of H or L, also with equal probabilities.[7] We consider the cases in which there is sufficient difference between the two types of firms, such that, $H - L < \Delta$. As is standard in the microstructure literature, there is uncertainty regarding order flow. Specifically, at $t = 1$ the outside shareholders face an uninsurable *liquidity* shock and must sell q shares where $q = \ell > 0$ or $q = h > 0$ with equal probability. Let $u \equiv h - \ell > 0$. Since these liquidity shocks are bounded from above by the holdings of outsiders we note that $h < 1 - \beta$.

At the outset, time $t = 0$, insiders privately observe firm type θ and choose $d \in \{A,\ NA\}$, i.e., whether or not to announce a repurchase program. An open-market program announcement authorizes but does not commit the insiders (the firm) to buy back shares at $t = 1$. The announcement of a repurchase program is costly. Costs include not only brokerage fees and transaction costs. The repurchase is costly also in terms of its regulatory implications, in the form of requirements imposed on firms with active repurchase programs, such as the recent restriction on COVID government support. It is also costly in terms of overall public image costs.[8] We capture this by assuming a benefit of $\Phi \geqslant 0$ from not announcing.[9]

At $t = 1$, insiders privately observe the realization of x. If the firm has a program in place,

[7] The assumption of equal probabilities is without loss of generality and is made for notational ease in the analysis of the model.

[8] See also "Coronavirus Stimulus Package to Include Curbs on Share Buybacks" Wall Street Journal, March 25, 2020, and "Why stock buybacks are dangerous for the economy" Harvard Business Review, January 7, 2020, respectively.

[9] Models assuming a fixed cost for announcing a repurchse include Lucas and McDonald (1998), Bhattacharya and Jacobson (2016).

it can repurchase r shares at $t = 1$, where $r \geq 0$. Execution of the program takes place at the insiders' discretion, and is not contractible. Beyond the ability of insiders to initiate repurchase by the firm, they can also sell shares on their own account. We follow the empirical evidence and cap the amount of selling in our model. Specifically, we allow insiders at the same time, $t = 1$, to sell s shares where the amount of selling is capped by k such that $0 \leq s < k$. All information becomes public at $t = 2$.[10]

Trade is centralized by a market maker in a discrete Kyle market setting, a là Bernhart, Hollifield and Hughson (1991), Maug (1998), and Kumar, Langberg, Oded and Sivaramakrishnan (2017). At $t = 1$, after insiders privately observe x, the market opens for trade. As standard in this literature, the market maker observes the total order flow $F = q + r + s$ but not its components. The market maker then sets time $t = 1$ price P_1 (short-term price) to earn zero expected profit given his beliefs about the firm value after observing the order flow. Of course, the insiders do not observe the liquidity shock before submitting their order. At $t = 2$ the firm's price P_2 (long-term price) perfectly reflects its true value. Note, if the firm repurchases shares at $t = 1$, at price P_1, then at $t = 2$ the share price is,[11]

$$P_2 = \frac{x - rP_1}{1 - r} = x + \frac{r}{1 - r}\left(x - P_1\right), \; x \in \{L, H, L + \Delta, H + \Delta\}. \tag{1}$$

The expected payoff to an insider that sells s shares at price P_1 and continues to hold $\beta - s$ shares with terminal price P_2, is given by,

$$V = sP_1 + (\beta - s)P_2. \tag{2}$$

3.1 Time Line

To summarize, the sequence of events is as follows (see Figure 1):

1. $t = 0$: Insiders privately observe firm type $\theta \in \{B, G\}$ and can announce a repurchase program $d \in \{A, NA\}$.

[10] In the US, corporate boards authorize repurchase programs. In most other countries the programs must be approved either by the board or by the shareholders. In our model the inside shareholders are essentially the board. In the US there is no reporting requirement on actual repurchases other than in the financial statements (in May 2023 the SEC enhanced these reporting requirements). The regulation of actual repurchases in other countries is more restrictive. Generally firms cannot start a repurchase program without announcing it before hand. (In the US this requirement comes from the exchanges.)

[11] We note that as is reflected in (1), as long as there is no repurchase at $t = 1$, P_2 is independent of P_1. This is because only the repurchase can change the value of the firm (and its shares). Furthermore, liquidity shock (h or ℓ), can affect the terminal value P_2 only through P_1, if at all.

2. $t = 1$: Insiders privately observe value realization x, submit selling order $s \in [0, k]$, and if a program is in place, repurchase $r \geq 0$. At the same time, the noise traders are subject to the *liquidity* shock $q \in \{\ell, h\}$. Short-term market price P_1 is set by the market maker as a function of order flow $F = q + r - s$

3. $t = 2$: All information becomes publicly observable and long-term price P_2 is set by market maker.

[**Insert Figure 1 about here**]

3.2 Equilibrium Definition

We analyze the Perfect Bayesian equilibrium (PBE) of the game corresponding to the above time-line. The PBE consists of:

Repurchase Program announcement strategy: At time $t = 0$, (in the first stage) insiders optimally—that is, to maximize their expected payoff (2)—decide whether to announce a repurchase program or not based on their type θ, $d : \{B, G\} \to \{A, NA\}$

Insider Selling and Repurchase: At time $t = 1$, insiders choose the amount of selling $s : \{L, H, L + \Delta, H + \Delta\} \to [0, k]$ and the amount repurchased $r : \{L, H, L + \Delta, H + \Delta\} \to [0, 1]$, (of course $r = 0$ when there is no repurchase plan in place).

Market-maker: The market-maker sets $P_1(F)$ and P_2 so that she breaks even on average, given her Bayes-consistent beliefs about the insiders' announcement and trading strategies.

Definition 1 *A PBE is the profile $\langle d, r, s, P_1(F), P_2 \rangle$ consisting of 1) a repurchase policy d set by insiders at $t = 0$, depending on their type $\theta \in \{B, G\}$, that specifies an open-market program announcement, or not; 2) a selling strategy s, and repurchase strategy r provided that a repurchase plan is in place; both set by insiders at time $t = 1$, given their information x; and 3) prices $\langle P_1(F), P_2 \rangle$ set by the competitive market maker, given the order flow and public information; such that insiders maximize their expected payoff, while the market maker makes zero expected profit, given their consistent Bayesian beliefs.*

4 Benchmark: No Insider Selling (k=0)

We initially assume that at $t = 1$ the firm can repurchase while insiders cannot trade *their own* shares (i.e., $s = k = 0$). The insiders can however decide whether to actually execute the repurchase program announced depending on the value realization L or H without worrying about violating the law. This is consistent with rule 10-18b which protects firms from being sued if they follow the guidelines set in the rule (The Safe Harbour Act)[12].

Because a repurchase is executed through the financial markets, the existence of an equilibrium with a repurchase announcement depends on the post-announcement response in the financial markets of: 1) the market maker, and 2) the firm (the insiders). In this subsection we consider the conditions under which such an equilibrium can hold when insiders cannot trade during the repurchase period ($t = 1$). Under this assumption we characterize the existence of an equilibrium with a repurchase program and the way the inside shareholders choose whether or not to announce a repurchase program.

4.1 Separating Equilibrium

In a separating equilibrium the good type firm announces a repurchase program and the bad type firm does not. Thus, in this equilibrium the bad-type firm is accurately detected, and its insiders' terminal wealth is βL and βH, when the value realized is L, and H, respectively, or on average they obtain $\beta\frac{L+H}{2}$. At the same time, in this separating equilibrium the good type firm that announces a repurchase plan does so in order to benefit from the possibility of repurchasing under-valued equity, as detailed in (3). That is, the good type firm announces a repurchase plan in order to gain from repurchasing shares when the realized cash flows are $H + \Delta$.

If the firm announces a repurchase program at $t = 0$, insiders can benefit from the repurchase only if the repurchase price is lower than the value. Following announcement of a repurchase plan, which in equilibrium identifies the good type firm, the market maker sets the $t = 1$ price, P_1, given order flow, to break even. Thus, in the above signaling equilibrium the price following announcement of a repurchase plan will lie between $L+\Delta$, the good type's low cash flow realization, and $H+\Delta$, the good type's high cash flow realization. That is, it must be that $L+\Delta \leq P_1 \leq H+\Delta$. The only cash flow realization relevant for the insiders for repurchase is $H+\Delta$. But, for the insiders to benefit from the repurchase, the repurchase must not be detected by the market maker.

Following a program announcement, at $t = 1$ the market maker observes the order flow $F = q+r$. Without the possibility to repurchase, the market maker will observe order flow either $-h$ or $-l$. Any order flow higher than $-l$ will tell the market maker that the firm is buying. Thus, the insiders

[12] These guidlines are: a) use only one brocker, b) do not trade in the first and last half hour of the trade, c) do not repurchase more than 25% of the average daily trade, and d) do not bid up the price.

maximize their wealth from the repurchase when they observe cash flow $H+\Delta$ by having the firm repurchase $r(H+\Delta)=h-l\equiv u$, and repurchase no shares when they observe cash flow $L+\Delta$. If the value realized is $H+\Delta$ and the liquidity trade is $-l$, the market maker sees order flow of $F=h-2l>-l$. He detects that the firm is buying, and concludes that the value realized is $H+\Delta$. Similarly, if the value realized is $L+\Delta$, and the liquidity trade is $-h$, the market maker sees the order flow of $F=-h$. He detects the firm is not buying, and concludes that the cash flow realization is $L+\Delta$. But if the cash flow realized is $H+\Delta$ and the liquidity trade is $-h$, the market maker sees an order flow of $F=h-l+h=-l$; and if the cash flow realized is $L+\Delta$ and the liquidity trade is $-l$, the market maker sees the same order flow $F=-l$. Thus, in these cases the market maker cannot tell whether realized cash flows are $H+\Delta$ (with a high liquidity shock) or $L+\Delta$ (with a low liquidity shock). To earn zero expected profit, he will thus set P_1 to the expected terminal value P_2 in the states in which he observes $-l$. This means he is overpaying when cash flows are $L+\Delta$ (with a low liquidity shock) but underpaying when cash flows are $H+\Delta$ (with a high liquidity shock). It also means that the insiders are gaining from repurchasing under-valued shares in cash flow state $H+\Delta$ (with a high liquidity shock) at liquidity sellers' expense. This result is summarized in Lemma 1. (All proofs appear in the appendix section.)

Lemma 1 ***[Repurchase Strategy without Insider Selling in Separating Equilibrium]*** *If only the insiders of the good type firm announce a repurchase program at $t=0$, i.e., $d(B)=NA$ and $d(G)=A$, then in equilibrium insiders of the good firm have the firm repurchase u shares when observing value $H+\Delta$, i.e., $r(H+\Delta)=u$, and not repurchase any shares when observing value $L+\Delta$, i.e., $r(L+\Delta)=0$.*

$$\text{Separating EQ: } \begin{cases} d(B)=NA \text{ and } r(L)=r(H)=0 \\ d(G)=A \quad\text{ and } r(L+\Delta)=0,\, r(H+\Delta)=u \end{cases} \tag{3}$$

Of course, in order for the good type firm to benefit from this strategy it must be that market prices do not always accurately reflect fundamentals. In the following, we establish the conditions under which a separating equilibrium of this nature exists.

4.1.1 Market Prices and Order Flow in a Separating Equilibrium

Lemma 1 implies that when order flow is extreme the market maker can accurately value the firm. Specifically, when cash flow state is $L+\Delta$ (i.e., the good type firm does not repurchase) and the liquidity shock is $-h$, so that order flow is $-h$, the market maker will set price $P_1(-h) = L + \Delta$. Similarly, in cash flow state $H + \Delta$ (i.e., the good type firm repurchases) and the liquidity shock is $-\ell$, so that order flow is $h - 2\ell$, the market maker will set price $P_1(h-2\ell) = H + \Delta$. It is only when the order flow is intermediate, $F = -\ell$, that the market maker assigns probability one half to the cash flow state being $L + \Delta$ (which implies that there was no repurchase) or $H + \Delta$ (which implies that there was a repurchase). Let the price set by the market maker in the benchmark case when observing order flow $F = -\ell$ be $P_1^{bm}(-\ell)$. Table 1A describes equilibrium repurchase, order flow, and prices for the four possible states span by x, q, in the setup in which the firm can repurchase but insiders cannot trade their own shares.

By assumption, when the market maker observes $-\ell$ (i.e. in states Ll, Hh) he sets the price P_1 to earn zero expected profit. That is, upon substitution of $h - \ell = u$ zero profits implies,

$$0 = \left(P_1^{bm}(-\ell) - (L + \Delta)\right) + \left(P_1^{bm}(-\ell) - \frac{H + \Delta - uP_1^{bm}(-\ell)}{1-u}\right).$$

We can solve for $P_1^{bm}(-\ell)$ to find that

$$P_1^{bm}(-\ell) = \frac{H + L(1-u)}{2-u} + \Delta \tag{4}$$

Lemma 2 ***[Market Prices and Order Flow]*** *In the above proposed signaling equilibrium, as specified in (3), market prices are given by (5), and (6)*

$$P_1(-h) = L + \Delta,\ P_1^{bm}(-\ell) = \frac{H + L(1-u)}{2-u} + \Delta,\ P_1(h-2\ell) = H + \Delta \tag{5}$$

$$P_0^{bm}(A) = \frac{1}{2}\left(\frac{4H + 4L - uH - uL - 2Lu}{2(2-u)}\right) - \frac{1}{4(1-\beta)}u\left[\frac{H-L}{2-u}\right] + \Delta \tag{6}$$

4.1.2 Optimal Announcement Decision

The expected gains to the insiders of the good type firm from announcing a repurchase plan stem from realized cash flow of $H + \Delta$ and liquidity shock $-h$; but in all other realized states of the world, there are no gains from trade. It can be shown that the expected benefit from trade is $\beta\frac{u}{4}\left(\frac{H-L}{2-u}\right)$ and the overall expected payoff is,

$$V(G|A) = \beta\left[\frac{H+L}{2} + \Delta + \frac{u}{4}\left(\frac{H-L}{2-u}\right)\right].$$

Alternatively, non-announcement leaves insiders with their share of the the expected value of the firm $\frac{H+L}{2} + \Delta$ in addition to the benefit Φ from non announcement;

$$V(G|NA) = \beta\left(\frac{H+L}{2} + \Delta + \Phi\right).$$

The insiders of the good type are better off announcing a program over non-announcement whenever $V(G|A) \geq V(G|NA)$ or,

$$\Phi \leq \frac{u}{4}\left(\frac{H-L}{2-u}\right) \equiv \Phi^{bm}. \tag{7}$$

To derive the conditions under which a signaling equilibrium exists we verify next that deviation for the bad type firm is not optimal. Deviation includes the announcement of a repurchase program by the bad type followed by any feasible trading strategies, as detailed below. A bad type that deviates and announces a repurchase plan will choose repurchase strategy r to maximize her expected payoff given cash flow realization $x \in \{L, H\}$. Thus, assume that a repurchase plan was announced by type B, and consider her incentives for trade. To begin with, consider cash flow realization $x = L$. In this case, insiders have no incentive to repurchase shares, since the market price cannot be lower than L, thus the insider will choose $r = 0$. Also, when $x = H$ it is not possible to profit from repurchasing under-valued shares since the lowest possible price satisfies $P_1(-h) = L + \Delta \geq H$ by the assumption $\frac{H-L}{\Delta} < 1$. Thus, the bad type cannot profit from trade in either states of the world

and a deviation (i.e., announcement of a repurchase program) yields the expected payoff,

$$V^{dev}(B|A) = \beta\left(\frac{H+L}{2}\right) \leq V(B|NA) = \beta\left(\frac{H+L}{2} + \Phi\right).$$

Proposition 1 ***[Signaling Equilibrium with no Selling]*** *A signaling equilibrium in which only the good type announces a repurchase program and repurchases shares to exploit undervaluation, as specified in (3), and where market prices are given by (5), exists when (8) is satisfied.*

$$0 \leq \Phi \leq \Phi^{bm} = \frac{u}{4}\frac{H-L}{2-u} \textbf{ [Separating Eq Condition]} \tag{8}$$

4.2 Pooling Equilibrium

We are thinking about a pooling equilibrium in which, at the announcement level, either both types announce or both types do not announce. We begin with establishing pooling equilibrium in which both types do not announce when the benefit from non-announcement is sufficiently high, such that a separating equilibrium does not exist. Specifically, a unique non-announcement pooling equilibrium exists when condition (8) is not satisfied.

Proposition 2 ***[Pooling Equilibrium with no Selling]*** *A pooling equilibrium in which both types do not announce a repurchase program, and out of equilibrium prices given order flow following announcement are given by (5), exists when (9) is satisfied.*

$$\Phi^{bm} = \frac{u}{4}\frac{H-L}{2-u} < \Phi \text{ [\textbf{Pooling Eq Condition}]} \tag{9}$$

It is shown in the proof that the alternative scenario where both firms announce a repurchase program is not an equilibrium due to the difference between firm types satisfying $H - L < \Delta$.

5 Insider Selling: Separating Equilibrium

We now allow insiders to sell shares. To begin with, we consider the conditions under which there exists a separating equilibrium with insider selling. We allow selling up to level $k \in (0, h-\ell)$.[13] Like before, in a separating equilibrium the good type firm announces a repurchase program and the bad type firm does not. Thus, like in the case without insider selling, in this equilibrium, firm-type is accurately detected at $t = 0$. But now, the trading strategy changes relative to the case with no insider selling. Now, we move on to analyzing the optimal trading behavior of insiders.

To begin with, consider the type B firm. Given that the firm does not announce a repurchase plan, $d(B) = NA$, insiders cannot repurchase but might sell shares. Notice that selling shares when firm value is $x = H$ cannot be profitable – this is because, given $d = NA$, the market maker will set the short-term price $P_1(F|d = NA) \leq H$. But, we need to consider the possibility of selling when $x = L$. The only way for insiders' trade to be undetected by the market maker they must sell $k = h - \ell$, which for now is unattainable since $k \in (0, h - \ell)$. That is, profitable insider trading is

[13] This allows us to focus on the case in which insider selling is camouflaged through the repurchase program. If, instead, there is no upper limit on insider sales, that is, $k \geq h - \ell$, then insiders can benefit from strategically selling over-valued shares even in the absence of a repurchase program. That is, repurchase programs are not necessarily required for supporting insider selling, which is outside the scope of our paper.

not feasible as an equilibrium outcome following $d = NA$ by type B. Therefore, for the bad type, wealth is βx or on average $\beta \frac{L+H}{2}$.

At the same time, in this separating equilibrium the good type firm that announces a repurchase plan does so in order to benefit from the possibility of repurchasing under-valued equity, as detailed in (3). That is, the good type firm announces a repurchase plan in order to gain from repurchasing shares when the realized cash flows are $H + \Delta$. But, the good type might also find it optimal to repurchase over-valued shares in order to support insider selling. Consider the following separating equilibrium candidate:

$$\text{Separating EQ:} \begin{cases} d(B) = NA \text{ and } r(L) = r(H) = 0 \\ \qquad\qquad s(L) = s(H) = 0 \\ d(G) = A \quad \text{ and } r(L+\Delta) = k,\ r(H+\Delta) = h - \ell \\ \qquad\qquad s(L+\Delta) = k,\ s(H+\Delta) = 0 \end{cases} \tag{10}$$

In the following, we establish the conditions under which this separating equilibrium exists.

5.1 Market Prices and Order Flow in a Separating Equilibrium

As before, in the benchmark case, when the cash flow realization is high, $H+\Delta$, in order not to be detected by the market maker, the firm will repurchase $r(H+\Delta) = h-\ell$. Of course, there is no incentive to sell shares in the high cash flow realization. However, in the low cash flow realization, when there is an incentive to sell over-valued shares, in order for insiders to hide their sale from the market maker, they must have the firm simultaneously repurchase the same amount that they sell. Notice that, the aggregate order flow is $F = q + r - s$ and whenever $r = s$ the market maker cannot perfectly identify if selling (and simultaneous repurchase) took place or not. Thus, in the low cash flow realization $L + \Delta$, insiders can exploit this the most by simultaneously selling $s(L+\Delta) = k$ shares while the firm repurchases $r(L+\Delta) = k$ (subsequently, we show that this is indeed optimal). Table 1B describes the repurchase and sell strategy in the separating equilibrium for the insiders and the resulting order flow and prices for the four possible states span by the realizations of x and q. To find $P_1(-\ell)$, that yields zero profits to the market maker in equilibrium, we can write

$$
\begin{aligned}
0 &= \left(P_1(-\ell) - \frac{L+\Delta-kP_1(-\ell)}{1-k}\right) + \left(P_1(-\ell) - \frac{H+\Delta-uP_1(-\ell)}{1-u}\right) \\
&\Rightarrow \; P_1(-\ell) = \frac{H\,(1-k) + L\,(1-u)}{2-k-u} + \Delta \qquad (11)
\end{aligned}
$$

Lemma 3 ***[Market Prices and Order Flow with Insider Selling]*** *In the above proposed separating equilibrium, as specified in (10), market prices are given by (12):*

$$
P_1(h-2\ell) = H+\Delta > P_1(-\ell) = \frac{H\,(1-k) + L\,(1-u)}{2-k-u} + \Delta > P_1(-h) = L+\Delta \qquad (12)
$$

Off-equilibrium beliefs are assumed to satisfy for a given $\eta \in (0, u)$,

$$
P_1(F) = \begin{cases} H+\Delta & F \geq -\ell+\eta \\ \frac{H(1-k)+L(1-u)}{2-k-u} + \Delta & otherwise \\ L+\Delta & F < -h+\eta \end{cases} \qquad (13)
$$

The specific value of η will be determined subsequently to satisfy the equilibrium conditions in this separating equilibrium.

5.2 Trading strategy (for Good Type)

To show that the above trading and repurchase strategies in the proposed separating equilibrium are optimal, in the subgame following announcement of a repurchase plan by the good type, we examine the trading gains for both cash flow realizations.

5.2.1 Cash flows $L+\Delta$

First, consider cash flow realization $L+\Delta$. When selling and repurchasing k shares market prices are either $P_1(-\ell)$ or $P_1(-h) = L+\Delta$ and therefore the expected payoff is

$$
V(L+\Delta|A, r=s=k) = \frac{1}{2}\left[kP_1(-\ell) + (\beta-k)\left[\frac{L+\Delta-kP_1(-\ell)}{1-k}\right]\right] + \frac{1}{2}\beta(L+\Delta).
$$

Upon substitution of $P_1(-\ell) = \frac{H(1-k)+L(1-u)}{2-k-u} + \Delta$ and rearrangement we obtain the expected payoff

$$V(L{+}\Delta|A, r=s=k) = \beta\,(L+\Delta) + \frac{(1-\beta)\,k}{2\,(2-k-u)}\,(H-L) \;\; \text{[Payoff from Proposed Equilibrium for } L{+}\Delta] \tag{14}$$

Notice, the above payoff exceeds the payoff $\beta\,(L+\Delta)$ from the alternative of not selling (and not repurchasing) and is *increasing* in k which implies that insiders prefer to sell (and repurchase) the maximum amount of shares when cash flows are low, consistent with the suggested equilibrium trading strategy.[14]

It remains to show that there does not exist an alternative strategy, when the cash flow is $L+\Delta$, that gives the insiders a higher payoff. First, consider the following possible deviation of repurchasing more than k in order to increase the price even further and benefit more from selling k shares. Specifically, allow insiders, when observing $L+\Delta$, to sell k and repurchase $k+\varepsilon$, for some $\varepsilon > 0$, which will lead to order flows $F=-h+\varepsilon$ or $F=-\ell+\varepsilon$. Since prices adjust upward at order flows $F=-h+\eta$ or $F=-\ell+\eta$, insiders will sell (and repurchase) at prices $P_1(-\ell)$ or $P_1(h-2\ell) = H+\Delta$, and it suffices to show that this deviation is not optimal for $\varepsilon=\eta$. The payoff from this deviation is,

$$\begin{aligned} V_{Dev}(L+\Delta|A, r &= k+\eta, s=k) = \frac{1}{2}\left[H+\Delta+P_1(-\ell)\right]k + \frac{L+\Delta-\frac{1}{2}(k+\eta)\left[H+\Delta+P_1(-\ell)\right]}{1-k-\eta}\,(\beta-k) \\ \text{[Deviation: sell } & k \text{ and repurchase } k+\eta] \end{aligned}$$

We show later that the payoff from the proposed equilibrium, as detailed in (14), exceeds the above

---

[14] Showing that it is increasing in k'. A deviation to consider is for the manager to repurchase $k' \leq k$ and sell the same amount. This will avoid detection by the market maker (since aggregate order flows will remain unchanged) and yield the following expected payoff:

$$\frac{1}{2}\left[kP_1(-\ell) + (\beta-k)\left[\frac{H+\Delta-kP_1(-\ell)}{1-k}\right]\right] + \frac{1}{2}\left[k\,(L+\Delta) + (\beta-k)\left[\frac{H+\Delta-k\,(L+\Delta)}{1-k}\right]\right]$$

Next we show that the above stratgy yields payoff that is smaller than $H+\Delta$ which implies that it is dominated by the suggested equilibrium strategy. Specifically,

$$\begin{aligned} \frac{1}{2}\left[kP_1(-\ell)\left(\frac{1-\beta}{1-k}\right) + (\beta-k)\left[\frac{H+\Delta}{1-k}\right]\right] + \frac{1}{2}\left[(L+\Delta)\,k\left(\frac{1-\beta}{1-k}\right) + (\beta-k)\left[\frac{H+\Delta}{1-k}\right]\right] &= \\ \frac{1}{2}k\left(\frac{1-\beta}{1-k}\right)\left(P_1(-\ell)+L+\Delta\right) + (\beta-k)\left[\frac{H+\Delta}{1-k}\right] & . \end{aligned}$$

Upon substitution of $P_1(-\ell) = \frac{H(1-k)+L(1-u)}{2-k-u} + \Delta$ and simplification we obtain,

$$\beta\,(H+\Delta) - \frac{1}{2}k\left(\frac{1-\beta}{1-k}\right)\frac{(1-k)}{(1-k)+1-u}\,(H-L) < \beta\,(H+\Delta)\,.$$

deviation payoff when,

$$\frac{k(1-\beta)}{\left(\frac{\beta-k}{2-k-u}+k\right)} < \eta \in (0,u) \text{ [Equilibrium Condition for case } L+\Delta\text{]}. \tag{15}$$

Second, consider the following possible deviation of repurchasing k but selling $k-\varepsilon$, $\varepsilon < k$, in order to increase the price even further and benefit more from selling $k-\varepsilon$ shares. Specifically, allow insiders, when observing $L+\Delta$, to sell $k-\varepsilon$ and repurchase k, which will lead to order flows $F=-h+\varepsilon$ or $F=-\ell+\varepsilon$. Since prices adjust upward at order flows $F=-h+\eta$ or $F=-\ell+\eta$, insiders will sell (and repurchase) at prices $P_1(-\ell)$ or $P_1(h-2\ell)=H+\Delta$, and it suffices to show that this deviation is not optimal for $\varepsilon=\eta$. The payoff from this deviation is,

$$\begin{aligned} V_{Dev}(L+\Delta|A,r &= k, s=k-\eta) = \frac{1}{2}\left[H+\Delta+P_1(-\ell)\right](k-\eta) + \frac{L+\Delta-\frac{1}{2}k\left[H+\Delta+P_1(-\ell)\right]}{1-k}(\beta-k+\eta) \\ \text{[Deviation: sell } & k-\eta \text{ and repurchase } k\text{]}. \end{aligned}$$

We show later that the payoff from this aforementioned deviation is lower than that from the proposed equilibrium if the above condition holds.

5.2.2 Cash flows $H+\Delta$

Next, we turn to cash flow realization $H+\Delta$. We now derive the conditions for optimality of strategy $r(H+\Delta)=h-\ell$ with $s(H+\Delta)=0$. To begin with, notice that the expected gain from this suggested equilibrium strategy is,

$$\frac{1}{2}\beta\left[\frac{H+\Delta-uP_1(-\ell)}{1-u}\right]+\frac{1}{2}\beta(H+\Delta). \quad \text{[Payoff from Proposed Equilibrium for } H+\Delta\text{]}$$

Upon substitution of $P_1(-\ell) = \frac{H(1-k)+L(1-u)}{2-k-u}+\Delta$ and rearrangement we obtain the expected payoff,

$$\beta\left(H+\Delta+\frac{u}{2(2-k-u)}(H-L)\right). \tag{16}$$

This is clearly larger than the alternative of not repurchasing and obtaining $\beta(H+\Delta)$. Yet, we consider the alternative deviation of repurchasing less than u so that the repurchase price is lower. Specifically, when observing $H+\Delta$, suppose that the insider sells 0 and repurchase $u-\varepsilon$. As a result, the MM will observe order flows of $h-2\ell-\varepsilon$ instead of $h-2\ell$ or $-\ell-\varepsilon$ instead of $-\ell$. The motivation of this deviation is to lower the order flow in order to get a lower price at the repurchase at the cost of repurchasing less. The relevant prices become $P_1(h-2\ell-\varepsilon)$, and $P_1(-\ell-\varepsilon)$. Since prices change downwards for $\varepsilon \geq u-\eta$ (from the proposed pricing function) it suffices to consider this point $\varepsilon = u-\eta$. This deviation in state $H+\Delta$ would imply the following payoff,

$$\beta\left[\frac{H+\Delta-\eta\frac{1}{2}\left[P_1(-\ell)+L+\Delta\right]}{1-\eta}\right]. \quad \text{[Deviation: (sell 0) repurchase } \eta\text{].}$$

It can be shown that the payoff from the proposed equilibrium, as detailed in (14), exceeds the above deviation payoff when,

$$\frac{u}{3-k-u} > \eta \ \in (0,u) \ \text{[Equilibrium Condition for case } H+\Delta\text{].} \tag{17}$$

5.2.3 Equilibrium conditions Trading by Good Type

Putting together both conditions for the good type, the following Lemma summarizes the conditions under which, following announcement by the good type, the proposed equilibrium trading strategy is optimal.

Lemma 4 ***[Trading by Good type (separating equilibrium)]*** *Under condition (18), when insiders can sell s shares, where $s \in [0,k]$ and where $k < (h-\ell)$ following an announcement of a repurchase plan by the good type firm, insiders will sell k shares when cash flows are $L+\Delta$ while the firm will simultaneously repurchase the same amount k. Insiders of the good type firm will not trade when cash flows are $H+\Delta$ but the firm will repurchase $h-\ell$ shares. Prices given order flow are given above in (13) for,*

$$\frac{k(1-\beta)}{\left(\frac{\beta-k}{2-k-u}+k\right)} < \eta \ < \frac{u}{3-k-u} \ \textit{[\textbf{Condition 1}].} \tag{18}$$

5.3 Announcement Strategy

Considering the payoffs from the above optimal trading strategy. According to the proposed separating equilibrium and the aforementioned condition, we now explore the incentives for announcement of a repurchase plan by the two types.

5.3.1 Announcement by Good Type

Next consider whether the good type will announce. Without announcement, insiders' expected wealth is $V_S(G|NA) = \beta\left[\frac{1}{2}(H+L) + \Delta + \Phi\right]$. With announcement, expected wealth is

$$V_S(G|A) = \beta\left[\frac{1}{2}(H+L) + \Delta\right] + \frac{1}{4}\frac{(1-\beta)k + \beta u}{2-k-u}(H-L)$$

Thus, we need to show that it is optimal for the good type to announce, i.e., $V_S(G|A) \geq V_S(G|NA)$.

Lemma 5 ***[Announcement by Good Type (separating equilibrium)]*** *Under condition (19), when insiders can sell s shares, where $s \in [0,k]$ and where $k < (h-\ell)$, and prices given order flow are given above in (12), the good type will announce a repurchase plan when*

$$\frac{1}{4}\frac{(1-\beta)k + \beta u}{2-k-u}(H-L) > \beta\Phi \text{ [\textbf{\textit{Condition 2}}].} \tag{19}$$

5.3.2 Non-Announcement by Bad Type

Next, consider the incentives of the bad type. Without announcement, her payoff is $V_S(B|NA) = \beta\left(\frac{H+L}{2} + \Phi\right)$. Consider the deviation of announcing a repurchase plan. To rule out this as a profitable deviation we need to consider the optimal trading strategy of the bad type following announcement, given the prices as set in the separating equilibrium.

Cash flow realization H To begin with, consider cash flow realization H. Here we show that a strategy of repurchasing shares (without selling) is not optimal, as the prices following repurchase are higher than the true value H. Specifically, suppose that she repurchases u shares (in order not to be detected). Then, the price that she faces is either $P_1(-h+u) = P_1(-\ell)$, when liquidity is $-h$, or $P_1(-l+u) = P_1(h-2l) = H+\Delta$ when liquidity shock is $-\ell$ (just like the prices facing the good type firm when cash flows are $H+\Delta$). Intuitively, repurchase is optimal (given announcement) and given cash flow H only if the expected price is attractive, i.e., $H > \frac{1}{2}(H+\Delta+P_1(-\ell))$. Since $\frac{H-L}{\Delta} < 1$ and $P_1(-\ell) \in [L+\Delta, H+\Delta]$ it follows that $H < \frac{1}{2}(H+\Delta+P_1(-\ell))$ and repurchase (alone) is not optimal. The price for order flow $-\ell$, as listed above, is $P_1(-\ell) = \frac{H(1-k)+L(1-u)}{2-k-u} + \Delta$ which can be rearranged as $H + \Delta - \frac{(1-u)}{2-k-u}(H-L)$. It can also be shown that repurchasing less than u, in order to repurchase at lower prices, is not optimal. This follows since the lowest possible price is $L+\Delta$ which exceeds the true value H.

We proceed by considering the deviation where the bad type attempts to sell (and simultaneously repurchase) k shares of over-valued stock. With this strategy of $r = s = k$ insiders are able to hide their trades and potentially gain from selling over-valued stock. The prices that emerge in equilibrium following this strategy are $L + \Delta$ for order flow $-h$ or $P_1(-\ell)$ for order flow $-\ell$, and the consequent terminal values from this strategy are,

firm value x	liquidity q	repurchase r	insider s	order flow F	MM price P_1	terminal value P_2
H	$-h$	k	$-k$	$-h$	$L + \Delta$	$\frac{H-k(L+\Delta)}{1-k}$
H	$-\ell$	k	$-k$	$-\ell$	$P_1(-\ell)$	$\frac{H-kP_1(-\ell)}{1-k}$

Lemma 6 ***[Deviation Trading Strategy Bad type Cash Flow*** H*] Following announcement by the bad type, the optimal trading strategy when cash flows are* H *is given by* $r = s = k$.

Cash Flow Realization L Next we consider the optimal trading by the bad type following deviation of announcement when cash flow is L. Without trading at all, the payoff to insiders in this state is βL. Clearly, it is not optimal to repurchase shares (without selling) when cash flows are L. Thus, we consider the payoff from repurchasing and selling k shares in order to profit from selling over-valued shares. Like before, following this strategy, the order flow, market prices and terminal value payoff depend on the state of liquidity and are given by the table below,

firm value x	liquidity q	repurchase r	insider s	order flow F	MM price P_1	terminal value P_2
L	$-h$	k	$-k$	$-h$	$L + \Delta$	$\frac{L-k(L+\Delta)}{1-k}$
L	$-\ell$	k	$-k$	$-\ell$	$P_1(-\ell)$	$\frac{L-kP_1(-\ell)}{1-k}$

Lemma 7 ***[Deviation Trading Strategy Bad type Cash Flow*** L*] Following announcement by the bad type, the optimal trading strategy when cash flows are* L *is given by* $r = s = k$.

Non-Deviation Condition Bad Type Now that the optimal trading strategy upon deviation by the bad type is shown to be a joint strategy of repurchasing and selling k shares in both cash flow states H and L, we can derive the expected payoff from this deviation. Recall, non-announcement yields payoff of $\beta\left(\frac{H+L}{2} + \Phi\right)$ while announcement yields payoff of $V^{Dev}(B|A, H, r = s = k)$ or $V^{Dev}(B|A, L, r = s = k)$ with equal probabilities depending on the realization of the liquidity shock. Thus, deviation is not optimal when

$$\beta\left(\frac{H+L}{2} + \Phi\right) > \frac{1}{2}\left[V^{Dev}(B|A, H, r = s = k) + V^{Dev}(B|A, L, r = s = k)\right] \quad [V_S(B|NA) > V_S(B|A)].$$

Lemma 8 ***[(Non) Announcement by Bad Type (separating equilibrium)]*** *When insiders can sell s shares, where $s \in [0, k]$ and where $k < (h - \ell)$, and prices given order flow are given above in (12), the bad type will not announce a repurchase plan when,*

$$\beta\Phi > \frac{k}{2}\left(2\Delta - \frac{(H-L)(1-u)}{2-k-u}\right)\frac{(1-\beta)}{(1-k)} \textbf{ [Condition 3]} \tag{20}$$

5.4 Equilibrium Analysis

We now present the conditions for the existence of a repurchase separating equilibrium. Before we do so, it is useful to notice that condition (18) is redundant, as long as the two firm types are sufficiently different. Specifically, the conditions for the optimal announcement strategies (i.e., conditions (19) and (20) together with requirement (21) (given below), imply that the condition for feasibility of a pricing schedule for the market maker (i.e., condition (18)) is satisfied. This is formally stated in the following Lemma.

Lemma 9 ***[Feasibility of Pricing Schedule]*** *Equilibrium conditions (19), (20) and condition (21) below imply that condition (18) is satisfied, i.e., that there exists an appropriate pricing schedule.*

$$\frac{H-L}{\Delta} \leq \frac{8}{9} \tag{21}$$

We are now ready to summarize the properties of the separating equilibrium.

Proposition 3 ***[Separating Equilibrium with Insider Selling]*** *A separating equilibrium with prices given by (12) and trading strategies (3) exists provided that conditions (19), (20) and (21) hold.*

It follows from above that a separating equilibrium exists as long as the benefit from non-announcement is sufficiently low in order not to deter the good type from announcing, and is sufficiently high so that it still deters the bad type from mimicking the good type and announcing a repurchase program. Indeed, the separating equilibrium exists for a non-empty interval specified in the Corollary below.

Corollary 1 ***[Non-Announcement Benefit]*** *A separating equilibrium exists for $\Phi \in \left(\underline{\Phi}(k), \overline{\Phi}(k)\right)$ which is a non-empty set for all $k \leq \min(k^*, u)$, where $k^* > 0$ is the unique feasible solution to*

$\underline{\Phi}(k) = \overline{\Phi}(k)$, *and where*

$$\overline{\Phi}(k) \equiv (H-L)\,\frac{(1-\beta)\,k+\beta u}{4\beta\,(2-k-u)},\ \textit{and}\ \underline{\Phi}(k) \equiv \frac{(1-\beta)k}{2\beta(1-k)}\left(2\Delta - \frac{(H-L)\,(1-u)}{2-k-u}\right).$$

Moreover, $\frac{\partial \underline{\Phi}(k)}{\partial k} > 0$ *and* $\frac{\partial \overline{\Phi}(k)}{\partial k} > 0$ *for* $k \leq k^*$.

It follows from Corollary 1 above, that the bounds on the non-announcement benefit Φ depend on the extent of insider selling k. The introduction of insider selling has a non-trivial effect on the equilibrium information environment. On the one hand, it encourages deviation by the bad type and at the same time encourages participation by the good type. As is formally stated in Corollary 1, (and is also apparent in Figure 2 below) both bounds are increasing in the extent of insider selling up until they intersect at the point k^*. Intuitively, higher insider selling encourages the bad type to deviate and announce a repurchase program. This occurs since the motivation of the bad type to announce a repurchase program stems from her expected gains from insider selling of over-valued shares (and not the opportunity to repurchase under-valued shares). Higher selling capacity improves the payoff from this deviation strategy. Thus, for higher selling capacity, a higher non-announcement benefit is required to support the separating equilibrium. On the other hand, higher insider selling increases the trading gains to the good type when realized cash flows are $L + \Delta$ and thus supports the separating equilibrium - by increasing the incentive to announce a repurchase program for the good type. Thus, the separating equilibrium with insider selling can still exist with high non-announcement benefit.

We now turn to the implications of the level of insider selling k on the existence of the separating equilibrium. As hinted upon above, an upper bound on the extent of insider selling together with a potential lower bound on insider selling are required in order for there to be a separating equilibrium. Specifically, one can define the lower and upper bounds $\left\langle \bar{k}(\Phi), \underline{k}(\Phi) \right\rangle$ as the solutions to $\underline{k}(\Phi) = \left\{k \text{ s.t. } \overline{\Phi}(k) = \Phi\right\}$ and $\bar{k}(\Phi) = \{k \text{ s.t. } \underline{\Phi}(k) = \Phi\}$, respectively. Also, let Φ^S be the solution to $\overline{\Phi}(k^*)$ (which of course also equals $\underline{\Phi}(k^*)$). Recall, Φ^{bm} is the upper bound on the benefit from non-announcement of a repurchase plan for which a signaling equilibrium exists in the benchmark case (where $k = 0$).

Corollary 2 ***[Level of Insider Selling]*** *A separating equilibrium exists for* $k \in \left(\underline{k}(\Phi), \overline{k}(\Phi)\right)$ *which is a non-empty set for all* $\Phi \leq \Phi^S$*, where* $\Phi^S = \overline{\Phi}(k^*) > 0$*. In the region* $\Phi < \Phi^{bm} = \frac{u(H-L)}{4(2-u)}$*, the lower bound is zero, i.e.,* $\underline{k}(\Phi) = 0 < \overline{k}(\Phi)$*, in the region region* $\Phi \in \left(\Phi^{bm}, \Phi^S\right)$*, we have*

$0 < \underline{k}(\Phi) < \overline{k}(\Phi)$, *and finally there is no separating equilibrium for any* k *in the region* $\Phi > \Phi^S$.

[**Insert Figure 2 about here**]

Figure 2 demonstrates existence of a signaling equilibrium for different levels of insider trading k (X axis) and benefit from not announcing Φ (Y axis). The figure uses parameter levels $H = 2$, $L = 1$, $\Delta = 1.125$, $\beta = 0.4$, and $u = 0.3$. The red line describes $\overline{\Phi}(k)$, the upper level on Φ below which the good firm will announce a repurchase program given equilibrium prices as a function of k. The green line describes $\underline{\Phi}(k)$, the upper level on Φ below which the good firm will not announce a repurchase program given equilibrium prices as a function of k. In the triangle bounded by the Y axis, the red line and the green line, a signaling equilibrium can hold. Consider a low level of Φ, indicated in the figure as Φ_{low}. When insider trading k is very low a signaling equilibrium holds. As we increase k, me move along the lower black line in the figure over the area where signaling holds. This line hits the green line when at $k = \bar{k}(\Phi_{low}) = \{k \text{ s.t. } \underline{\Phi}(k) = \Phi_{low}\}$, where a signaling equilibrium stops holding and does not hold for all $k > \bar{k}(\Phi_{low})$ Similarly consider a different level of Φ in the figure indicated in the figure as $\Phi = \Phi_{high}$. When $k = 0$ a signaling equilibrium does not hold. As we increase k, once $k = \bar{k}(\Phi_{high}) = \left\{k \text{ s.t. } \overline{\Phi}(k) = \Phi_{high}\right\}$ a signaling equilibrium starts holding. As k is further increased, once it reaches $k = \underline{k}(\Phi_{high}) = \{k \text{ s.t. } \underline{\Phi}(k) = \Phi_{high}\}$, a signaling equilibrium stops holding and does not hold for all $k > \underline{k}(\Phi_{high})$.

Examination of the equilibrium conditions from the perspective of the level of insider selling reveals two substantial insights. First, both upper and lower bounds on the level of insider selling are required in order to control the participation incentives of the two types. Of course, higher insider selling increases the benefits from selling over-valued shares for the bad type. As discussed above, insider selling can also encourage the good type to announce a repurchase program and thus supports the separating equilibrium. Second, the introduction of insider selling can expand the region in which a separating equilibrium exists. When the benefit from non-announcement is intermediate $\Phi \in \left(\Phi^{bm}, \Phi^S\right)$ and the good type announces a repurchase program only if insider selling is possible. This can be seen in Figure 2 in Separating Equilibrium region which lies also above the upper bound Φ^{bm}.

6 Insider Selling - Pooling Equilibrium

We are thinking of a pooling equilibrium in which, at the announcement time, either both types announce or both types do not announce. We begin with establishing a pooling equilibrium in which both types do not announce when the benefit from non-announcement is sufficiently high, such that a separating equilibrium does not exist.

Proposition 4 ***[Both Types do not Announce]*** *An equilibrium in which both types do not announce a program exists when* $\Phi \geq \max\left[\overline{\Phi}(k), \underline{\Phi}(k)\right]$*, in this region the separating equilibrium does not exist.*

Intuitively, consider out-of-equilibrium beliefs following announcement that assign probability one that the announcing firm is the good type and that the price following order flow are as given in the above separating equilibrium. Then it is clear that if the good type announces a repurchase plan, her expected payoff is as calculated in the separating equilibrium which is not high enough to justify announcement, due to the high benefit from non-announcement $\Phi > \overline{\Phi}(k)$. On the other hand, if the bad type announces, then her expected payoff given the above out-of-equilibrium beliefs, equals the deviation payoff she faces in the separating equilibrium. Therefor, the bad type will not deviate an announce (since, $\Phi > \underline{\Phi}(k)$).

Next, consider a pooling equilibrium in which both firms announce a repurchase program. We have tried all possible pooling with sale trading strategies and found that only the following two trading strategies can support a pooling equilibrium. To begin with, we consider the pooling equilibrium in which the bad type repurchases and sells k, while the good type does not trade when cash flows are $L + \Delta$ and repurchases u when cash flows are $H + \Delta$. In this equilibrium the bad type can benefit from selling over-valued shares and the good type with cash flows $H + \Delta$ benefits from repurchasing under-valued shares

$$\begin{aligned} & d(B) = A \text{ and } r(L) = s(L) = k,\ r(H) = s(H) = k \qquad \text{[EQ I]} \\ & d(G) = A \quad \text{ and } r(L+\Delta) = s(L+\Delta) = 0, \\ & \qquad\qquad r\left(H+\Delta\right) = u,\ s\left(H+\Delta\right) = 0 \end{aligned} \tag{22}$$

The proposed equilibrium [EQ I] implies a revealing price when order flow is $2h - \ell$ with price $P_{1I}(2h - \ell) = H + \Delta$ and intermediate order flow prices of

$$\begin{aligned} P_{1I}(-\ell) &= \frac{(H+L)(2-k-u) + [2\Delta - u(L+\Delta)](1-k)}{4-2k-u(3-k)} \\ P_{1I}(-h) &= \frac{H + L(2-k) + \Delta(1-k)}{3-k} \end{aligned} \tag{23}$$

The following proposition gives the conditions for the existence of this pooling equilibrium.

Proposition 5 ***[Both Types Announce (I)]*** *A pooling equilibrium in which both types announce a repurchase program, trade is according to (22), and prices are according to (23) exists when the following conditions hold:*

$$\begin{aligned} \Phi &\leq \min\left[\underline{\Phi}_I(k), \overline{\Phi}_I(k)\right], \text{ where } \underline{\Phi}_I(k) \text{ and } \overline{\Phi}_I(k) \text{ are given in (59) and} \\ P_{1I}(-\ell) &> \min\left[2L + \Delta - H, 2H - P_{1I}(-h)\right] \end{aligned}$$

In this region the separating equilibrium does not exist.

Next, we consider the pooling equilibrium in which the bad type repurchases and sells k only when cash flows are L and does not trade when cash flows are H, and the good type does not trade when cash flows are $L + \Delta$ and repurchase u shares when cash flows are $H + \Delta$. In this equilibrium only the extreme value realizations trigger insider trading or informed repurchase.

$$\begin{aligned} &d(B) = A \text{ and } r(L) = s(L) = k,\ r(H) = s(H) = 0 \qquad \text{[EQ II]} \\ &d(G) = A \quad \text{ and } r(L+\Delta) = s(L+\Delta) = 0, \\ &\qquad\qquad r(H+\Delta) = u,\ s(H+\Delta) = 0 \end{aligned} \tag{24}$$

The proposed equilibrium [EQ II] too implies a revealing price when order flow is $2h - \ell$ with price $P_{1I}(2h - \ell) = H + \Delta$ and intermediate order flow prices of

$$\begin{aligned} P_{1II}(-\ell) &= \frac{(2-u)(1-k)(H+L+\Delta) - (u-k)L}{4-3u-3k+2uk} \\ P_{1II}(-h) &= \frac{L + (1-k)(H+L+\Delta)}{3-2k} \end{aligned} \tag{25}$$

The following proposition gives the conditions for the existence of this pooling equilibrium.

Proposition 6 ***[Both Types Announce (II)]*** *A pooling equilibrium in which both types an-*

nounce a repurchase program and trade according to (24), and prices are according to (25) exists when the following conditions hold:

$$\Phi \leq \min\left[\underline{\Phi}_{II}(k), \overline{\Phi}_{II}(k)\right], \text{ where } \underline{\Phi}_I(k) \text{ and } \overline{\Phi}_I(k) \text{ are given in (66) and}$$
$$2L + \Delta - H < P_{1II}(-\ell) < 2H - P_{1II}(-h)$$

In this region the separating equilibrium does not exist.

Figure 3 demonstrates existence of a pooling equilibrium for different levels of insider trading k (X axis) and benefit from not announcing Φ (Y axis). This figure uses the same parameter levels for H, L, Δ, β, and u as in Figure 2. As in Figure 2, the triangle bounded by the Y axis, the red line, $\overline{\Phi}(k)$, and the green line, $\underline{\Phi}(k)$, indicates the range over k and Φ where a signaling equilibrium can hold. In the area above the red line and to the left of the green line we are in the area of Proposition 4, i.e. $\Phi \geq \max\left[\overline{\Phi}(k), \underline{\Phi}(k)\right]$. In this area only a pooling equilibrium with no repurchase announcement and no insider trade holds.

Below the blue line, the pooling with announcement equilibrium described in Proposition 5 (Pooling equilibrium EQI) holds. Recall, in this pooling equilibrium the bad type with cash flow H both sells and repurchases shares. Staring from the origin, as the level of insider selling increases the profits from the pooling equilibrium to the bad type increases. This is represented by the increasing part of the blue line which equals the lower bound $\underline{\Phi}_I(k)$. However, this strategy of the bad type remains optimal only for sufficiently small values of insider selling. As the level of insider selling increases, the market maker adjusts prices downwards, and eventually this strategy of the bad type with cash flow H of selling and repurchasing shares is not longer optimal and the equilibrium EQI does not hold. At this critical level of insider selling the blue line collapses to zero. The second feasible pooling equilibrium EQII is represented by the purple line. Here, the bad type with cash flow H is required not to repurchase shares and this is optimal only for sufficiently low market prices. At first, when the level of insider selling is low, market prices are too high to justify no repurchase for the bad type with cash flow H. But, for sufficiently high level of insider selling, the market maker adjusts prices sufficiently downwards so that not repurchasing shares become optimal. This is represented by the upward jump of the purple line. After this point, further increasing insider selling further dampens prices and increases the benefits from repurchasing shares. This is reflected in the upward slope of the purple line. The upward portion of the purple line captures the lower bound $\underline{\Phi}_{II}(k)$. In this example depicted in Figure 3, the range of parameters are such that the participation incentives of the bad type are binding (i.e.,, $\underline{\Phi}_I(k) < \overline{\Phi}_I(k)$ and $\underline{\Phi}_{II}(k) < \overline{\Phi}_{II}(k)$). In general, however, for higher levels of insider selling this can change, and as indicated formally earlier in propositions 5 and 6 what matters is the minimum of the two bounds.

[**Insert Figure 3 about here**]

7 Discussion

7.1 Repurchase Announcement Plan Return

The model at hand can lend itself to an exploration of the stock price reaction to announcements of a repurchase program. It has been documented empirically that such announcements, albeit having a favorable upward price movement on average, also exhibit significant variability in the data (Comment and Jarrell 1991; Ikenberry et al. 2000; Grullon and Michaely 2004; Anolick et al. 2021). This suggests that beyond the well-known signaling of high firm prospects, market participants may also be responding to other elements embedded in repurchase announcements. In addition to this signaling effect that is present in the separating equilibrium developed above, market participants in our model take into account the value implications from insider trading; in particular, insider selling when the stock price is over-valued (along the equilibrium path). Of course, the higher the ability of insiders to strategically sell shares, the higher the price discount due to insider selling—from the perspective of the uninformed outsiders. As a result, an increase in insider selling can lead to prices following announcement being either higher or lower than ex-ante (i.e., prior to announcement) fundamental values.

It also follows from Propositions 3-6 that the price following announcement depends on the equilibrium type. To begin with, in the region of the separating equilibrium of Proposition 3, announcing firms have higher market price than non-announcement firms. Here, the signaling effect dominates the informed-selling effect and leads to an overall positive price movement following announcement. In other words, the announcement price is higher than the ex-ante fundamental value of an average firm in the separating equilibrium, which is simply given by $(H + L + \Delta + \Phi)/2$ (recall that ex-ante, it is known that an announcement will happen with probability one-half). This result, however, is reversed in the pooling equilibrium: the price following announcement is lower than the fundamental value. Of course, in the announcement pooling equilibrium (see Propositions 5 and 6), the signaling effect is absent. Consequently, the market price following announcement incorporates only the negative implications for outsiders due to informed trading. This leads to and announcement price that is lower than the ex-ante fundamental value of an average firm in the pooling equilibrium, which is simply given by $(H + L + \Delta)/2$ (recall that ex-ante it is known that an announcement will happen with probability one). It is noteworthy that, in the parameter space supporting the non-announcement pooling equilibrium (see Proposition 4), the ex-ante fundamental value of an average firm is simply given by $(H + L + \Delta)/2 + \Phi$ (recall that ex-ante it is known that an announcement will not happen). In this last case, since there is no announcement, discussion of price reaction is not relevant.

7.2 Information Environment

We turn now to discuss the overall information embedded in prices. In addition to that revealed following trading, one should consider the information revealed during the announcement stage, which is summarized by the price P_1. It is important to distinguish between the separating and the pooling equilibrium outcomes. In the separating equilibrium, the announcement of a repurchase program is of course informative about the type of the firm, being "good" or "bad." This is reflected empirically by a market reaction to announcement or non-announcement. Because order flow moves prices, trading that takes place following the announcement of a repurchase plan reveals further information about the realized cash flows $L + \Delta$ or $H + \Delta$. Following non-announcement, it is revealed that cash flows are either L or H with equal probabilities, but, since there is no informed trading, order flow does not provide further cash flow related information. In the pooling equilibrium, either both firm types announce or both do not announce. In both cases, no information about firm type is revealed in the announcement stage. However, in the former equilibrium, order flow is informative and further information is revealed regarding the realization of cash flows.

Ex-ante, comparing the information environment in the separating equilibrium to that in the pooling equilibrium (where both firms announce) is not trivial. On the one hand, the separating equilibrium offers firm "type" information, but order flow is informative only for the good type and not for the bad type. On the other hand, the pooling equilibrium does not offer "type" information (as both announce), but order flow is informative for both types. Thus, overall, a comparison of price efficiency is in general ambiguous. However, in the case at hand, where the distribution of types/cash flows is equally weighted, the information environment is ordered across these two regimes. In particular, under the pooling equilibrium order flow does not help distinguish between cash flow realizations of the bad type. Further, the order flow provides information about the cash flows of the good type but to a lesser extent relative to the signaling equilibrium. Overall, the signaling equilibrium dominates the pooling equilibrium both in terms of type related information (following announcement) and cash flow related information (following trade).

The main implication of the above discussion related to the effects of insider selling on the type of equilibrium, and therefore, also on the information environment. Specifically, an increase in insider selling can either improve price efficiency or worsened it. To begin with, price efficiency improves when the increase in insider selling leads to a shift from a pooling equilibrium in which both firms do not announce to (i) a separating equilibrium or (ii) to a pooling equilibrium in which both types announce. An examination of figure 3 can help identify the relevant cases as they correspond to the level of insider selling k and the cost of announcing a repurchase program Φ. For example, insider selling improves price efficiency when it shifts the equilibrium from a pooling equilibrium in which both types do not announce to a pooling equilibrium in which both types announce. Similarly, when an increase in insider selling shifts the equilibrium from a pooling equilibrium in which both types do not announce to a separating equilibrium. On the other hand, an increase in insider selling can also shift the equilibrium from a separating equilibrium to a pooling equilibrium in which both types announce. As discussed above, price efficiency is reduced as the result of this increase in insider selling.

8 Summary and Conclusions

Due to their dramatic and continuing growth in the past four decades, stock repurchases attract substantial attention from academics and policy makers. Based on empirical findings of positive announcement and long-run returns for repurchase programs, the standard view is that informed, value-maximizing managers use repurchases to signal stock undervaluation. However, there is increasing evidence at odds with this view: Firms also repurchase overvalued security; insider trading is correlated with repurchase activity; and there are weak announcement effects of repurchases. We therefore examine signaling by repurchases in the presence of strategic insider selling by wealth-maximizing managers, that is, in the realistic setting of information signaling and shareholder-manager agency conflicts.

Our analysis shows that information signaling through share repurchases is significantly modified by the presence of insider selling. In particular, there is signaling by repurchases in *both* undervalued and overvalued equity states. We show that informed insiders can increase their wealth at the expense of uninformed shareholders by repurchasing shares both when the stock is under-valued or over-valued, and by strategically timing their sales to coincide with over-valuation states. By increasing benefits from repurchase announcements, insider-selling amplifies the incentives of managers of good firms to separate and those of bad firms to mimic. Insider-selling can thus both increase price efficiency by supporting a signaling equilibrium or dampen efficiency by disallowing separation, depending on salient characteristics such as variance of firm value, liquidity, and insider equity ownership. We thus offer a novel perspective on the effects of repurchases on price discovery and on the redistribution of wealth from uninformed outside shareholders to informed insiders.

While the signaling properties of stock repurchase have been considered extensively in the theoretical literature, to our knowledge their interaction with agency conflicts due to insider trading by self-interested managers has not been under-explored. Our theoretical findings are consistent with the empirical evidence about insiders timing their trading with firms' repurchase activity, and that the announcement return on repurchase programs has great variability, and has decreased significantly over the years. The model also generates new empirical predictions. It predicts for example that repurchase program announcement returns can be either negatively or positively related to insider trading. Implications for regulators are, for example, that insider trading should be more carefully considered after repurchase program announcements.

Tables

Table 1A describes equilibrium repurchase, order flow, and prices for the four possible states span by x, q, in the setup in which the firm can repurchase but insiders cannot trade their own shares.

Table 1A: Signaling Equilibrium, $\mathbf{k = 0}$

firm value x	liquidity q	repurchase r	order flow F	MM price P_1	terminal value P_2
$L+\Delta$	$-h$	0	$-h$	$L+\Delta$	$L+\Delta$
$L+\Delta$	$-\ell$	0	$-\ell$	$P_1^{bm}(-\ell)$	$L+\Delta$
$H+\Delta$	$-h$	$h-\ell$	$-\ell$	$P_1^{bm}(-\ell)$	$\frac{H+\Delta-(h-\ell)P_1^{bm}(-\ell)}{1-(h-\ell)}$
$H+\Delta$	$-\ell$	$h-\ell$	$h-2\ell$	$H+\Delta$	$H+\Delta$

Table 1B describes the repurchase and sell strategy in the separating equilibrium for the insiders and the resulting order flow and prices for the four possible states span by the realizations of x and q.

Table 1B: Insider Trading and Repurchase following announcement by Good type

firm value x	liquidity q	repurchase r	insider s	order flow F	MM price P_1	terminal value P_2
$L+\Delta$	$-h$	k	$-k$	$-h$	$L+\Delta$	$L+\Delta$
$L+\Delta$	$-\ell$	k	$-k$	$-\ell$	$P_1(-\ell)$	$\frac{L+\Delta-kP_1(-\ell)}{1-k}$
$H+\Delta$	$-h$	$h-\ell$	0	$-\ell$	$P_1(-\ell)$	$\frac{H+\Delta-(h-\ell)P_1(-\ell)}{1-(h-\ell)}$
$H+\Delta$	$-\ell$	$h-\ell$	0	$h-2\ell$	$H+\Delta$	$H+\Delta$

Appendix

Proof. Lemma 1[Repurchase Strategy without Insider Selling in Separating Equilibrium] We show that the insiders will not deviate, neither when they observe $L+\Delta$, nor when they observe $H+\Delta$. The insiders will not deviate and repurchase in state $L+\Delta$, because if they do, they dilute the value of their own shares. The insiders will also not deviate in state $H+\Delta$. This is because if they repurchase more than $h-l$, the MM will always observe an order flow higher than $-l$ in both states $\{H+\Delta, h\}$ and $\{H+\Delta, l\}$. He will conclude that the firm is buying, set the price to $H+\Delta$ and they will repurchase at fair value. Any positive repurchase smaller than $h-l$ will also reveal to the MM that the firm is buying, and because he knows the firm will not buy when the value is $L+\Delta$ he will conclude that the value is $H+\Delta$ and set the price accordingly. If they do not repurchase when observing $H+\Delta$ the MM will set the price to $P_1^{bm}(-\ell)$ in state $\{H+\Delta, h\}$ and to $L+\Delta$ in state $\{H+\Delta, l\}$, but the insiders do not benefit because they do not repurchase. ■

Proof. Lemma 2 [Market Prices and Order Flow] Prices given order flow follow directly from the derivations in the text. We turn to explore the implications of these equilibrium prices for the time $t=0$ price of the stock before the announcement decision. The non-announcing firm in the separating equilibrium has price $P_0^{bm}(NA) = \frac{H+L}{2}$. The price of the announcing firm $P_0^{bm}(A)$ is given as follows:

$$P_0^{bm}(A) = \frac{1}{2}\left(\frac{H+L}{2}+\Delta\right) + \frac{1}{4(1-\beta)}\left(\begin{array}{r} (1-\beta-h)\left[\frac{H+\Delta-uP_1^{bm}(-\ell)}{1-u}\right] + hP_1^{bm}(-\ell)... \\ ... + (1-\beta-\ell)\left[L+\Delta\right] + \ell P_1^{bm}(-\ell) \end{array}\right)$$

and upon rearrangement

$$P_0(A) = \frac{1}{2}\left(\frac{H+L}{2}+\Delta\right) + \frac{1}{4(1-\beta)}\left(2P_1^{bm}(-\ell)(1-\beta) - u\left[P_1^{bm}(-\ell) - (L+\Delta)\right]\right)$$

notice that

$$P_1^{bm}(-\ell) = \frac{H + L(1-u)}{2-u} + \Delta - (L + \Delta) = \frac{H-L}{2-u} \tag{26}$$

and hence,

$$P_0^{bm}(A) = \frac{1}{2}\left(\frac{4H + 4L - uH - uL - 2Lu}{2(2-u)}\right) - \frac{1}{4(1-\beta)}u\left[\frac{H-L}{2-u}\right] + \Delta.$$

■

Proof. Proposition 1 [Signaling Equilibrium with no Selling] Follows from derivation in the text. ■

Proof. Proposition 2[**Pooling Equilibrium with no Selling**]: We begin by stating that the pooling equilibrium in which both types do not announce a repurchase program exist when $\Phi \geq \Phi^{bm}$, for out of equilibrium beliefs prices that exactly equal the prices derived in the separating equilibrium. Of course, this implies that if the good type deviates and announces a repurchase program then it will face expected profits that are below Φ^{bm}, as shown when deriving the conditions for the existence of the separating equilibrium.

For completeness, we show that other types of pooling equilibrium with repurchase do not exist. We will examine two possible pooling equilibrium outcomes in which both types announce a program. In the first, both repurchase only when cash flows are high and trade identically. Specifically,

$$\text{Candidate Pooling EQI:} \begin{cases} d(B) = A \text{ and } r(L) = 0,\, r(H) = u \\ d(G) = A \quad \text{ and } r(L+\Delta) = 0,\, r(H+\Delta) = u \end{cases} \tag{27}$$

This proposed pooling equilibrium is not possible since $\frac{H-L}{\Delta} < 1$. Specifically, this implies that it must be optimal for the good type with cash flows $L + \Delta$ to repurchase if the bad type with cash flows H repurchases along the equilibrium path. Thus, we consider a second type of pooling equilibrium. In the second type, repurchase takes place in all cash flow states besides $x = L$.

$$\text{Candidate Pooling EQII:} \begin{cases} d(B) = A \text{ and } r(L) = 0,\, r(H) = u \\ d(G) = A \quad \text{ and } r(L+\Delta) = r(H+\Delta) = u \end{cases} \tag{28}$$

This implies the lowest order flow can only imply that the firm had not repurchased shares, thus leading to price $P_1(-h) = L$. On the other extreme, the highest order flow must imply that the firm repurchased shares, which in turn, implies that cash flows are either $L+\Delta$, H, or $H+\Delta$. These outcomes are equally likely. Thus, this leads to price $P_1(h-2\ell) = \frac{2(H+\Delta)+L}{3}$. When order flow is intermediate $(-\ell)$, however, the market maker does not know whether repurchase took place or not and sets price $\hat{P}(-\ell)$. Importantly, in order for this pooling equilibrium to exist, it must be that the bad type with cash flow H finds it optimal to repurchase. Thus, since the price $P_1(h-2\ell) > H$, it must be that $\hat{P}(-\ell) < H$, to allow for expected gains following repurchase. One can derive the equilibrium price $\hat{P}(-\ell)$ and notice that it exceeds the cash flow value H under the assumption $\frac{H-L}{\Delta} < 1$.[15] Thus, the second suggested pooling equilibrium does not exist either. ■

Proof. Lemma 3 [Market Prices and Order Flow with Insider Selling] Follows from discussion in the text. ■

Proof. Lemma 4 [Trading by the Good Type in the Separating Equilibrium]: First we show that when cash flows are $L+\Delta$, then for no deviation the condition is

$$\frac{k(1-\beta)}{\left[\frac{3-2k-u}{2-k-u}\right]} < \eta \in (0,u) \text{[Equilibrium Condition for case } L+\Delta\text{]}.$$

Consider the alternative of selling $k-\eta$ and repurchasing k when $L+\Delta$. The payoff from this deviation is,

$$\frac{1}{2}\left[H+\Delta+P_1(-\ell)\right](k-\eta) + \frac{L+\Delta-\frac{1}{2}k\left[H+\Delta+P_1(-\ell)\right]}{1-k}(\beta-k+\eta)H$$

For no such deviation, this payoff must be lower than the payoff without deviation, that is,

$$\begin{aligned} & \frac{1}{2}\left[H+\Delta+P_1(-\ell)\right](k-\eta) + \frac{L+\Delta-\frac{1}{2}k\left[H+\Delta+P_1(-\ell)\right]}{1-k}(\beta-k+\eta) \\ < \ & \frac{1}{2}\left[P_1(-\ell)+L+\Delta\right]k + \frac{L+\Delta-\frac{1}{2}k\left[P_1(-\ell)+L+\Delta\right]}{1-k}(\beta-k). \end{aligned}$$

This simplifies to,

$$\frac{k}{2}\left[H-L\right]\left[1-\beta\right] < \eta\left[\frac{1}{2}\left[H+P_1(-\ell)+\Delta\right]-(L+\Delta)\right]$$

[15] In this proposed pooling equilibrium the market price following interemediate order flow satisfies $\hat{P}(-\ell) = \frac{1}{4}L + \frac{3}{4}\left[\frac{\frac{2(H+\Delta)+L}{3}-up^m}{1-u}\right] \Leftrightarrow \hat{P}(-\ell) = \frac{2H+2\Delta+2L-Lu}{4-u} > H$. As mentioned above, $\hat{P}(-\ell) = \frac{2H+2\Delta+2L-Lu}{4-u} > \frac{2H+2H-Lu}{4-u} > \frac{2H+2H-Hu}{4-u} = H$.

Now, we substitute $P_1(-\ell) = \frac{H(1-k)+L(1-u)}{2-k-u} + \Delta$ to get

$$\frac{k}{2}\left[H-L\right]\left[1-\beta\right] < \eta\left[\frac{1}{2}\left[H + \frac{H\left(1-k\right)+L\left(1-u\right)}{2-k-u}\right] - L\right]$$

which boils down to

$$\frac{k\left(1-\beta\right)}{\left[\frac{3-2k-u}{2-k-u}\right]} < \eta.$$

Next consider the alternative of repurchasing $k+\eta$ and selling k when $L+\Delta$. In this case we require that,

$$\begin{aligned} & \frac{1}{2}\left[H+\Delta+P_1\left(-\ell\right)\right]k + \frac{L+\Delta-\frac{1}{2}(k+\eta)\left[H+\Delta+P_1\left(-\ell\right)\right]}{1-k-\eta}\left(\beta-k\right) \\ < \quad & \frac{1}{2}\left[P_1\left(-\ell\right)+L+\Delta\right]k + \frac{L+\Delta-\frac{1}{2}k\left[P_1\left(-\ell\right)+L+\Delta\right]}{1-k}\left(\beta-k\right) \end{aligned}$$

This simplifies to

$$(H-L)k(1-k)\left[\frac{(1-\beta-\eta)}{(\beta-k)}\right] < \eta\left[\left(H-L\right)\left(1-k\right)+P_1\left(-\ell\right)-\Delta-L\right].$$

Now, we substitute for $P_1(-\ell) = \frac{H(1-k)+L(1-u)}{2-k-u} + \Delta$ to get

$$(H-L)k(1-k)\left[\frac{(1-\beta-\eta)}{(\beta-k)}\right] < \eta\left[\left(H-L\right)\left(1-k\right) + \frac{H\left(1-k\right)+L\left(1-u\right)}{2-k-u} - L\right]$$

which reduces to

$$\frac{k\left(1-\beta\right)}{\left(\frac{\beta-k}{2-k-u}+k\right)} < \eta.$$

Now, it is clear that

$$\frac{k\left(1-\beta\right)}{\left(\frac{\beta-k}{2-k-u}+k\right)} < \eta \Rightarrow \frac{k\left(1-\beta\right)}{\left[\frac{3-2k-u}{2-k-u}\right]} < \eta$$

This follows since,

$$\begin{aligned} \frac{\beta-k}{2-k-u}+k \quad & < \quad \frac{3-2k-u}{2-k-u} \Leftrightarrow \\ \left(1-k\right)\left(2-k-u\right) \quad & < \quad 0 < 1-\beta \text{ [always holds]} \end{aligned}$$

Hence, the condition for no deviation when cash flows are $L+\Delta$ is

$$\frac{k(1-\beta)}{\left[\frac{3-2k-u}{2-k-u}\right]} < \eta.$$

Next we show that when cash flows are $H+\Delta$, then for no deviation the condition is

$$\frac{u}{3-k-u} > \eta \ \in (0,u)[\text{Equilibrium Condition for case } H+\Delta].$$

Consider the alternative of selling 0 and repurchasing $u-\eta$ when $H+\Delta$. For no such deviation, this payoff must be lower than the payoff without deviation, that is,

$$\begin{aligned} & \frac{1}{2}\beta\left[\frac{H+\Delta-\eta P_1(-\ell)}{1-\eta}\right]+\frac{1}{2}\beta\left[\frac{H+\Delta-\eta(L+\Delta)}{1-\eta}\right] \\ < \ & \frac{1}{2}\beta\left[\frac{H+\Delta-uP_1(-\ell)}{1-u}\right]+\frac{1}{2}\beta(H+\Delta) \end{aligned}$$

This simplifies to

$$u > \eta\left[1+\frac{(1-u)(H-L)}{H+\Delta-P_1(-\ell)}\right] \text{ where } P_1(-\ell)=\frac{H(1-k)+L(1-u)}{2-k-u}+\Delta$$

Now substitute $P_1(-\ell)=\frac{H(1-k)+L(1-u)}{2-k-u}+\Delta$ to write this as

$$\frac{u}{\eta}-1 > \frac{(1-u)(H-L)}{H+\Delta-\frac{H(1-k)+L(1-u)}{2-k-u}-\Delta} = \frac{(1-u)(H-L)}{H-\frac{H(1-k)+L(1-u)}{2-k-u}}$$

and upon simplification

$$\eta < \frac{u}{3-k-u}.$$

■

Proof. Lemma 5 [Announcement by Good Type (separating equilibrium)]

It follows from $V_S(G|A)=\beta\left[\frac{1}{2}(H+L)+\Delta\right]+\frac{1}{4}\frac{(1-\beta)k+\beta u}{2-k-u}(H-L)$ that $V_S(G|A)\geq V_S(G|NA)$ can be summarized by the condition

$$\frac{1}{4}\frac{(1-\beta)k+\beta u}{2-k-u}(H-L) > \beta\Phi \ \textbf{[Condition 2]}.$$

■

Proof. Lemma 6[Deviation Trading Strategy Bad type Cash Flow H] Following announcement (deviation) trading of $r = s = k$ when cash flow state is H is given by:

$$(1)\ V^{Dev}(B|A, H, r = s = k) = \frac{1}{2}\left(k(L+\Delta) + (\beta - k)\left[\frac{H - k(L+\Delta)}{1-k}\right]\right) + \frac{1}{2}\left(kP_1(-\ell) + (\beta - k)\left[\frac{H - kP_1(-\ell)}{1-k}\right]\right) \tag{29}$$

$$= \frac{1}{2}\left(k(L+\Delta+P_1(-\ell)) + (\beta - k)\left[\frac{2H - k(L+\Delta+P_1(-\ell))}{1-k}\right]\right) \tag{30}$$

Next, consider the deviations of (2) $r = k + \eta$, $s = k$ and (3) $r = k$, $s = k - \eta$. After deriving the expected payoff from these deviations, it will become apparent that deviation (2) dominates deviation (3). Specifically, the expected payoff from deviation (2) is,

$$(2)\ V^{Dev}(B|A, H, r = k+\eta, s = k) = \beta H + \frac{1}{2}(\Delta + P_1(-\ell) - H)\left(\frac{k - \beta(k+\eta)}{1-k-\eta}\right) \tag{31}$$

and the payoff from deviation (3) is,

$$(3)\ V^{Dev}(B|A, H, r = k, s = k-\eta) = \beta H + \frac{1}{2}(\Delta + P_1(-\ell) - H)\left(\frac{k(1-\beta) - \eta}{1-k}\right)$$

The dominance of deviation (2) over deviation (3) follows from

$$\frac{k - \beta(k+\eta)}{1-k-\eta} = \frac{k(1-\beta) - \beta\eta}{1-k-\eta} > \frac{k(1-\beta) - \eta}{1-k}.$$

The above trade-off between deviation (1) and (2) is similar to the trade-off earlier analyzed for type $L + \Delta$ when comparing these two strategies. Specifically, we show that the condition required earlier (15) implies that deviation strategy (1) dominates deviation strategy (2) for cash flows H.

Specifically, given (15) we know that $V(G|A, L+\Delta, r = s = k) > V_{Dev}(G|A, L+\Delta, r = k+\eta, s =$

k). That is,

$$
\begin{aligned}
V(G|A, L+\Delta, r &= s=k) = \frac{1}{2}\left[kP_1(-\ell) + (\beta-k)\left[\frac{L+\Delta-kP_1(-\ell)}{1-k}\right]\right] + \frac{1}{2}\beta(L+\Delta) \\
&= \frac{1}{2}\left[L+\Delta+P_1(-\ell)\right]k + (\beta-k)\left[\frac{L+\Delta-k\frac{1}{2}\left[L+\Delta+P_1(-\ell)\right]}{1-k}\right] > \\
V_{Dev}(G|A, L+\Delta, r &= k+\eta, s=k) \; = \frac{1}{2}\left[H+\Delta+P_1(-\ell)\right]k + (\beta-k)\,\frac{L+\Delta-\frac{1}{2}(k+\eta)\left[H+\Delta+P_1(-\ell)\right]}{1-k-\eta} \\
&= \frac{1}{2}\left[H+\Delta+P_1(-\ell)\right]k + (\beta-k)\,\frac{L+\Delta-\frac{1}{2}(k+\eta)\left(H+\Delta+P_1(-\ell)\right)}{1-k-\eta}.
\end{aligned}
$$

Of course, now considering cash flow H we want to check whether this implies that $V^{Dev}(B|A, H, r = s = k) > V^{Dev}(B|A, H, r = k+\eta, s = k)$. That is,

$$
\begin{aligned}
V^{Dev}(B|A, H, r &= s=k) = \frac{1}{2}\left(k\left(L+\Delta\right) + (\beta-k)\left[\frac{H-k(L+\Delta)}{1-k}\right]\right) \\
&\quad + \frac{1}{2}\left(\left(kP_1(-\ell) + (\beta-k)\left[\frac{H-kP_1(-\ell)}{1-k}\right]\right)\right) && (32) \\
&= \frac{1}{2}\left[L+\Delta+P_1(-\ell)\right]k + (\beta-k)\left[\frac{H-k\frac{1}{2}\left[L+\Delta+P_1(-\ell)\right]}{1-k}\right] >? && (33) \\
V^{Dev}(B|A, H, r &= k+\eta, s=k) = \frac{1}{2}\left[k\left(H+\Delta\right) + (\beta-k)\,\frac{H-(k+\eta)\left(H+\Delta\right)}{1-k-\eta}\right] && (34) \\
&\quad + \frac{1}{2}\left[kP_1(-\ell) + (\beta-k)\,\frac{H-(k+\eta)P_1(-\ell)}{1-k-\eta}\right] && (35) \\
&= \frac{1}{2}\left[H+\Delta+P_1(-\ell)\right]k + \frac{H-\frac{1}{2}(k+\eta)\left(H+\Delta+P_1(-\ell)\right)}{1-k-\eta}\left(\beta-k\right) && (36)
\end{aligned}
$$

Notice that the only difference between the two aforementioned inequalities is the value of the cash flow state (being either $L+\Delta$ in the former or H the latter). In order to show that the above inequality holds we define the function $\Psi(z)$ be given by,

$$
\begin{aligned}
\Psi(z) \equiv\; & \frac{1}{2}\left[L+\Delta+P_1(-\ell)\right]k + (\beta-k)\left[\frac{z-k\frac{1}{2}\left[L+\Delta+P_1(-\ell)\right]}{1-k}\right] \\
& -\frac{1}{2}\left[H+\Delta+P_1(-\ell)\right]k - \frac{z-\frac{1}{2}(k+\eta)\left(H+\Delta+P_1(-\ell)\right)}{1-k-\eta}\left(\beta-k\right).
\end{aligned}
$$

Since $\Psi(L+\Delta) > 0$, $\Psi(z) \propto z\left(\frac{1}{1-k} - \frac{1}{1-k-\eta}\right)$, $\Psi'(z) < 0$ and $H < L+\Delta$, we conclude that

$\Psi(H) > 0$. Thus,

$$V_{Dev}(B|A, H, r = s = k) > V_{Dev}(B|A, H, r = k + \eta, s = k).$$

■

Proof. Lemma 7[Deviation Trading Strategy Bad type Cash Flow L] The proposed strategy of repurchasing and selling is better than not trading at all, since L is the smallest possible valuation of the firm and prices are strictly larger in any separating equilibrium where the good type announces and the bad type does not announce. Specifically, the expected payoff from this strategy is,

$$(1)\ V(B|A, L, r = s = k) = \frac{1}{2}\left[kP_1(-\ell) + (\beta - k)\left[\frac{L - kP_1(-\ell)}{1-k}\right] + k(L + \Delta) + (\beta - k)\frac{L - k(L + \Delta)}{1-k}\right]$$

Finally, like before, we consider the deviations of (2) $r = k + \eta$, $s = k$ and (3) $r = k$, $s = k - \eta$. Starting from the former,

$$\begin{aligned} (2)\ V^{Dev}(B|A, L, r &= k + \eta, s = k) = \frac{1}{2}\left[k(H + \Delta) + (\beta - k)\frac{L - (k + \eta)(H + \Delta)}{1 - k - \eta}\right] \\ &+ \frac{1}{2}\left[kP_1(-\ell) + (\beta - k)\frac{L - (k + \eta)P_1(-\ell)}{1 - k - \eta}\right] \quad (37) \\ &= \beta L + \frac{1}{2}(H + \Delta + P_1(-\ell) - 2L)\left(\frac{k - \beta(k + \eta)}{1 - k - \eta}\right) \quad (38) \end{aligned}$$

and,

$$\begin{aligned} (3)\ V^{Dev}(B|A, L, r &= k, s = k - \eta) = \frac{1}{2}\left[(k - \eta)(H + \Delta + P_1(-\ell))\right] \\ &+ \frac{1}{2}\left[(\beta - k + \eta)\left(\frac{2L - k(H + \Delta + P_1(-\ell))}{1 - k}\right)\right] \\ &= \beta L + \frac{1}{2}(H + \Delta + P_1(-\ell) - 2L)\left(\frac{k(1 - \beta) - \eta}{1 - k}\right) \end{aligned}$$

It can be shown that (2) dominates (3) since,

$$\begin{aligned} \frac{k - \beta(k + \eta)}{1 - k - \eta} &= \frac{k(1 - \beta) - \beta\eta}{1 - k - \eta} > \frac{k(1 - \beta) - \eta}{1 - k} \Leftrightarrow \\ V^{Dev}(B|A, L, r &= k + \eta, s = k) > V^{Dev}(B|A, L, r = k, s = k - \eta). \end{aligned}$$

Next, we show that (1) dominates (2). Like in the proof of Lemma **6**, from the condition for the Good type $V(G|A, L+\Delta, r=s=k) > V_{Dev}(G|A, L+\Delta, r=k+\eta, s=k)$, it follows that $V^{Dev}(B|A, L, r=s=k) > V^{Dev}(B|A, L, r=k+\eta, s=k)$ since since $L < L+\Delta$. ■

Proof. Lemma 8[**(Non) Announcement by Bad Type (separating equilibrium)**] We examine the condition for non-announcement:

$$\beta\left(\frac{H+L}{2}+\Phi\right) > \frac{1}{2}\left[V^{Dev}(B|A, H, r=s=k) + V^{Dev}(B|A, L, r=s=k)\right] \tag{39}$$

Notice that,

$$V^{Dev}(B|A, L, r=s=k) = \frac{1}{2}\left(k\left(L+\Delta+P_1(-\ell)\right) + (\beta-k)\left[\frac{2L-k(L+\Delta+P_1(-\ell))}{1-k}\right]\right) \tag{40}$$

and,

$$V^{Dev}(B|A, H, r=s=k) = \frac{1}{2}\left(k\left(L+\Delta+P_1(-\ell)\right) + (\beta-k)\left[\frac{2H-k(L+\Delta+P_1(-\ell))}{1-k}\right]\right) \tag{41}$$

The average of the two is,

$$\begin{aligned} V^{Dev}(B|A) &= \frac{1}{4}\left[k\left(L+\Delta+P_1(-\ell)\right) + (\beta-k)\left[\frac{2H-k(L+\Delta+P_1(-\ell))}{1-k}\right]\right] \\ &\quad +\frac{1}{4}\left[k\left(L+\Delta+P_1(-\ell)\right) + (\beta-k)\left[\frac{2L-k(L+\Delta+P_1(-\ell))}{1-k}\right]\right] \\ &= \frac{1}{2}\left[k\left(L+\Delta+P_1(-\ell)\right)\frac{(1-\beta)}{(1-k)} + \frac{(\beta-k)}{(1-k)}(H+L)\right] \end{aligned}$$

Now we can substitute $P_1(-\ell) = \frac{H(1-k)+L(1-u)}{2-k-u} + \Delta$ and write

$$V^{Dev}(B|A) = \frac{1}{2}\left[k\left(L+\Delta+\frac{H(1-k)+L(1-u)}{2-k-u}+\Delta\right)\frac{(1-\beta)}{(1-k)} + \frac{(\beta-k)}{(1-k)}(H+L)\right] \tag{42}$$

$$= \beta\frac{H+L}{2} + \frac{k}{2}\left(2\Delta - \frac{(H-L)(1-u)}{2-k-u}\right)\frac{(1-\beta)}{(1-k)} \tag{43}$$

Then the condition for non-announcement becomes

$$\beta\left(\frac{H+L}{2}+\Phi\right) > \beta\frac{H+L}{2} + \frac{k}{2}\left(2\Delta - \frac{(H-L)(1-u)}{2-k-u}\right)\frac{(1-\beta)}{(1-k)}. \tag{44}$$

or

$$\beta\Phi > \frac{k}{2}\left(2\Delta - \frac{(H-L)(1-u)}{2-k-u}\right)\frac{(1-\beta)}{(1-k)}. \tag{45}$$

which is condition (20). ■

Proof. Lemma 9[Feasibility of Pricing Schedule] We show here that when that when $\frac{H-L}{\Delta} \leq \frac{8}{9}$ holds together with conditions (19) and (20), then (18) also holds. Thus, assume that $\frac{H-L}{\Delta} \leq \frac{8}{9}$ holds, and recall that the relevant parameter space is given by $\beta \in (0,1), u \in (0, 1-\beta), k \in (0, \min(u, \beta))$.

Denote the equilibrium boundaries by $\overline{\Phi}(k) \equiv \frac{1}{4\beta}\frac{(1-\beta)k+\beta u}{2-k-u}(H-L)$, and $\underline{\Phi}(k) \equiv \frac{k}{2\beta}\left(2\Delta - \frac{(H-L)(1-u)}{2-k-u}\right)\left(\frac{1-\beta}{1-k}\right)$. Conditions (19) and (20) imply that $\overline{\Phi}(k) > \Phi > \underline{\Phi}(k)$, i.e., that

$$\frac{1}{4}\frac{(1-\beta)k+\beta u}{2-k-u}(H-L) > \frac{k}{2}\left(2\Delta - \frac{(H-L)(1-u)}{2-k-u}\right)\left(\frac{1-\beta}{1-k}\right).$$

Rearranging, this is equivalent to

$$\frac{1}{4}\frac{(1-\beta)k+\beta u}{2-k-u}(H-L) + \frac{k}{2}\frac{(H-L)(1-u)(1-\beta)}{(2-k-u)(1-k)} > k\Delta\frac{1-\beta}{1-k}$$

Multiplying by $\frac{4(1-k)(2-k-u)}{k(1-\beta)(H-L)}$, which is strictly positive, gives

$$1-k+\frac{\beta(1-k)}{k(1-\beta)}u + 2(1-u) > 4\frac{\Delta}{H-L}(2-k-u)$$

or simply

$$\frac{\beta(1-k)}{k(1-\beta)}u + 3 - k - 2u > 4\frac{\Delta}{H-L}(2-k-u) \tag{46}$$

We now show that when (46) holds, then (18) also holds.

Equivalently, we will show the contrapositive, i.e., that whenever (18) does not hold, the above does not either. Thus, assume that (18) does not hold. That is, $\frac{k(1-\beta)}{\frac{\beta-k}{2-k-u}+k} \geq \frac{u}{3-k-u}$. So we have

$$\frac{k(1-\beta)}{\frac{\beta-k}{2-k-u}+k} \geq \frac{u}{3-k-u} \iff$$

$$k(1-\beta)(3-k-u) \geq u\left(\frac{\beta-k}{2-k-u}+k\right) \iff$$

$$k(1-\beta)(3-k-u)(2-k-u) \geq u(\beta-k)+uk(2-k-u)$$

Since $k < \beta < 1-u$, we have $2-k-u > 1$, hence

$$u(\beta-k)+uk(2-k-u) > u(\beta-k)+uk = u\beta$$

Therefore, we have

$$k(1-\beta)(3-k-u)(2-k-u) \geq u\beta$$

and equivalently

$$(3-k-u)(2-k-u) \geq \frac{u\beta}{k(1-\beta)}$$

Using this, we get

$$\begin{aligned}
&\frac{\beta(1-k)}{k(1-\beta)}u + 3 - k - 2u \leq (3-k-u)(2-k-u)(1-k) + 3 - k - 2u \\
&\leq^{*} (3-k-u)(2-k-u)(1-k) + 3 - 1.5k - 1.5u \\
&\leq (3 * 1 + 1.5)(2-k-u) = 4.5(2-k-u) \\
&\leq^{**} 4\frac{\Delta}{H-L}(2-k-u)
\end{aligned}$$

where (*) holds since $k < u$, and where (**) holds since $\frac{\Delta}{H-L} \geq \frac{9}{8}$.

We therefore showed that if (18) doesn't hold, then (19) and (20) cannot both hold, which completes the proof. ■

Proof. Proposition 3[Separating Equilibrium with Insider Selling]: The proof follows directly from Lemma 9 and the earlier conditions for optimal best responses. ■

Proof. Corollary 1[Non-Announcement Benefit]: To begin with, we wish to show that there is a unique, feasible, positive solution to

$$\overline{\Phi}(k) \equiv (H-L)\frac{(1-\beta)k + \beta u}{4\beta(2-k-u)} = \frac{(1-\beta)k}{2\beta(1-k)}\left(2\Delta - \frac{(H-L)(1-u)}{2-k-u}\right) \equiv \underline{\Phi}(k)$$

Recall that relevant parameter space is given by $\beta \in (0,1)$, $u \in (0, 1-\beta)$, $k \in (0, \min(u, \beta))$, and also $H - L \in (0, \frac{8}{9}\Delta)$. Multiplying the above equality by $4\beta(2-k-u)(1-k)$, we get:

$$(H-L)((1-\beta)k + \beta u)(1-k) = 4k\Delta(1-\beta)(2-k-u) - 2(1-\beta)k(H-L)(1-u).$$

Next, this can be written as,

$$\begin{aligned}
&-k^2(H-L)(1-\beta) + k(H-L)(1-\beta-\beta u) + (H-L)\beta u = \\
&-k^2 4\Delta(1-\beta) + k(1-\beta)(4\Delta(2-u) - 2(H-L)(1-u)).
\end{aligned}$$

This leads to the following quadratic equation $ak^2 + bk + c = 0$, where,

$$a = (1-\beta)(4\Delta - H + L)$$
$$b = ((H-L)(1-\beta-\beta u) - (1-\beta)(4\Delta(2-u) - 2(H-L)(1-u)))$$
$$c = (H-L)\beta u$$

It follows that $a > 0$ and $b > 0$. Turning to the sign of c notice that

$$\begin{aligned}
b &= (H-L)(1-\beta-\beta u) - (1-\beta)(4\Delta(2-u) - 2(H-L)(1-u)) \\
&< (H-L)(1-\beta) - (1-\beta)(4\Delta(2-u) - 2(H-L)(1-u)) \\
&= (H-L)(1-\beta)\left(1 - \frac{4\Delta(2-u)}{H-L} + 2(1-u)\right) \\
&< (H-L)(1-\beta)\left(3 - \frac{4\Delta}{H-L}\right) \\
&< (H-L)(1-\beta)(3-4) < 0
\end{aligned}$$

Any solution must be positive, as $a > 0, c > 0, b < 0$. To explore the existence of solutions consider the discriminant $b^2 - 4ac$. Let us denote,

$$LHS \equiv \left((1-\beta-\beta u) - 2(1-\beta)\left(\frac{2\Delta}{H-L}(2-u) - 1 + u\right)\right)^2$$

and

$$RHS \equiv 4\beta u(1-\beta)\left(\frac{4\Delta}{H-L} - 1\right)$$

Of course, two distinct solutions exist if $LHS > RHS$, a unique solution in case of equality, or none otherwise. We will next show that two possible solutions exist and that the larger between the two is not feasible.

Two possible solutions exist:

We need to show here that $LHS > RHS$. Note regarding LHS that

$$\begin{aligned}
&2(1-\beta)\left(\frac{2\Delta}{H-L}(2-u) - 1 + u\right) > 2(1-\beta)(2(2-u) - 1 + u) > \\
&> 2(1-\beta)(2-1+u) > 2(1-\beta) > 1-\beta > 1-\beta-\beta u.
\end{aligned}$$

This implies that

$$LHS > RHS \Leftrightarrow \sqrt{LHS} > \sqrt{RHS} \Leftrightarrow$$
$$2(1-\beta)\left(\frac{2\Delta}{H-L}(2-u)-1+u\right)-(1-\beta-\beta u) > \sqrt{4\beta u(1-\beta)\left(\frac{4\Delta}{H-L}-1\right)}$$

Now, consider $\sqrt{LHS}$:

$$\begin{aligned}
\sqrt{LHS} &= 2(1-\beta)\left(\frac{2\Delta}{H-L}(2-u)-1+u\right)-(1-\beta-\beta u)\\
&> 2(1-\beta)\left(\frac{2\Delta}{H-L}(2-u)-1+u\right)-(1-\beta)\\
&= 2(1-\beta)\left(\frac{2\Delta}{H-L}(1-u)-(1-u)+\frac{2\Delta}{H-L}\right)-(1-\beta)\\
&= (1-\beta)\left(2\left((1-u)\left(\frac{2\Delta}{H-L}-1\right)+\frac{2\Delta}{H-L}\right)-1\right)\\
&>^{*} (1-\beta)\left(2\beta\left(\frac{2\Delta}{H-L}-1\right)+\frac{4\Delta}{H-L}-1\right)
\end{aligned}$$

The last inequality $>^{*}$follows since $\beta < 1-u$.

Next, we consider $\sqrt{RHS}$:

First consider the case $b \leq \frac{1}{2}$, then:

$$\begin{aligned}
\sqrt{RHS} &= \sqrt{4\beta u(1-\beta)\left(\frac{4\Delta}{H-L}-1\right)} <^{*} \sqrt{4\beta(1-\beta)(1-\beta)\left(\frac{4\Delta}{H-L}-1\right)}\\
&= 2(1-\beta)\sqrt{\beta\left(\frac{4\Delta}{H-L}-1\right)} \leq^{**} 2\sqrt{\frac{1}{2}}(1-\beta)\left(\frac{4\Delta}{H-L}-1\right)\frac{1}{\sqrt{\left(\frac{4\Delta}{H-L}-1\right)}}\\
&= (1-\beta)\left(\frac{4\Delta}{H-L}-1\right)\sqrt{\frac{2}{\left(\frac{4\Delta}{H-L}-1\right)}} <^{***} (1-\beta)\left(\frac{4\Delta}{H-L}-1\right) < \sqrt{LHS}
\end{aligned}$$

The inequality $<^{*}$follows since $u < 1-\beta$, the inequality $\leq^{**}$follows since $\beta \leq \frac{1}{2}$, and finally $<^{***}$follows since $H-L < \Delta$.

Now consider the case $b > \frac{1}{2}$, then:

$$\begin{aligned}
\sqrt{RHS} &= \sqrt{4\beta u(1-\beta)\left(\frac{4\Delta}{H-L}-1\right)} < 2(1-\beta)\sqrt{\beta\left(\frac{4\Delta}{H-L}-1\right)} \\
&= 2\beta(1-\beta)\left(\frac{4\Delta}{H-L}-1\right)\frac{1}{\sqrt{\beta\left(\frac{4\Delta}{H-L}-1\right)}} < 2\sqrt{\frac{2}{3}}\beta(1-\beta)\left(\frac{4\Delta}{H-L}-1\right) \\
&< 1.65\beta(1-\beta)\left(\frac{4\Delta}{H-L}-1\right) = \beta(1-\beta)\left(\frac{4\Delta}{H-L}-1\right) + \frac{2}{3}\beta(1-\beta)\left(\frac{4\Delta}{H-L}-1\right) \\
&< (1-\beta)\left(\frac{4\Delta}{H-L}-1\right) + \frac{2}{3}\beta(1-\beta)\left(\frac{4\Delta}{H-L}-1\right) \\
&= (1-\beta)\left(\frac{4\Delta}{H-L}-1\right) + 2\beta(1-\beta)\left(\frac{4\Delta}{3(H-L)}-\frac{1}{3}\right) \\
&<^* (1-\beta)\left(\frac{4\Delta}{H-L}-1\right) + 2\beta(1-\beta)\left(\frac{4\Delta}{3(H-L)}-\frac{1}{3}+\frac{2\Delta}{3(H-L)}-\frac{2}{3}\right) \\
&= (1-\beta)\left(\frac{4\Delta}{H-L}-1\right) + 2\beta(1-\beta)\left(\frac{2\Delta}{H-L}-1\right) \\
&= (1-\beta)\left(2\beta\left(\frac{2\Delta}{H-L}-1\right)+\frac{4\Delta}{H-L}-1\right) < \sqrt{LHS}
\end{aligned}$$

Inequality $<^*$follows from $H-L<\Delta$.

We therefore showed that it always holds $LHS > RHS$, so the equation has two distinct positive roots.

Largest solution is not feasible:

Denote the two solutions by $k_1 < k_2$. Here we will show that $0 \leq k_1 < u < k_2$ provided that $\beta \leq \frac{6}{7}$. Recall that

$$\overline{\Phi}(k) \equiv (H-L)\frac{(1-\beta)k+\beta u}{4\beta(2-k-u)} = \frac{(1-\beta)k}{2\beta(1-k)}\left(2\Delta - \frac{(H-L)(1-u)}{2-k-u}\right) \equiv \underline{\Phi}(k)$$

Thus, we can see that

$$\overline{\Phi}(0) = (H-L)\frac{\beta u}{4\beta(2-u)} > 0 = \underline{\Phi}(0)$$

Further, the smaller solution k_1 satisfies by definition

$$\overline{\Phi}(k_1) = \underline{\Phi}(k_1)$$

Thus, for all $k < k_1$ we have $\overline{\Phi}(k) > \underline{\Phi}(k)$. Now, since there are only two solutions, it must also be that for all $k > k_2$ we also have that $\overline{\Phi}(k) > \underline{\Phi}(k)$. But, notice for $k = u$, and $u \leq \frac{6}{7}$ we can show that:

$$\overline{\Phi}(u) \equiv (H-L)\frac{u}{8\beta(1-u)} < \frac{(1-\beta)u}{2\beta(1-u)}\left(2\Delta - \frac{(H-L)}{2}\right) \equiv \underline{\Phi}(u).$$

Namely,

$$\begin{aligned}(H-L)\frac{u}{8\beta(1-u)} &< \frac{(1-\beta)u}{2\beta(1-u)}\left(2\Delta - \frac{(H-L)}{2}\right) \Leftrightarrow \\ (H-L) &< 4(1-\beta)2\Delta - 4(1-\beta)\frac{(H-L)}{2} \Leftrightarrow \\ (H-L)(3-2\beta) &< 8(1-\beta)\Delta \Leftrightarrow \\ \frac{H-L}{\Delta} &< \frac{8(1-\beta)}{(3-2\beta)}\end{aligned}$$

Now, since $\frac{H-L}{\Delta} < \frac{8}{9}$ this condition requires that $\frac{8(1-\beta)}{(3-2\beta)} > \frac{8}{9}$ or that $\beta \leq \frac{6}{7}$.

Thus, we conclude that $0 \leq k_1 < u < k_2$ provided that $\beta \leq \frac{6}{7}$.

Properties of Signaling Equilibrium Boundaries

We now move on to show $\frac{\partial\overline{\Phi}(k)}{\partial k} > 0$ and $\frac{\partial\underline{\Phi}(k)}{\partial k} > 0$.

We will start with $\frac{\partial\overline{\Phi}(k)}{\partial k}$:

$$\begin{aligned}&\frac{\partial}{\partial k}\left(\frac{1}{4\beta}\frac{(1-\beta)k+\beta u}{2-k-u}(H-L)\right) = \frac{H-L}{4\beta}\frac{\partial}{\partial k}\left(\frac{(1-\beta)k+\beta u}{2-k-u}\right) \\ &= \frac{H-L}{4\beta}\frac{(1-\beta)(2-k-u)+(1-\beta)k+\beta u}{(2-k-u)^2} \\ &= \frac{(H-L)\left((1-\beta)(2-u)+\beta u\right)}{4\beta\left(2-k-u\right)^2} > 0\end{aligned}$$

Next, we look at $\frac{\partial\underline{\Phi}(k)}{\partial k}$:

$$\begin{aligned}&\frac{\partial}{\partial k}\left(\frac{k}{2\beta}\left(2\Delta - \frac{(H-L)(1-u)}{2-k-u}\right)\left(\frac{1-\beta}{1-k}\right)\right) = \\ &= \frac{1-\beta}{2\beta}\frac{\partial}{\partial k}\left(\frac{2k\Delta(2-k-u)-k(H-L)(1-u)}{(1-k)(2-k-u)}\right) = \\ &= \frac{1-\beta}{2\beta}\frac{\partial}{\partial k}\left(\frac{2k\Delta(2-k-u)-k(H-L)(1-u)}{(1-k)(2-k-u)}\right)\end{aligned}$$

Since we only wish to show that $\frac{\partial\underline{\Phi}(k)}{\partial k} > 0$, we can ignore the $\frac{1-\beta}{2\beta}$ term, which is always positive, and we will also ignore the denominator of the resulting derivation, which is $((1-k)(2-k-u))^2 > 0$.

We only focus on the numerator of the derivation, which is

$$
\begin{aligned}
&(1-k)(2-k-u)\frac{\partial}{\partial k}\left(2k\Delta(2-k-u)-k(H-L)(1-u)\right)\\
&-\left(2k\Delta(2-k-u)-k(H-L)(1-u)\right)\frac{\partial}{\partial k}\left((1-k)(2-k-u)\right)=\\
&\left((4-2u)\Delta-4\Delta k-(H-L)(1-u)\right)(1-k)(2-k-u)\\
&-(2k-3+u)\left(2k\Delta(2-k-u)-k(H-L)(1-u)\right)
\end{aligned}
$$

We will group the above by powers of k.

The coefficient for k^3 is $4\Delta - 4\Delta = 0$.

The coefficient for k^2 is

$$
\begin{aligned}
&4\Delta(3-u)+(4-2u)\Delta-(H-L)(1-u)-4\Delta(2-u)+2(H-L)(1-u)\\
&-2\Delta(3-u)=2\Delta+(H-L)(1-u)>0
\end{aligned}
$$

The coefficient for k is

$$
\begin{aligned}
&\left((H-L)(1-u)-(4-2u)\Delta\right)(3-u)-4\Delta(2-u)\\
&+(3-u)((4-2u)\Delta-(H-L)(1-u))=-4\Delta(2-u)
\end{aligned}
$$

The constant is

$$
\left((4-2u)\Delta-(H-L)(1-u)\right)(2-u)
$$

So that overall we have
$(2\Delta+(H-L)(1-u))k^2-4\Delta(2-u)k+((4-2u)\Delta-(H-L)(1-u))(2-u)$. If we show that this is always positive, then $\frac{\partial\Phi(k)}{\partial k}>0$, completing the proof.

Since the constant and k^2's coefficient are positive and k's coefficient is negative, showing that the discriminant is negative would suffice.

Indeed, we have

$$
\begin{aligned}
&4(2\Delta + (H-L)(1-u))((4-2u)\Delta - (H-L)(1-u))(2-u) \\
&= (2-u)^2(4\Delta + 2(H-L)(1-u))\left(4\Delta - \frac{2(H-L)(1-u)}{2-u}\right) \\
&= (2-u)^2\left((4\Delta)^2 + 4\Delta * 2(H-L)(1-u)\left(1-\frac{1}{2-u}\right) - \frac{4(H-L)^2(1-u)^2}{2-u}\right) \\
&= (2-u)^2\left((4\Delta)^2 + \frac{4\Delta * 2(H-L)(1-u)^2}{2-u} - \frac{4(H-L)^2(1-u)^2}{2-u}\right) \\
&> (2-u)^2(4\Delta)^2 = (4\Delta(2-u))^2
\end{aligned}
$$

This completes the proof, and we have shown $\frac{\partial \Phi(k)}{\partial k} > 0$. ■

Proof. Corollary 2[Level of Insider Selling]: This follows directly from Corollary 1 and the analysis of the benchmark case. ■

Proof. Proposition 4[Pooling both not Announce]: See discussion in text. ■

Proof. Proposition 5[Pooling both Announce EQ I] We have considered the five possible pooling equilibria with selling candidates (henceforth "Candidate Pooling with selling EQ I-V," respectively), and found that only the first two (EQI and EQII) can hold. The proof that the last three candidates do not hold is available from the authors upon request.

$$
\text{Candidate Pooling w Selling Eq 1:} \quad
\begin{array}{ll}
d(B) = A & \text{and } r(L) = s(L) = k,\ r(H) = s(H) = k \qquad \text{[EQ I]} \\
d(G) = A & \text{and } r(L+\Delta) = s(L+\Delta) = 0, \\
& r\left(H+\Delta\right) = u,\ s\left(H+\Delta\right) = 0
\end{array}
\tag{47}
$$

$$
\text{Candidate Pooling w Selling Eq 2:} \quad
\begin{array}{ll}
d(B) = A & \text{and } r(L) = s(L) = k,\ r(H) = s(H) = 0 \qquad \text{[EQ II]} \\
d(G) = A & \text{and } r(L+\Delta) = s(L+\Delta) = 0, \\
& r\left(H+\Delta\right) = u,\ s\left(H+\Delta\right) = 0
\end{array}
\tag{48}
$$

$$
\text{Candidate Pooling w sell Eq 3:} \quad
\begin{array}{ll}
d(B) = A & \text{and } r(L) = s(L) = k,\ r(H) = s(H) = k \qquad \text{[EQ III]} \\
d(G) = A & \text{and } r(L+\Delta) = u,\ s(L+\Delta) = 0, \\
& r\left(H+\Delta\right) = u,\ s\left(H+\Delta\right) = 0
\end{array}
\tag{49}
$$

$$d(B) = A \text{ and } r(L) = s(L) = k,\ r(H) = u,\ s(H) = 0 \qquad \text{[EQ IV]}$$

Candidate Pooling w sell Eq 4:

$$d(G) = A \quad \text{and } r(L+\Delta) = u,\ s(L+\Delta) = 0,$$
$$r(H+\Delta) = u,\ s(H+\Delta) = 0 \tag{50}$$

$$d(B) = A \text{ and } r(L) = s(L) = k,\ r(H) = s(H) = k \qquad \text{[EQ V]}$$

Candidate Pooling w Sell Eq 5:

$$d(G) = A \quad \text{and } r(L+\Delta) = s(L+\Delta) = k,$$
$$r(H+\Delta) = u,\ s(H+\Delta) = 0 \tag{51}$$

Pooling Equilibrium with Selling EQI As indicated in (47), in this equilibrium, the bad type always buys and sells k, and the good type does nothing in state $L+\Delta$, and repurchases u in state $H+\Delta$.

Table Polling with selling EQI:

firm value x	liquidity q	repurchase r	insider s	order flow F	MM price P_1	terminal value P_2
L	$-h$	k	$-k$	$-h$	$P_1(-h)$	$\frac{L-k[P_1(-h)]}{1-k}$
L	$-\ell$	k	$-k$	$-\ell$	$P_1(-\ell)$	$\frac{L-kP_1(-\ell)}{1-k}$
H	$-h$	k	$-k$	$-h$	$P_1(-h)$	$\frac{H-k[P_1(-h)]}{1-k}$
H	$-\ell$	k	$-k$	$-\ell$	$P_1(-\ell)$	$\frac{H-kP_1(-\ell)}{1-k}$
$L+\Delta$	$-h$	0	0	$-h$	$P_1(-h)$	$L+\Delta$
$L+\Delta$	$-\ell$	0	0	$-\ell$	$P_1(-\ell)$	$L+\Delta$
$H+\Delta$	$-h$	$h-\ell$	0	$-\ell$	$P_1(-\ell)$	$\frac{H+\Delta-uP_1(-\ell)}{1-u}$
$H+\Delta$	$-\ell$	$h-\ell$	0	$h-2\ell$	$H+\Delta$	$H+\Delta$

For this equilibrium to hold, we need to check that A) Type $L+\Delta$ does not deviate to sell and repurchase k, or B) repurchase u. and that C) Type H does not deviate to "do nothing."

To find $P_1(-\ell)$ that yields zero expected profit to the market maker in equilibrium, we can write

$$\begin{aligned} 0 &= \left(P_1(-\ell) - \frac{L - kP_1(-\ell)}{1-k}\right) + \left(P_1(-\ell) - \frac{H - kP_1(-\ell)}{1-k}\right) \\ &\quad + \left(P_1(-\ell) - (L+\Delta)\right) + \left(P_1(-\ell) - \frac{H + \Delta - uP_1(-\ell)}{1-u}\right) \end{aligned}$$

and upon rearrangement

$$P_1(-\ell) = P_{1I}(-\ell) \equiv \frac{(H+L)(2-k-u) + [2\Delta - u(L+\Delta)](1-k)}{4 - 2k - u(3-k)} \tag{52}$$

Similarly to find $P_1(-h)$, zero expected profit to the market maker requires

$$0 = \left(P_1(-h) - \frac{L - kP_1(-h)}{1-k}\right) + \left(P_1(-h) - \frac{H - kP_1(-h)}{1-k}\right) + \left(P_1(-h) - (L+\Delta)\right)$$

and upon rearrangement

$$P_1(-h) = P_{1I}(-h) \equiv \frac{H + L\,(2-k) + \Delta\,(1-k)}{3-k} \tag{53}$$

A) Consider the payoff of cash flow type $L+\Delta$ from the proposed strategy. Since it does not repurchase nor sell, it gets $\beta\,(L+\Delta)$. For no deviation of selling and repurchasing k we need the selling price to be low enough. In fact, we can show that the average selling price must be lower than $L+\Delta$. To see this, note that if the bad type deviates and sells and repurchases k it will get

$$\begin{aligned} & \frac{1}{2}\left[kP_{1I}(-h) + (\beta - k)\,\frac{L+\Delta - k\,[P_{1I}(-h)]}{1-k} + kP_1(-l) + (\beta-k)\,\frac{L+\Delta-k\,[P_{1I}(-l)]}{1-k}\right] \\ = \quad & k\left[\frac{P_{1I}(-h)+P_{1I}(-\ell)}{2}\right] + (\beta-k)\,\frac{L+\Delta-k\left[\frac{P_{1I}(-h)+P_{1I}(-\ell)}{2}\right]}{1-k} \end{aligned}$$

and upon rearrangement

$$= \beta\,(L+\Delta) - \frac{k\,(1-\beta)}{1-k}\left((L+\Delta) - \frac{P_{1I}(-h)+P_{1I}(-\ell)}{2}\right).$$

For no deviation we need

$$\beta\,(L+\Delta) - \frac{k\,(1-\beta)}{1-k}\left((L+\Delta) - \frac{P_{1I}(-h)+P_{1I}(-\ell)}{2}\right) < \beta\,(L+\Delta)$$

which simplifies to

$$P_{1I}(-h) + P_{1I}(-\ell) < 2\,(L+\Delta) \tag{54}$$

Upon substitution of $P_{1I}(-h)$ and $P_{1I}(-\ell)$ using (53) and (52), respectively, we can rearrange the LHS to

$$= \frac{[L+H+(L+\Delta)\,(1-k)]\,[4-2k-u\,(3-k)] + [(L+H)\,(2-k-u) + [2\Delta - u\,(L+\Delta)]\,(1-k)]\,(3-k)}{(3-k)\,[4-2k-u\,(3-k)]}$$

and further rearrange to

$$\frac{H\left[2\left(2-k\right)+\left(2-k-2u\right)\left(3-k\right)\right]+L\left(2-k\right)\left[7-3k-2u\left(3-k\right)\right]+\Delta\left(1-k\right)2\left[2-k+\left(3-k\right)\left(1-u\right)\right]}{\left(3-k\right)\left[4-2k-u\left(3-k\right)\right]} \tag{55}$$

and write condition (54) as

$$\begin{aligned} &H\left[2\left(2-k\right)+\left(2-k-2u\right)\left(3-k\right)\right]+L\left(2-k\right)\left[7-3k-2u\left(3-k\right)\right]+ \\ &\Delta\left(1-k\right)2\left[2-k+\left(3-k\right)\left(1-u\right)\right]<\left(3-k\right)\left[4-2k-u\left(3-k\right)\right]2\left(L+\Delta\right) \end{aligned} \tag{56}$$

which we can rearrange to

$$\left(10-7k-6u+kk+2ku\right)H<\left(10-7k-6u+kk+2uk\right)L+\left(14-6k-12u+4uk\right)\Delta$$

Which always holds since $H<L+\Delta$.

B) The other deviation to consider for type $L+\Delta$ is to repurchase u. In this case the payoff is

$$\frac{1}{2}\left[\beta\frac{L+\Delta-uP_1(-\ell)}{1-u}+\beta\frac{L+\Delta-u\left(H+\Delta\right)}{1-u}\right]=\beta\frac{L+\Delta-u\left[\frac{H+\Delta+P_1(-\ell)}{2}\right]}{1-u}.$$

For no deviation we need the insiders' payoff with deviation to be lower than without it, that is,

$$\beta\frac{L+\Delta-u\left[\frac{H+\Delta+P_1(-\ell)}{2}\right]}{1-u}<\beta\left(L+\Delta\right)$$

where $P_1(-\ell)=P_{1I}(-\ell)$, and upon rearrangement

$$2L+\Delta-H<P_{1I}(-\ell) \tag{57}$$

C) Lastly, we consider the payoff of cash flow type H from the proposed strategy ($r(H)=s(H)=k$ see (47))

$$\begin{aligned} &\frac{1}{2}\left[kP_1(-h)+\left(\beta-k\right)\frac{H-k\left[P_1(-h)\right]}{1-k}+kP_1(-\ell)+\left(\beta-k\right)\frac{H-kP_1(-\ell)}{1-k}\right] \\ =\;&\frac{1}{2}\left[k[P_1(-h)+P_1(-\ell)]+\left(\beta-k\right)\frac{2H-k\left[P_1(-h)+P_1(-\ell)\right]}{1-k}\right]. \end{aligned}$$

Which we can rearrange to

$$\beta H + \frac{k(1-\beta)}{2(1-k)}\left(P_1(-h) + P_1(-\ell) - 2H\right)$$

For this to be optimal it must yield higher payoff than the payoff without repurchase and sell βH

$$\beta H < \beta H + \frac{k(1-\beta)}{2(1-k)}\left(P_1(-h) + P_1(-\ell) - 2H\right)$$

or

$$2H < P_{1I}(-h) + P_{1I}(-\ell) \tag{58}$$

This makes sense. We want the average price to be higher than H so that the bad type would want to sell.

Next, considering the announcement, we begin by defining the following:

$$\overline{\Phi}_I(k) \equiv \frac{1}{4}\frac{u}{1-u}\left(H + \Delta - P_{1I}(-\ell)\right)\ ,\ \underline{\Phi}_I(k) \equiv \frac{k(1-\beta)}{2(1-k)}\left[P_{1I}(-\ell) + P_{1I}(-h) - (H+L)\right] \tag{59}$$

Turn now to the good type's expected payoff from the proposed strategy (47) which is

$$\frac{1}{2}\left[\beta(L+\Delta) + \frac{1}{2}\beta\frac{H + \Delta - uP_{1I}(-\ell)}{1-u} + \frac{1}{2}\beta(H+\Delta)\right]$$

which we can rearrange to

$$\beta\left(\frac{L+H}{2} + \Delta\right) + \frac{u}{4(1-u)}\beta\left[(H+\Delta) - P_{1I}(-\ell)\right]$$

The good type will announce if this is more than what it gets without announcement i.e. if

$$\beta\left(\frac{L+H}{2} + \Delta + \Phi\right) < \beta\left(\frac{L+H}{2} + \Delta\right) + \frac{u}{4(1-u)}\beta\left[(H+\Delta) - P_{1I}(-\ell)\right],$$

that is if

$$\Phi < \overline{\Phi}_I(k) \equiv \frac{1}{4}\frac{u}{1-u}\left(H + \Delta - P_{1I}(-\ell)\right) \tag{60}$$

Considering the announcement, the bad type's expected payoff from this strategy (47) is

$$\begin{aligned}
& \frac{1}{4}\left[kP_1(-h)+(\beta-k)\,\frac{L-k\left[P_{1I}(-h)\right]}{1-k}+kP_1(-l)+(\beta-k)\,\frac{L-k\left[P_{1I}(-l)\right]}{1-k}\right] \\
& +\frac{1}{4}\left[kP_1(-h)+(\beta-k)\,\frac{H-k\left[P_{1I}(-h)\right]}{1-k}+kP_1(-l)+(\beta-k)\,\frac{H-k\left[P_{1I}(-l)\right]}{1-k}\right] \\
= \; & \frac{1}{4}\left[2k\Omega_I+(\beta-k)\,\frac{2H+2L-2k\Omega_I}{1-k}\right]
\end{aligned}$$

which we can rearrange to

$$=\beta\frac{H+L}{2}+\frac{k\,(1-\beta)}{2\,(1-k)}\left[P_{1I}(-\ell)+P_{1I}(-h)-(H+L)\right]$$

This is better than not announcing if

$$\beta\frac{H+L}{2}+\Phi<\beta\frac{H+L}{2}+\frac{k\,(1-\beta)}{2\,(1-k)}\left[P_{1I}(-\ell)+P_{1I}(-h)-(H+L)\right]$$

or[16]

$$\Phi<\underline{\Phi}_I(k)\equiv\frac{k\,(1-\beta)}{2\,(1-k)}\left[P_{1I}(-\ell)+P_{1I}(-h)-(H+L)\right] \tag{61}$$

■

Proof. Proposition 6[Pooling both Announce EQ II]

As indicated in (48), in this equilibrium, the bad type buys and sells k in state L, and does nothing in state H. The good type does nothing in state $L+\Delta$, and repurchases u in state $H+\Delta$.

Table: Pooling with selling EQ II

[16] It can be shown that conditions (57) and (56) can be combined to the condition

$$\max\left[\frac{2\,(1-u)}{6-3k-u\,(4-k)},\frac{10-14k-6u+8uk+4kk-2kuk}{14-13k-12u+3kk+10uk-2ukk}\right]<\frac{H-L}{\Delta}$$

The proof is available from the authors upon request.

firm value x	liquidity q	repurchase r	insider s	order flow F	MM price P_1	terminal value P_2
L	$-h$	k	$-k$	$-h$	$P_1(-h)$	$\frac{L-k[P_1(-h)]}{1-k}$
L	$-\ell$	k	$-k$	$-\ell$	$P_1(-\ell)$	$\frac{L-kP_1(-\ell)}{1-k}$
H	$-h$	0	0	$-h$	$P_1(-h)$	H
H	$-\ell$	0	0	$-\ell$	$P_1(-\ell)$	H
$L+\Delta$	$-h$	0	0	$-h$	$P_1(-h)$	$L+\Delta$
$L+\Delta$	$-\ell$	0	0	$-\ell$	$P_1(-\ell)$	$L+\Delta$
$H+\Delta$	$-h$	$h-\ell$	0	$-\ell$	$P_1(-\ell)$	$\frac{H+\Delta-uP_1(-\ell)}{1-u}$
$H+\Delta$	$-\ell$	$h-\ell$	0	$h-2\ell$	$H+\Delta$	$H+\Delta$

For this equilibrium to hold, we need to check that A) H does not sell and buy k and that B) $L+\Delta$ does not repurchase u. (We do not need to check that $L+\Delta$ does not sell and repurchase k because if type H does not do it, then certainly type $L+\Delta$ does not do it).

To find $P_1(-\ell)$ that yields zero expected profit to the market maker in equilibrium, we can write

$$0=\left(P_1(-\ell)-\frac{L-kP_1(-\ell)}{1-k}\right)+(P_1(-\ell)-H)+(P_1(-\ell)-(L+\Delta))+\left(P_1(-\ell)-\frac{H+\Delta-uP_1(-\ell)}{1-u}\right)$$

and upon rearrangement

$$P_1(-\ell)=P_{1II}(-\ell)\equiv\frac{(2-u)(1-k)(H+L+\Delta)-(u-k)L}{4-3u-3k+2uk} \tag{62}$$

Similarly to find $P_1(-h)$, zero expected profit to the market maker requires

$$0=\left(P_1(-h)-\frac{L-kP_1(-h)}{1-k}\right)+(P_1(-h)-H)+(P_1(-h)-(L+\Delta))$$

and upon rearrangement

$$P_1(-h)=P_{1II}(-h)\equiv\frac{L+(1-k)(H+L+\Delta)}{3-2k} \tag{63}$$

A) The payoff of cash flow type H from the proposed strategy is βH if it deviates to buy k and sell k it will end up with

$$\frac{1}{2}\left[kP_{1II}(-h)+(\beta-k)\frac{H-kP_{1II}(-h)}{1-k}+kP_{1II}(-\ell)+(\beta-k)\frac{H-kP_{1II}(-\ell)}{1-k}\right]$$
$$=\frac{1}{2}\left[k\left[P_{1II}(-h)+P_{1II}(-\ell)\right]+(\beta-k)\frac{2H-k\left[P_{1II}(-h)+P_{1II}(-\ell)\right]}{1-k}\right]$$

which we can rearrange to

$$\beta H+\frac{k\,(1-\beta)}{2\,(1-k)}\left(\left[P_{1II}(-h)+P_{1II}(-\ell)\right]-2H\right)$$

No deviation of type H requires from doing nothing to selling and repurchasing k requires

$$\beta H+\frac{k\,(1-\beta)}{2\,(1-k)}\left(\left[P_{1II}(-h)+P_{1II}(-\ell)\right]-2H\right)<\beta H$$

or

$$P_{1II}(-h)+P_{1II}(-\ell)<2H \tag{64}$$

B) Now consider type $L+\Delta$. With the proposed strategy it gets $\beta\,(L+\Delta)$. If it deviates to repurchasing u, it will end up with

$$\beta\frac{1}{2}\left[\frac{L+\Delta-u\left[H+\Delta\right]}{1-u}+\frac{L+\Delta-uP_{1II}(-\ell)}{1-u}\right]$$

which we can rearrange to

$$=\beta\,(L+\Delta)+\beta\frac{u}{2\,(1-u)}\left[2L+\Delta-H-P_{1II}(-\ell)\right]$$

So that for no deviation we need

$$\beta\,(L+\Delta)+\beta\frac{u}{2\,(1-u)}\left[2L+\Delta-H-P_{1II}(-\ell)\right]<\beta\,(L+\Delta)$$

Upon rearrangement and since $P_1(-\ell)=P_{1II}(-\ell)$ we can write this condition as

$$2L+\Delta-H<P_{1II}(-\ell) \tag{65}$$

Next, considering the announcement, we begin by defining the following:

$$\overline{\Phi}_{II}(k) \equiv \frac{u}{4\,(1-u)}\left[H+\Delta-P_{1II}(-\ell)\right]\ ,\ \underline{\Phi}_{II}(k) \equiv \frac{k}{(1-k)\,\beta}\left[\frac{3-k-2\beta}{4}\left[P_{1II}(-h)+P_{1II}(-\ell)\right]-(1-\beta)\,L\right] \tag{66}$$

For the good firm to announce we need

$$\beta\left(\frac{H+L}{2}+\Delta+\Phi\right)<\frac{1}{2}\left[\frac{1}{2}\left[\beta\frac{H+\Delta-uP_{1II}(-\ell)}{1-u}+\beta\,(H+\Delta)\right]+\beta\,(L+\Delta)\right]$$

which can be rearranged to

$$\Phi<\overline{\Phi}_{II}(k)\equiv\frac{u}{4\,(1-u)}\left[H+\Delta-P_{1II}(-\ell)\right] \tag{67}$$

For the bad type firm to announce we need

$$\beta\left(\frac{H+L}{2}+\Phi\right)<\frac{1}{2}\left[\frac{1}{2}\left[kP_{1II}(-h)+(\beta-k)\,\frac{L-kP_{1II}(-h)}{1-k}+kP_{1}(-l)+(\beta-k)\,\frac{L-k\left[P_{1II}(-\ell)\right]}{1-k}\right]+\beta H\right]$$

which can be rearranged to[17]

$$\Phi<\underline{\Phi}_{II}(k)\equiv\frac{k}{(1-k)\,\beta}\left[\frac{3-k-2\beta}{4}\left[P_{1II}(-h)+P_{1II}(-\ell)\right]-(1-\beta)\,L\right] \tag{68}$$

■

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[17] It can be shown that conditions (64) and (65) can be combined to the condition

$$\max\left[\frac{10-7k-6u+4uk}{14-12u-17k+14uk+5kk-4kuk},\frac{2+k-2u+ku}{6-5k-4u+3uk}\right]<\frac{H-L}{\Delta}$$

The proof is available from the authors upon request.

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Figure 1: Time line

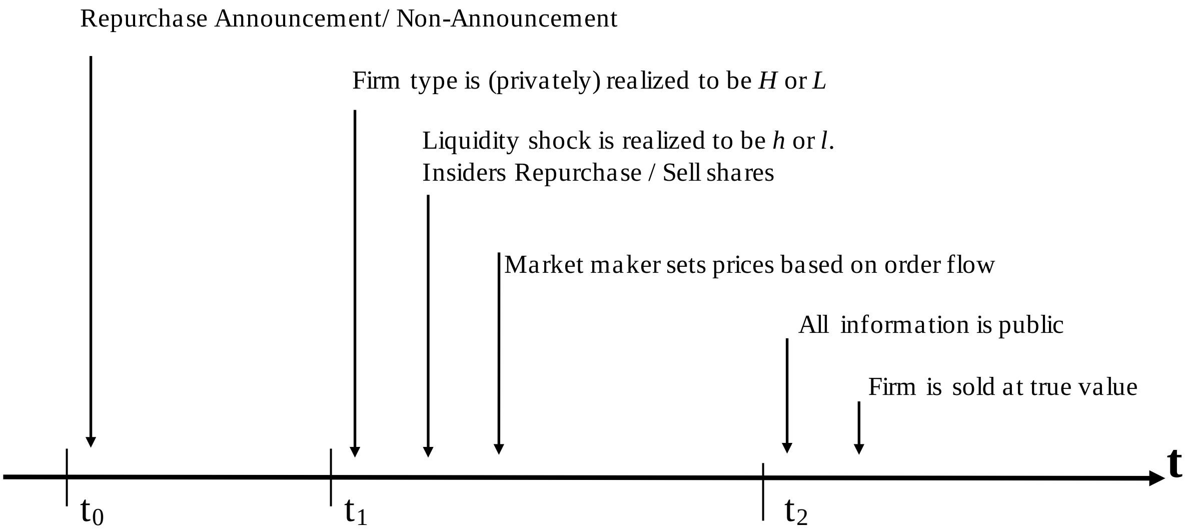

Figure 2:

Signaling Equilibrium with Insider Selling

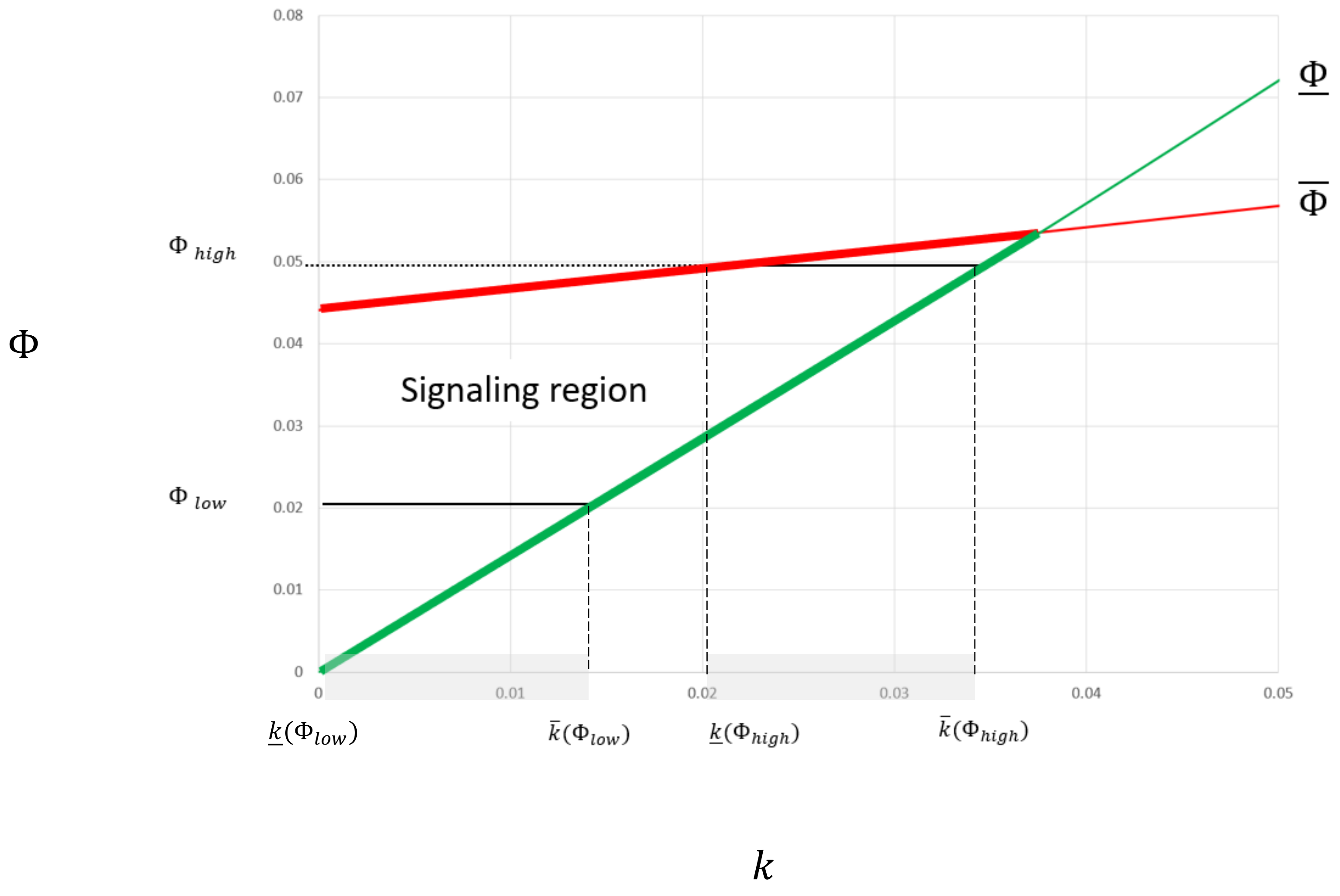

Figure 3:

Pooling Equilibrium with Insider Selling