

# Feedback Effects and the Limits to Arbitrage\*

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## Abstract

This paper identifies a limit to arbitrage that arises because firm value is endogenous to the exploitation of arbitrage. Trading on private information reveals this information to managers and improves their real decisions, enhancing fundamental value. While this feedback effect increases the profitability of a long position, it reduces the profitability of a short position. Thus, investors may refrain from trading on negative information, and so bad news is incorporated more slowly into prices than good news. This has potentially important real consequences – if negative information is not incorporated into prices, inefficient projects are not canceled, leading to overinvestment.

KEYWORDS: Limits to arbitrage, feedback effect, overinvestment

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# 1 Introduction

Whether financial markets are informationally efficient is one of the most hotly-contested debates in finance. Proponents of market efficiency argue that profit opportunities in the financial market will lead speculators to trade in a way that eliminates any mispricing. For example, if speculators have negative information about a stock, and this information is not reflected in the price, they will find it profitable to sell the stock. This action will push down the price, reflecting the speculators' information. However, a sizable literature identifies various limits to arbitrage, which may deter speculators from trading on their information. (This notion of "arbitrage" is broader than the traditional textbook notion of risk-free arbitrage from trading two identical securities. Here, we use "arbitrage" to refer to investors trading on their private information.) Examples include holding costs, transactions costs, price impact, and short-sales constraints.

In this paper, we identify a quite different limit to arbitrage, which instead arises endogenously as part of the arbitrage process. It stems from the fact that the *value of the asset being arbitrated is endogenous to the act of exploiting the arbitrage*. By informed trading, speculators cause prices to move, which in turn reveals information to real decision makers, such as managers, board members, corporate raiders, and regulators. These decision makers then take actions based on the information revealed in the price, and these actions change the underlying asset value. This feedback effect may make the initial trading less profitable, deterring it from occurring in the first place.

To fix ideas, consider the following example. Suppose that a firm (acquirer) announces the acquisition of a target. Also assume that a large speculator has conducted analysis suggesting that this acquisition will be value-destructive. Traditional theory suggests that the speculator should sell the acquirer's stock. However, large-scale selling will convey to the acquirer that the speculator believes that the acquisition is a bad idea. As a result, the acquirer may end up cancelling the acquisition. In turn, cancellation of a bad acquisition will boost firm value, reducing the speculator's profit from her short position and in some cases causing her to suffer a loss. Put differently, the acquirer's decision to cancel the acquisition means that the negative information possessed by the speculator is now less relevant, and hence she should not trade on it. Thus, her information ends up not being reflected in the price. Therefore, the market is not strong-form efficient in the Fama (1970) sense, in that private information is not reflected in the price. However, it is strong-form efficient in the Jensen (1978) sense, in that a privately-informed investor cannot earn profits by trading on her information.

Our mechanism is based on the presence of a feedback effect from the financial market to real economic decisions – real decision makers learn from the market when deciding their actions. A common perception is that managers know more about their own firms than outsiders (e.g. Myers and Majluf (1984)). While this perception is plausible for internal information about the firm in isolation, optimal managerial decisions also depend on external information (such as market demand for a firm's products, the future prospects of the industry, or potential synergies

with a target) which outsiders may possess more of. For example, a potential acquirer hires investment bank advisors at high fees because, while advisors have less internal information than the manager, they can add value on target selection, e.g. by evaluating which target will be the most synergistic. Note that we only require that outside investors possess some information that the manager does not have; they need not be more informed than the manager on an absolute basis.

A classic example of how information from the stock market can shape real decisions is Coca-Cola's attempted acquisition of Quaker Oats. On November 20, 2000, the *Wall Street Journal* reported that Coca-Cola was in talks to acquire Quaker Oats. Shortly thereafter, Coca-Cola confirmed such discussions. The market reacted negatively, sending Coca-Cola's shares down 8% on November 20th and 2% on November 21st. Coca-Cola's board rejected the acquisition later on November 21st, potentially due to the negative market reaction. The following day, Coca-Cola's shares rebounded 8%. Thus, speculators who had short-sold on the initial merger announcement, based on the belief that the acquisition would destroy value, lost money – precisely the effect modeled by this paper.<sup>1</sup> Luo (2005) provides large-sample evidence that an acquisition is more likely to be canceled if the market's reaction implies that it will be non-synergistic. The effect is stronger when the acquirer is more likely to have something to learn from the market, e.g., for non-high-tech deals and deals in which the bidder is small. Relatedly, Edmans, Goldstein, and Jiang (2012) demonstrate that a firm's market price affects the likelihood that it becomes a takeover target, which may arise because potential acquirers learn from the market price. More broadly, Chen, Goldstein, and Jiang (2007) show that the sensitivity of investment to price is higher when the price contains more private information not known to managers.

Moreover, our model can apply to corrective actions (i.e., actions that improve firm value upon learning negative information about firm prospects) undertaken by stakeholders other than the manager. Such stakeholders likely have less information than the manager and may be more reliant on information held by outsiders. Examples include managerial replacement (undertaken by the board, or by shareholders who lobby the board), a disciplinary takeover (undertaken by an acquirer), or the granting of a subsidy or a bail-out (undertaken by the government). We demonstrate a barrier to decision makers learning from investors – investors may choose not to impound their information into prices by trading. Furthermore, the model can apply in a non-corporate context. For example, in late 2011, investors sold Italian bonds due to concerns about Prime Minister Silvio Berlusconi's handling of the debt crisis. Commentators argue that his resignation on November 16 was due to pressure partly resulting from rising bond yields.<sup>2</sup>

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<sup>1</sup>Our model predicts that speculators refrain from short-selling in expectation of deal cancelation, the direct evidence of which is not empirically detectable. However, the model prediction is consistent with the poor long-term performance of mergers and acquisitions (e.g., Andrade, Mitchell, and Stafford (2001)). In the above example, speculators who sold might have expected that the acquisition would go through due to managerial private benefits. Hence, the example should be used to demonstrate the losses incurred by speculators when a corrective action was unexpectedly adopted in response to their selling.

<sup>2</sup>For example, see the news segment “Berlusconi Facing Intensified Pressure to Resign as Italian Bond Rates

After his resignation, bond yields fell from over 7% on November 16 to 6.6% on November 18 and below 6% in early December.

An important aspect of our theory is that it generates asymmetry between trading on positive and negative information. The feedback effect delivers an equilibrium in which the speculator trades on good news but do not trade on bad news. Yet, it does not give rise to the opposite equilibrium in which the speculator trades on bad news only. The intuition is as follows. When a speculator trades on information, she improves the efficiency of the firm's decisions – regardless of the direction of her trade. If she has positive information on a firm's prospects, trading on it will reveal to the manager that investment is profitable. This revelation will cause the firm to invest more, thus increasing its value. If the speculator has negative information, trading on it will reveal to the manager that investment is unprofitable. This revelation will cause the firm to invest less, also increasing its value as contraction is the correct decision. When a speculator buys and takes a long position in a firm, she benefits not only from her positive information, but also from increasing the firm's value via the feedback effect. By contrast, when she sells and takes a short position, she loses from increasing the firm's value via the feedback effect. Note that for the speculator to lose from the feedback effect, she must end up with a short position. If she ends with a long position, the value of the shares she retains are enhanced by the feedback effect. Thus, the model implies that investors are less likely to engage in short-sales than sales – even though the model contains no short-sale constraints.

Even though the speculator's trading behavior is asymmetric, it is not automatic that the impact on prices will be asymmetric. The market maker is fully rational and takes into account the fact that the speculator trades only on positive information, and so he adjusts his pricing function accordingly. Therefore, it may seem that negative information will have the same price impact as positive information – even though it may lead to a neutral rather than negative order flow, the market maker knows that a neutral order flow can stem from the speculator having negative information but choosing not to trade, and therefore should decrease the price accordingly. We show that asymmetry in trading behavior does translate into asymmetry in price impact. The crux is that the market maker cannot distinguish the case of a speculator who has negative information but chooses to withhold it, from the case in which the speculator is absent (i.e., there is no private information). Thus, a neutral order flow does not lead to a large stock price decrease, and so negative information has a smaller effect on prices. Indeed, Hong, Lim, and Stein (2000) show empirically that bad news is incorporated into prices more slowly than good news. They conjecture that this phenomenon arises because firm management possesses value-relevant information and publicizes it more enthusiastically for favorable than unfavorable information. Our paper presents a formal model that offers an alternative explanation. Here, key information is held by a firm's investors rather than its

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Continue Climbing” on ForexTV on November 9, 2011, and the Yahoo Finance article “Berlusconi Urged To Quit As Bond Yields Climb” on October 31, 2011.

managers, who “publicize” it not through public news releases, but by trading on it. They also choose to disseminate good news more readily than bad news, but for a reason very different from that of firm management, i.e., because of the feedback effect and its implications for trading profits.

In addition to its effects on stock returns, the asymmetry of the speculator’s trading strategy can also generate important real consequences. Since negative information is not incorporated into prices, it does not influence management decisions. Thus, while positive net present value (“NPV”) projects will be encouraged, some negative-NPV projects will not be canceled, leading to overinvestment overall. In contrast to standard overinvestment theories based on the manager having private benefits (e.g., Jensen (1986), Stulz (1990), Zwiebel (1996)), here the manager is fully aligned with firm value and there are no agency problems. The manager wishes to maximize firm value by learning from prices, but is unable to do so since speculators refrain from revealing their information. Applied to M&A as well as organic investment, the theory may explain why M&A appears to be “excessive” and a large fraction of acquisitions destroy value (see, e.g., Andrade, Mitchell, and Stafford (2001)). While traditional finance theory would suggest that the market can prevent bad acquisitions by communicating negative information to the manager, our model shows that the market might fail to do so due to the adverse effect on speculators’ trading incentives: revealing negative information to the firm is unprofitable for them if the information is then used to correct the underlying problem.

Our source of the limits to arbitrage – the feedback effect – is different from the mechanisms studied by prior research. Campbell and Kyle (1993) focus on fundamental risk, i.e., the risk that firm fundamentals will change while the arbitrage strategy is being pursued. In their model, such changes are unrelated to speculators’ arbitrage activities. De Long, Shleifer, Summers, and Waldmann (1990) argue that noise-trading risk, i.e., the risk that noise trading will increase the degree of mispricing, may render arbitrage activities unprofitable. Noise trading only affects the asset’s market price and not its fundamental value, which is again exogenous to the act of arbitrage. Shleifer and Vishny (1997) show that, even if an arbitrage strategy is sure to converge in the long-run, the possibility that mispricing may widen in the short-term may deter speculators from pursuing it, if they are concerned with short-term redemptions by their own investors. Similarly, Kondor (2009) demonstrates that financially-constrained arbitrageurs may stay out of a trade if they believe that it will become more profitable in the future. Many authors (e.g., Pontiff (1996), Mitchell and Pulvino (2001), and Mitchell, Pulvino, and Stafford (2002)) focus on the transaction costs and holding costs that arbitrageurs have to incur while pursuing an arbitrage strategy. Others (Geczy, Musto, and Reed (2002), and Lamont and Thaler (2003)) discuss the importance of short-sales constraints.

While these papers emphasize market frictions as the source of limits to arbitrage, our paper shows that limits to arbitrage arise when the market performs its utmost efficient role: guiding the allocation of real resources. Thus, while limits to arbitrage based on market frictions tend to attenuate with the development of financial markets, the effect identified by this paper will

remain: informed investors with no constraints, trading restrictions, or risk aversion may nevertheless refrain from trading on negative information due to the feedback effect. This mechanism adds to “limit to arbitrage” studied in the vast literature following Kyle (1985), in which speculators decrease their trading volumes to reduce price impact. Here, speculators are also concerned about the impact on managerial decisions and hence on the real value of the firm. Moreover, as investors become more sophisticated, managers will learn from them to a greater degree. As a result, the effect may even strengthen with the development of financial markets.

Our paper is related to the literature exploring the theoretical implications of the feedback effects from market prices to real decision making. Several papers in this literature show that the feedback effect can be harmful for real efficiency: see Bond, Edmans, and Goldstein (2012) for a survey. Most closely related is Goldstein and Guembel (2008), who show that the feedback effect provides an incentive for uninformed speculators to short sell a stock, reducing its value by inducing a real decision (investment) based on false information. Their paper also highlights an asymmetry between buy-side and sell-side speculation, but only with respect to uninformed trading; here, we show that informed speculators are less likely to trade on bad news rather than good news, in turn generating implications for the speed of incorporation of news into prices. Bond, Goldstein, and Prescott (2010), Dow, Goldstein, and Guembel (2010), and Goldstein, Ozdenoren, and Yuan (2011) also model complexities arising from the feedback effect. Overall, the point in our paper – that negatively informed speculators will strategically withhold information from the market, because they know that the release of negative information will lead managers to fix the underlying problem – is new in this literature.

This paper proceeds as follows. Section 2 presents the model. Section 3 contains the core analysis, demonstrating the asymmetric limit to arbitrage. Section 4 investigates the extent to which information affects beliefs and prices and Section 5 concludes. Appendix A contains all proofs not in the main text and other peripheral material such as additional comparative statics.

## 2 The Model

The model has three dates,  $t \in \{0, 1, 2\}$ . There is a firm whose stock is traded in the financial market. The firm’s manager needs to take a decision as to whether to continue or abandon an investment project. The manager’s goal is to maximize expected firm value; since there are no agency problems between the manager and the firm, we will use these two terms interchangeably. At  $t = 0$ , a risk-neutral speculator may be present in the financial market. If present, she is informed about the state of nature  $\theta$  that determines the profitability of continuing vs. abandoning the project. Trading in the financial market occurs at  $t = 1$ . In addition to the speculator, two other types of agents participate in the financial market: a noise trader whose trades are unrelated to the realization of  $\theta$ , and a risk-neutral market maker. The latter collects

the orders from the speculator and noise trader, and sets a price at which he executes the orders out of his inventory. At  $t = 2$ , the manager takes the decision, which may be affected by the trading in the financial market at  $t = 1$ . Finally, all uncertainty is resolved and payoffs are realized. We now describe the firm’s investment problem and the trading process in more detail.

## 2.1 The Firm’s Decision

Suppose that the firm has an investment project that can be either continued or abandoned at  $t = 2$ . We denote the firm’s decision as  $d \in \{i, n\}$ , where  $d = i$  represents continuing the investment and  $d = n$  represents no investment (also referred to as “abandonment” or “correction”). The firm faces uncertainty over the realization of value under each possible action. In particular, there are two possible states  $\theta \in \Theta \equiv \{H, L\}$  (“high” and “low”). We denote the value of the firm realized in  $t = 2$  as  $v = R_\theta^d$ , which depends on both the state of nature  $\theta$  and the manager’s action  $d$ .

We assume that whether continuation or abandonment is desirable depends on the state of nature (i.e., there is no dominant action). Without loss of generality, we set:

$$R_H^i > R_H^n, \quad (1)$$

$$R_L^n > R_L^i, \quad (2)$$

that is, continuation is optimal in state  $H$ , while abandonment is optimal in state  $L$ . We also set:

$$R_H^i > R_L^n, \quad (3)$$

that is, under the optimal action, the highest firm value is achieved in state  $H$ , consistent with this being labeled as the “high” state. This assumption is also without loss of generality as, if it is not satisfied, the highest firm value is achieved in state  $L$  and we can simply reverse notations. The assumption is only used in Section 4 when we calculate stock returns.

Note that inequalities (1) and (2) imply:

$$R_H^i - R_L^i > R_H^n - R_L^n. \quad (4)$$

Inequality (4) is the driving force behind our results. It means that taking the corrective action reduces the negative effect of state  $L$  on firm value. Put differently, if the state is  $L$  rather than  $H$ , the reduction in firm value is lower if the manager has taken action  $n$ . In turn, inequality (4) incorporates two cases, depending on whether firm value is monotonic in the underlying state:

*Case 1:*  $R_H^n > R_L^n$ . In this case, state  $H$  is better for firm value, no matter what action has been taken by the firm. Hence, the corrective action attenuates, but does not eliminate, the effect of the state on firm value. Abandonment reduces the volatility of firm value, i.e., the dependence of firm value on the state. For example, state  $H$  can represent high demand for the

firm's products, while state  $L$  represents low demand. Whether the firm continues to invest in its production process or not, its value will be lower in state  $L$ , but the negative effect of state  $L$  is attenuated if the firm does not invest.

*Case 2:  $R_L^n > R_H^n$ .* In this case, if the corrective action is taken, firm value is higher in state  $L$ . Put differently, the corrective action is sufficiently powerful to overturn the effect of the state on firm value. Importantly, this second case does not require that abandonment reduces the volatility of firm value: it could be that  $abs(R_H^n - R_L^n) > abs(R_H^i - R_L^i)$  so volatility is higher under correction. Instead, the case  $R_L^n > R_H^n$  implies non-monotonicity of firm value in the state: one state does not dominate the other. For example, consider the case where continuation implies proceeding with a takeover decision, and abandonment implies keeping the cash for future opportunities. State  $H$  corresponds to a state in which current acquisition opportunities dominate future ones, and state  $L$  refers to the reverse. Under continuation, firm value is higher in state  $H$ , whereas if the firm chooses to postpone acquisitions, its value is higher in state  $L$  in which future acquisition opportunities are superior. Another example is related to Aghion and Stein (2008):  $d = i$  corresponds to a growth strategy, and  $d = n$  corresponds to a strategy focused on current profit margins. Growth prospects are good if  $\theta = H$  and bad if  $\theta = L$ . If the firm eschews the growth strategy ( $d = n$ ), its value is higher in the low state in which there are no growth opportunities, since in the high state, its rivals could pursue the growth opportunities, in turn worsening its competitive position.

The prior probability that the state is  $\theta = H$  is  $y = \frac{1}{2}$ , which is common knowledge. We use  $q$  to denote the posterior probability the manager assigns to the case  $\theta = H$ . The manager bases his decision on  $q$ , which is calculated using information arising from trades in the financial market. Let  $\gamma$  denote the posterior belief that the state is  $H$  such that the manager is indifferent between continuation and abandonment, i.e.:

$$\gamma R_H^i + (1 - \gamma)R_L^i = \gamma R_H^n + (1 - \gamma)R_L^n. \quad (5)$$

For completeness and without loss of generality, if the manager is indifferent between continuation and abandonment, we assume that he will not invest. The value of  $\gamma$  represents a ‘‘cutoff’’ that determines the manager’s action. If and only if  $q > \gamma$ , he will continue the project. We will distinguish between two cases. The first case is where  $\gamma < \frac{1}{2}$ . Since the prior  $y$  is  $\frac{1}{2}$ , the manager would continue the investment without further information, i.e., ex ante, the investment has a positive NPV. The second case is where  $\gamma \geq \frac{1}{2}$ , and so the manager will abandon the investment without further information since its ex-ante NPV is non-positive.



## 2.2 Trade in the Financial Market

At  $t = 0$ , a speculator arrives in the financial market with probability  $\lambda$ , where  $0 < \lambda < 1$ . Whether the speculator is present or not is unknown to anyone else.<sup>3</sup> If the speculator is present, she observes the state of nature  $\theta$  with certainty. We will use the term “positively-informed speculator” to describe a speculator who observes  $\theta = H$ , and “negatively-informed speculator” to describe a speculator who observes  $\theta = L$ . The variable  $\lambda$  is a measure of market sophistication or the informedness of outside investors and will generate a number of comparative statics.

Trading in the financial market happens at  $t = 1$ . Always present is a noise trader, who trades  $z = -1, 0$ , or  $1$  with equal probabilities. If the speculator is present, she makes an endogenous trading choice  $s \in \{-1, 0, 1\}$ . Trading either  $-1$  or  $1$  is costly for the speculator and entails paying a cost of  $\kappa$ . The trading cost  $\kappa$  should be interpreted broadly. While direct transaction costs coming from commissions are typically small, other indirect costs can be very large. These include borrowing costs (for short sales) and the opportunity costs of capital commitment (for purchases). These costs may differ between buying and selling, but the relative size is a priori unclear. Given our interest in exploring the endogenous asymmetry between buying and selling due to the feedback effect, we assume the same trading cost  $\kappa$  in both directions to avoid generating any asymmetry mechanically. Unless otherwise specified, we refer to trading profits and losses gross of the cost  $\kappa$ . If the speculator is indifferent between trading and not trading (because her expected profits from trading exactly equal  $\kappa$ ), we assume that she will not trade.

Following Kyle (1985), orders are submitted simultaneously to a market maker who sets the price and absorbs order flows out of his inventory. The orders are market orders and are not contingent on the price. The competitive market maker sets the price equal to expected asset value, given the information contained in the order flow. The market maker can only observe total order flow  $X = s + z$ , but not its individual components  $s$  and  $z$ . Possible order flows are  $X \in \{-2, -1, 0, 1, 2\}$  and the pricing function is  $p(X) = E(v|X)$ . A critical departure from Kyle (1985) is that firm value here is endogenous, because the manager’s action is based on information revealed during the trading process.

Specifically, the manager observes total order flow  $X$ , and uses the information in  $X$  to form his posterior  $q$ , which is then used in the investment decision. Allowing the manager to observe order flow  $X$ , rather than just the price  $p$ , simplifies the analysis without affecting its economic content. In the equilibria that we analyze, there is a one-to-one correspondence between the price and the order flow in most cases; in the few cases where two order flows correspond to the same price, the manager’s decision is the same for both order flows. Under the alternative assumption that the manager observes  $p$ , other equilibria can arise, in which the market maker

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<sup>3</sup>Since private information is not public knowledge, its existence is also unlikely to be public knowledge. Chakraborty and Yilmaz (2004) also feature uncertainty on whether the speculator is present, in an equilibrium in which informed insiders manipulate the market by trading in the wrong direction.

sets a price that is consistent with a different managerial decision (one that is suboptimal given the information in the order flow) and this becomes self-fulfilling due to the dependence of the manager’s decision on the price. Since our interest is on the feedback effect, we focus on equilibria where the manager’s decision responds optimally to the information in the order flow. Moreover, it seems reasonable to assume that managers have access to information about trading quantities in the financial market: first, market making is competitive and so there is little secrecy in the order flow; second, microstructure databases (such as TAQ) provide such information at a short lag – rapidly enough to guide investment decisions.

As is standard in the feedback literature, we assume that the speculator cannot communicate her information directly to the manager. It is clear that she has neither incentive nor credibility to do so in our model since she has no initial stake in the firm; instead, she wishes to use her information to maximize her trading profits (as in the theories of governance through trading/“exit” by Admati and Pfleiderer (2009), Edmans (2009), and Edmans and Manso (2011)). For speculators with an initial stake (blockholders), their trade-off between using her private information to trade or intervene has been studied by Maug (1998) and Kahn and Winton (1998).

## 2.3 Equilibrium

The equilibrium concept we use is the Perfect Bayesian Nash Equilibrium. Here, it is defined as follows: (i) A trading strategy by the speculator:  $S : \Theta \rightarrow \{-1, 0, 1\}$  that maximizes his expected final payoff  $s(v - p) - |s|\kappa$ , given the price setting rule, the strategy of the manager, and his information about the realization of  $\theta$ . (ii) An investment strategy by the firm  $D : \mathcal{Q} \rightarrow \{i, n\}$  (where  $\mathcal{Q} = \{-2, -1, 0, 1, 2\}$ ), that maximizes expected firm value  $v = R_\theta^d$  given the information in the order flow and all other strategies. (iii) A price setting strategy by the market maker  $p : \mathcal{Q} \rightarrow \mathbb{R}$  that allows him to break even in expectation, given the information in the price and all other strategies. Moreover, (iv) the firm and the market maker use Bayes’ rule in order to update their beliefs from the order they observe in the financial market, and (v) beliefs on outcomes not observed on the equilibrium path satisfy the Cho and Kreps (1987) intuitive criterion. Finally, (vi) all agents have rational expectations in that each player’s belief about the other players’ strategies is correct in equilibrium.

## 3 Feedback Effect and Asymmetric Limits to Arbitrage

In this section, we characterize the pure-strategy equilibria in our model. We demonstrate the emergence of asymmetric limits to arbitrage as a result of the feedback from market trading outcomes to the firm’s investment decision. We consider Case 1 ( $R_H^n > R_L^n$ ) first and then proceed to Case 2 ( $R_H^n < R_L^n$ ).

### 3.1 Case 1: Firm Value is Monotone in the State: $R_H^n > R_L^n$

We start with the case where  $\gamma < \frac{1}{2}$ , i.e., without further information, the firm will choose to invest. Later, we will show that our main insight carries through to the case where  $\gamma \geq \frac{1}{2}$ . In our characterization, we make use of three different threshold levels of the cost of trading  $\kappa$ :

$$\kappa_1 \equiv \frac{1}{3} \left[ \frac{1}{2} (R_H^i - R_L^i) + \frac{1-\lambda}{2-\lambda} (R_H^n - R_L^n) \right], \quad (6)$$

$$\kappa_2 \equiv \frac{1}{3} \left( \frac{1}{2} + \frac{1-\lambda}{2-\lambda} \right) (R_H^i - R_L^i), \quad (7)$$

$$\kappa_3 \equiv \frac{1}{3} (R_H^i - R_L^i), \text{ where} \quad (8)$$

$$\kappa_1 < \kappa_2 < \kappa_3, \text{ and} \quad (9)$$

$$\kappa_2 - \kappa_1 = \frac{1}{3} \frac{1-\lambda}{2-\lambda} [(R_H^i - R_L^i) - (R_H^n - R_L^n)] > 0. \quad (10)$$

The results also depend on whether order flow is sufficiently informative to overturn the decision to invest, which is the ex-ante optimal decision. Hence, we distinguish between two cases depending on whether the cutoff  $\gamma$  is higher or lower than  $\frac{1-\lambda}{2-\lambda}$ . As we will show, the quantity  $\frac{1-\lambda}{2-\lambda}$  is relevant as, in some equilibria, it represents the posterior probability of state  $H$  under an order flow of  $X = -1$ . The first case is  $\frac{1-\lambda}{2-\lambda} \leq \gamma$ . Here, the probability  $\lambda$  that the speculator is present is sufficiently high that a negative order of  $X = -1$  is sufficiently informative to deter the manager from investing. Thus, there is feedback from the market to real decisions for the case of  $X = -1$ .<sup>4</sup> The second case is  $\frac{1-\lambda}{2-\lambda} > \gamma$ . Here, a negative order of  $X = -1$  is not sufficiently informative to lead the manager to abandon the default plan of investing. Thus, there is no feedback effect for  $X = -1$ .

As we will show, depending on the values of  $\kappa$ , four equilibrium outcomes can arise:

1. No Trade Equilibrium *NT*: the speculator does not trade,
2. Trade Equilibrium *T*: the speculator buys when she knows that  $\theta = H$  and sells when she knows that  $\theta = L$ ,
3. Partial Trade Equilibrium *BNS* (Buy - Not Sell): the speculator buys when she knows that  $\theta = H$  and does not trade when she knows that  $\theta = L$ ,
4. Partial Trade Equilibrium *SNB* (Sell - Not Buy): the speculator does not trade when she knows that  $\theta = H$  and sells when she knows that  $\theta = L$ .

Proposition 1 provides the characterization of equilibrium outcomes.

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<sup>4</sup>While  $X = -2$  is also a negative order flow, the firm's decision in this case is not relevant for equilibrium trading strategies as the speculator's information is fully revealed and so she never makes a profit. Thus, this node is not relevant for determining the equilibrium trading strategies.

**Proposition 1** (*Equilibrium, firm value is monotone in the state, investment is ex-ante desirable*). Suppose that  $R_H^n > R_L^n$  and  $\gamma < \frac{1}{2}$ . Then the trading game has the following pure-strategy equilibria:

When  $\kappa < \kappa_1$ , the only pure-strategy equilibrium is *T*.

When  $\kappa_1 \leq \kappa < \kappa_2$ : in the case of feedback ( $\frac{1-\lambda}{2-\lambda} \leq \gamma$ ), the only pure-strategy equilibrium is *BNS*; in the case of no feedback ( $\frac{1-\lambda}{2-\lambda} > \gamma$ ), the only pure-strategy equilibrium is *T*.

When  $\kappa_2 \leq \kappa < \kappa_3$ , there are two pure-strategy equilibria: *BNS* and *SNB*.

When  $\kappa \geq \kappa_3$ , the only pure-strategy equilibrium is *NT*.

That is, if and only if there is feedback ( $\frac{1-\lambda}{2-\lambda} \leq \gamma$ ), there is a strictly positive range of parameter values ( $\kappa_1 \leq \kappa < \kappa_2$ ) for which the *BNS* equilibrium exists but the *SNB* equilibrium does not exist. There is no range of parameter values for which the *SNB* equilibrium exists but the *BNS* equilibrium does not exist.

**Proof.** Given that firm value is always higher when  $\theta = H$  than when  $\theta = L$ , it is straightforward to show that the speculator will never buy when she knows that  $\theta = L$  and will never sell when she knows that  $\theta = H$ . Then, the only possible pure-strategy equilibria are *NT*, *T*, *BNS*, and *SNB*. Below, we identify the conditions under which each one of these equilibria holds. If an order flow of  $X = -2$  ( $X = 2$ ) is observed off the equilibrium path, the beliefs of the market maker and the manager are that the speculator knows that the state is *L* (*H*). Given that speculators always lose if they trade against their information, this is the only belief that is consistent with the intuitive criterion.

#### **No Trade Equilibrium *NT*:**

For a given order flow  $X$ , the posterior  $q$ , the manager's decision  $d$  and the price  $p$  are given by the following table (see Appendix A for the full calculations):

| $X$ | -2      | -1                                    | 0                                     | 1                                     | 2       |
|-----|---------|---------------------------------------|---------------------------------------|---------------------------------------|---------|
| $q$ | 0       | $\frac{1}{2}$                         | $\frac{1}{2}$                         | $\frac{1}{2}$                         | 1       |
| $d$ | $n$     | $i$                                   | $i$                                   | $i$                                   | $i$     |
| $p$ | $R_L^n$ | $\frac{1}{2}R_H^i + \frac{1}{2}R_L^i$ | $\frac{1}{2}R_H^i + \frac{1}{2}R_L^i$ | $\frac{1}{2}R_H^i + \frac{1}{2}R_L^i$ | $R_H^i$ |

As shown in Appendix A, the profit for the negatively-informed speculator from deviating to selling is  $\frac{1}{3}(R_H^i - R_L^i)$ , and this is also the profit for the positively-informed speculator from deviating to buying. Thus, this equilibrium holds if and only if  $\kappa \geq \kappa_3$ .

#### **Partial Trade Equilibrium *SNB*:**

For a given order flow  $X$ , the posterior  $q$ , the manager's decision  $d$  and the price  $p$  are given

by the following table:

| $X$ | -2      | -1                                    | 0                                     | 1   | 2       |
|-----|---------|---------------------------------------|---------------------------------------|---|---------|
| $q$ | 0       | $\frac{1}{2}$                         | $\frac{1}{2}$                         | $\frac{1}{2-\lambda}$   | 1       |
| $d$ | $n$     | $i$                                   | $i$                                   | $i$   | $i$     |
| $p$ | $R_L^n$ | $\frac{1}{2}R_H^i + \frac{1}{2}R_L^i$ | $\frac{1}{2}R_H^i + \frac{1}{2}R_L^i$ | $\frac{1}{2-\lambda}R_H^i + \frac{1-\lambda}{2-\lambda}R_L^i$ | $R_H^i$ |

Calculating the profit for the negatively-informed speculator from deviating to not trading and for the positively-informed speculator from deviating to buying, we can see that this equilibrium holds if and only if  $\kappa_2 \leq \kappa < \kappa_3$ .

### Partial Trade Equilibrium $BNS$ :

For a given order flow  $X$ , the posterior  $q$ , the manager's decision  $d$  and the price  $p$  are given by the following table:

| $X$ | -2      | -1  | 0                                     | 1                                     | 2       |
|-----|---------|---|---------------------------------------|---------------------------------------|---------|
| $q$ | 0       | $\frac{1-\lambda}{2-\lambda}$   | $\frac{1}{2}$                         | $\frac{1}{2}$                         | 1       |
| $d$ | $n$     | $\begin{cases} n & \text{if } \frac{1-\lambda}{2-\lambda} \leq \gamma \\ i & \text{if } \frac{1-\lambda}{2-\lambda} > \gamma \end{cases}$   | $i$                                   | $i$                                   | $i$     |
| $p$ | $R_L^n$ | $\begin{cases} \frac{1-\lambda}{2-\lambda}R_H^n + \frac{1}{2-\lambda}R_L^n & \text{if } \frac{1-\lambda}{2-\lambda} \leq \gamma \\ \frac{1-\lambda}{2-\lambda}R_H^i + \frac{1}{2-\lambda}R_L^i & \text{if } \frac{1-\lambda}{2-\lambda} > \gamma \end{cases}$ | $\frac{1}{2}R_H^i + \frac{1}{2}R_L^i$ | $\frac{1}{2}R_H^i + \frac{1}{2}R_L^i$ | $R_H^i$ |

Calculating the profit for the negatively-informed speculator from deviating to selling and for the positively-informed speculator from deviating to not trading, we can see that this equilibrium holds if and only if  $\kappa_2 \leq \kappa < \kappa_3$  for the case of no feedback ( $\frac{1-\lambda}{2-\lambda} > \gamma$ ) and if and only if  $\kappa_1 \leq \kappa < \kappa_3$  for the case of feedback ( $\frac{1-\lambda}{2-\lambda} \leq \gamma$ ).

### Trade Equilibrium $T$ :

For a given order flow  $X$ , the posterior  $q$ , the manager's decision  $d$  and the price  $p$  are given by the following table:

| $X$ | -2      | -1  | 0                                     | 1   | 2       |
|-----|---------|---|---------------------------------------|---|---------|
| $q$ | 0       | $\frac{1-\lambda}{2-\lambda}$   | $\frac{1}{2}$                         | $\frac{1}{2-\lambda}$   | 1       |
| $d$ | $n$     | $\begin{cases} n & \text{if } \frac{1-\lambda}{2-\lambda} \leq \gamma \\ i & \text{if } \frac{1-\lambda}{2-\lambda} > \gamma \end{cases}$   | $i$                                   | $i$   | $i$     |
| $p$ | $R_L^n$ | $\begin{cases} \frac{1-\lambda}{2-\lambda}R_H^n + \frac{1}{2-\lambda}R_L^n & \text{if } \frac{1-\lambda}{2-\lambda} \leq \gamma \\ \frac{1-\lambda}{2-\lambda}R_H^i + \frac{1}{2-\lambda}R_L^i & \text{if } \frac{1-\lambda}{2-\lambda} > \gamma \end{cases}$ | $\frac{1}{2}R_H^i + \frac{1}{2}R_L^i$ | $\frac{1}{2-\lambda}R_H^i + \frac{1-\lambda}{2-\lambda}R_L^i$ | $R_H^i$ |

Calculating the profit for the negatively-informed speculator from deviating to not trading and for the positively-informed speculator from deviating to not trading, we can see that this equilibrium holds if and only if  $\kappa < \kappa_2$  for the case of no feedback ( $\frac{1-\lambda}{2-\lambda} > \gamma$ ) and if and only if  $\kappa < \kappa_1$  for the case of feedback ( $\frac{1-\lambda}{2-\lambda} \leq \gamma$ ).

Thus, there is a range of  $\kappa$  for which the only equilibrium is *BNS* if  $\kappa_1 < \kappa_2$  and  $\frac{1-\lambda}{2-\lambda} \leq \gamma$ . From (4) and (10),  $\kappa_1 < \kappa_2$  requires  $\lambda < 1$ . In turn,  $\frac{1-\lambda}{2-\lambda} \leq \gamma$  requires  $\lambda > \frac{1-2\gamma}{1-\gamma}$ . Thus, there exist values of  $\lambda$  that satisfy both of the above conditions if  $\frac{1-2\gamma}{1-\gamma} < 1$ , which always holds. ■

Proposition 1 demonstrates the sources of limits to arbitrage in our model, one of which is the feedback effect that is the focus of our paper. To understand the various forces, we start by describing the equilibrium outcomes in the case of no feedback, i.e., when  $\frac{1-\lambda}{2-\lambda} > \gamma$ . Here, an order flow of  $X = -1$  may convey (depending on the equilibrium) negative information, but not sufficiently negative to deter the manager from abandoning the default plan of investing. In this case, there are three regions of the parameter  $\kappa$ . When  $\kappa < \kappa_2$ , the only pure-strategy equilibrium is one in which the speculator always trades on her information. When  $\kappa_2 \leq \kappa < \kappa_3$ , there are two pure strategy equilibria, exhibiting limited trade, one in which the speculator buys on good news but does not trade on bad news, and one in which she sells on bad news but does not trade on good news. When  $\kappa \geq \kappa_3$ , the only pure-strategy equilibrium entails no trade at all by the speculator.

Two sources of limits to arbitrage are present in the no-feedback case, both of which are common in the literature. The first source is the trading cost  $\kappa$ . As  $\kappa$  increases, we move to equilibria in which speculators trade less on their information. Clearly, when speculators are subject to greater transaction costs, they have lower incentives to trade. The second source is the price impact that speculators exert when they trade on their information. In the intermediate region  $\kappa_2 \leq \kappa < \kappa_3$ , there are equilibria in which the speculator trades on one type of information but not the other. There is symmetry in that both types of asymmetric equilibria are possible in exactly the same range of parameters. To understand the intuition behind these asymmetric equilibria, consider the *BNS* equilibrium without feedback (the case of the *SNB* equilibrium is analogous). Given that the market maker believes that the speculator buys on good news, a negative order flow is very revealing that the speculator is negatively informed and the price moves sharply to reflect this. Specifically,  $X = -1$  is inconsistent with the speculator having positive information, and so she only receives  $\frac{1-\lambda}{2-\lambda}R_H^i + \frac{1}{2-\lambda}R_L^i$ . Thus, the speculator makes little profit from selling on bad news; knowing this, she chooses not to trade on bad news. Conversely, given that the market maker believes that the speculator does not sell on bad news, a positive order flow of  $X = 1$  is consistent with the speculator being negatively informed and choosing not to trade. Thus, the market maker sets a relatively low price of  $\frac{1}{2}R_H^i + \frac{1}{2}R_L^i$ , which allows the speculator to make high profits by buying. Thus, the equilibrium is sustainable. In sum, in both partial trade equilibria, the order flow in the direction in which the speculator does not trade becomes particularly informative, leading to a larger price impact which reduces the potential trading profits. Thus, not trading in this direction is sustained in equilibrium. This force is symmetric in the absence of feedback.

We now move to the case of feedback, i.e., when  $\frac{1-\lambda}{2-\lambda} \leq \gamma$ . Here, an order flow of  $X = -1$  provides enough negative information for the manager to abandon the investment. Abandonment is the optimal decision in state  $L$ ; thus, improving the manager's decision reduces the

speculator's profit in the node of  $X = -1$  from  $\frac{1-\lambda}{2-\lambda}(R_H^i - R_L^i)$  (in the case of no-feedback) to only  $\frac{1-\lambda}{2-\lambda}(R_H^n - R_L^n)$ . This reduced profit affects the speculator's equilibrium trading strategy and causes her not to sell on bad news if  $\kappa_1 \leq \kappa$ . Our main result is that the feedback effect introduces an additional limit to arbitrage that is distinct from those identified in prior literature – *arbitrage is limited because the value of the asset being arbitrated is endogenous to the act of arbitrage*. Unlike trading costs and price impact, the limit to arbitrage arising from the feedback effect is asymmetric: it reduces the extent of selling on bad news but not the extent of buying on good news. Indeed, the difference between equilibrium outcomes in the two cases of no-feedback and feedback is that, in the range  $\kappa_1 \leq \kappa < \kappa_2$ , the Trade Equilibrium  $T$  is replaced with the Partial Trade Equilibrium  $BNS$ . However, there is no range of parameters for which the  $SNB$  equilibrium exists but the  $BNS$  equilibrium does not exist.

A change in the speculator's strategy from  $T$  to  $BNS$  reduces the efficiency of the manager's investment decision by reducing the amount of information available to him, which in turn reduces the value of the firm. Suppose the trading cost  $\kappa$  changes from  $\kappa_1 - \varepsilon$  to  $\kappa_1 + \varepsilon$  for an arbitrarily small positive  $\varepsilon$ , the equilibrium, in the case of feedback, switches from  $T$  to  $BNS$ . The calculation of firm value in both equilibria is as follows. In both equilibria, with probability  $\frac{1}{2}$ ,  $\theta = H$  and the project is undertaken in all cases, so  $V(\cdot, H) = R_H^i$ . With probability  $\frac{1}{2}$ ,  $\theta = L$ . In the  $T$  equilibrium,  $X \in \{-2, -1, 0\}$  and the project is undertaken only if  $X = 0$ , so  $V(T, L) = \frac{2}{3}R_L^n + \frac{1}{3}R_L^i$ . In the  $BNS$  equilibrium,  $X \in \{-1, 0, 1\}$  and the project is undertaken if  $X \in \{0, 1\}$ , so  $V(BNS, L) = \frac{1}{3}R_L^n + \frac{2}{3}R_L^i$ . The difference in firm value between the two equilibria is thus  $\frac{1}{6}(R_L^n - R_L^i)$ , which is strictly positive. Thus, while the feedback effect from stock prices to firm decisions adds value, since the stock market provides the manager with decision-relevant information, the change in the speculator's strategy due of the feedback effect – her reluctance to trade on negative information – reduces value.

The intuition behind the asymmetry between the  $BNS$  and  $SNB$  equilibria is as follows. In the case of feedback, when the speculator sells on bad news, she may lead the manager to abandon a bad investment. By doing so, she improves firm value, because  $R_L^n > R_L^i$ . Since she has a short position, this increase in firm value reduces her profit. Hence, it deters the speculator from selling on bad news. On the other hand, the feedback effect does not deter the positively-informed speculator from buying on good news. Buying on good news may reveal to the manager that the state is good, which (weakly) causes him to increase investment; since investment is desirable in the high state, this augments firm value. The speculator will then profit from the increase in the value of her long position, which will further increase her incentive to trade.<sup>5</sup>

Overall, trading on her information in either direction – whether it is buying on positive

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<sup>5</sup>In the case discussed so far ( $\gamma < \frac{1}{2}$ ) the default option for the manager is to invest, and so positive news from the market does not change his decision and does not affect firm value. Hence we state that buying on good information causes the manager to weakly increase investment. As we will show later, if  $\gamma > \frac{1}{2}$ , buying on good news causes the manager to strictly increase investment, in turn strictly improving firm value. This effect is the driving force behind our results in the case of  $\gamma > \frac{1}{2}$ .

information or selling on negative information – conveys information to the manager. This improves his decision making and thus firm value. Increased firm value augments the profitability of a long position but reduces the profitability of a short position. By contrast, the two limits to arbitrage studied in prior research are symmetric. A high trading cost  $\kappa$  leads to the *NT* equilibrium in which there is no trading in either direction. Price impact leads to the two partial trade equilibria, *BNS* and *SNB*, but there is symmetry in that both equilibria are possible in exactly the same range of parameters. In particular, without feedback (i.e., if  $\gamma \geq \frac{1}{2}$ ), there is no value of  $\kappa$  in which there is one partial trade equilibrium but not the other.

The reason for why the feedback effect reduces trading profits is nuanced. Intuition may suggest that the market maker’s pricing function will “undo” the feedback effect: since he is rational, the price he sets for a given order flow takes into account the order flow’s effect on the manager’s decision. Thus, the price received by the speculator will always reflect the manager’s action (be it continuation or investment), and so it seems that the action will not affect her profits. Such intuition turns out to be incorrect. The source of the speculator’s profits is not superior knowledge of the manager’s action, since the market maker can always perfectly predict this action from the order flow, but superior knowledge of the state – the speculator directly observes  $\theta$ , but the market maker can only imperfectly infer it from the order flow. In turn, the manager’s action  $d$  (and thus the feedback effect on the manager’s action) affects trading profits because it affects the dependence of the firm value on the state. From (4), firm value is more sensitive to the state – and thus the speculator makes greater profits from her information on the state – if the investment is undertaken. For example, when  $X = -1$ , the speculator’s profit is  $\frac{1-\lambda}{2-\lambda} (R_H^d - R_L^d)$ , which depends on the decision  $d$ .

We now wish to verify that the asymmetry between buy-side speculation and sell-side speculation, driven by the feedback effect, is not an artifact of the fact that investment is the default decision, i.e., the case  $\gamma < \frac{1}{2}$ . We now show that when  $\gamma \geq \frac{1}{2}$ , i.e., when the default decision is abandonment, our results are qualitatively similar: without feedback, *BNS* and *SNB* equilibria occur over the same range of parameters, whereas with feedback, the *BNS* equilibrium occurs over a wider range than the *SNB* equilibrium. For  $\gamma < \frac{1}{2}$ , the source of the limit to arbitrage was that the feedback effect reduces the profitability of a short position but does not affect the profitability of a long position, since a positive order flow leads to investment but the investment would be undertaken in the absence of further information anyway. Here, for  $\gamma \geq \frac{1}{2}$ , the source is that the feedback effect increases the profitability of a long position but does not affect the profitability of a short position, since abandonment would be undertaken in the absence of further information anyway. In both cases (for both  $\gamma < \frac{1}{2}$  and  $\gamma \geq \frac{1}{2}$ ), the intuition is the same: the feedback effect (weakly) increases the profitability of a long position and (weakly) decreases the profitability of short position, as discussed above.



Define new threshold levels of the cost of trading  $\kappa$ :

$$\kappa'_1 \equiv \frac{1}{3} \left[ \frac{1}{2} (R_H^n - R_L^n) + \frac{1-\lambda}{2-\lambda} (R_H^i - R_L^i) \right], \quad (11)$$

$$\kappa'_2 \equiv \frac{1}{3} \left( \frac{1}{2} + \frac{1-\lambda}{2-\lambda} \right) (R_H^n - R_L^n), \quad (12)$$

$$\kappa'_3 \equiv \frac{1}{3} (R_H^n - R_L^n), \quad \text{and} \quad (13)$$

$$\kappa'_2 < \kappa'_3, \quad \kappa'_2 < \kappa'_1. \quad (14)$$

The cutoff for the feedback effect to exist is also adjusted here. In some equilibria,  $\frac{1}{2-\lambda}$  represents the posterior probability of state  $H$  if  $X = 1$ . If  $\frac{1}{2-\lambda} > \gamma$ , the probability  $\lambda$  that the speculator is present is sufficiently high that an order flow of  $X = 1$  contains enough information to lead the manager to invest (as opposed to the default option of abandoning). Hence, there is feedback. If  $\frac{1}{2-\lambda} \leq \gamma$ , an order flow of  $X = 1$  is not informative enough to lead the manager to invest. This is the case where there is no feedback.

The following proposition provides the characterization of equilibrium outcomes.

**Proposition 2** (*Equilibrium, firm value is monotone in the state, investment is ex-ante undesirable*). *Suppose that  $R_H^n > R_L^n$  and  $\gamma \geq \frac{1}{2}$ , then the trading game has the following pure-strategy equilibria:*

*When  $\kappa < \kappa'_2$ , the only pure-strategy equilibrium is  $T$ .*

*When  $\kappa'_2 \leq \kappa < \kappa'_3$ : in the case of no feedback ( $\frac{1}{2-\lambda} \leq \gamma$ ), there are two pure-strategy equilibria,  $BNS$  and  $SNB$ ; in the case of feedback ( $\frac{1}{2-\lambda} > \gamma$ ), the  $BNS$  equilibrium always exists, whereas the  $SNB$  equilibrium exists only in the sub-range  $\kappa'_1 \leq \kappa < \kappa'_3$  or does not exist (if  $\kappa'_1 > \kappa'_3$ ).*

*When  $\kappa \geq \kappa'_3$ , the only pure-strategy equilibrium is  $NT$ .*

*That is, if and only if there is feedback ( $\frac{1}{2-\lambda} > \gamma$ ), there is a range of parameter values for which the  $BNS$  equilibrium exists but the  $SNB$  equilibrium does not exist. If  $\kappa'_1 > \kappa'_3$ , this range is  $\kappa'_2 \leq \kappa < \kappa'_3$ ; if  $\kappa'_1 < \kappa'_3$ , this range is  $\kappa'_2 \leq \kappa < \kappa'_1$ . There is no range of parameter values for which the  $SNB$  equilibrium exists but the  $BNS$  equilibrium does not exist.*

**Proof.** The proof repeats similar steps to those in the proof of Proposition 1, and is thus omitted for brevity. ■

In the case of  $\gamma < \frac{1}{2}$ , the role of the feedback effect can be seen in the  $BNS$  equilibrium: it reduces the profits that the negatively-informed speculator would earn by deviating and selling, and so the  $BNS$  equilibrium is sustainable over a wider range of parameters than the  $SNB$  equilibrium. Here, where  $\gamma \geq \frac{1}{2}$ , the feedback effect impacts the  $SNB$  equilibrium. Since buying improves firm value, the feedback effect increases the profit that the positively-informed speculator would earn by deviating and buying, and so the  $SNB$  equilibrium is sustainable over a narrower range of parameters than the  $BNS$  equilibrium (indeed, if  $\kappa'_1 > \kappa'_3$ , it is not

sustainable at all). In both cases (for  $\gamma < \frac{1}{2}$  and  $\gamma \geq \frac{1}{2}$ ), the end result is the same: the feedback effect (weakly) increases the profits from informed buying and (weakly) reduces the profits from informed selling, leading to the *BNS* equilibrium being sustainable over a wider range of transactions costs than the *SNB* equilibrium.

### 3.2 Case 2: Firm Value is Non-Monotone in the State: $R_H^n < R_L^n$

In this subsection, we consider the case where, if the firm does not invest, its value is higher in state  $\theta = L$  ( $R_H^n < R_L^n$ ). Hence, the corrective action is sufficiently powerful to outweigh the effect of the state on firm value and lead to a higher value in the low state. We start by characterizing equilibrium outcomes for the case where  $\gamma < \frac{1}{2}$ , i.e., without further information, the firm will choose to invest.

The analysis of equilibrium outcomes becomes more complicated in the case of non-monotonicity. In the previous subsection, where firm value is monotone in the state, a positively-informed speculator always loses money by selling and a negatively-informed speculator always loses money by buying, since firm value is always higher in state  $H$  than in state  $L$ . However, now that firm value may be higher in state  $L$ , a positively-informed speculator may find it optimal to sell and a negatively-informed speculator may find it optimal to buy. Hence, there are nine possible pure-strategy equilibria (each type of speculator – positively-informed and negatively-informed – may either buy, sell, or not trade). The following lemma simplifies the equilibrium analysis, moving us closer to the analysis conducted in the previous subsection.

**Lemma 1** *Suppose that  $R_H^n < R_L^n$  and  $\gamma < \frac{1}{2}$ , then:*

(i) *The trading game has no pure-strategy equilibrium where the speculator sells when she knows that  $\theta = H$ .*

(ii) *The trading game has no pure-strategy equilibrium where the speculator buys when she knows that  $\theta = L$ .*

**Proof.** (i) Suppose that the speculator sells when she knows that  $\theta = H$ : then  $X \in \{-2, -1, 0\}$  when  $\theta = H$ . In each one of these nodes, posterior probability  $q$  of state  $H$  is at least  $\frac{1}{2}$  (given that these nodes are consistent with the action of the positively-informed speculator and may or may not be consistent with the action of the negatively-informed speculator, depending on her equilibrium action). Then, since  $\gamma < \frac{1}{2}$ , investment will occur, and so firm value is  $R_H^i$ . The price, however, will be between  $R_L^i$  and  $R_H^i$ , and so the speculator makes a loss from selling.

(ii) Suppose that the speculator buys when she knows that  $\theta = L$ : then  $X \in \{0, 1, 2\}$  when  $\theta = L$ . Given that the positively-informed speculator does not sell, the posterior probability  $q$  is  $\frac{1}{2}$  at  $X \in \{0, 1\}$ . Hence, since  $\gamma < \frac{1}{2}$ , investment will occur, and so firm value is  $R_L^i$ . Since the price is  $\frac{1}{2}R_H^i + \frac{1}{2}R_L^i$ , the speculator will lose money on these nodes. When  $X = 2$ , there are two possibilities. If the positively-informed speculator buys in equilibrium, then the outcome is the same as on the other nodes. If she does not trade in equilibrium, then the negatively-informed

speculator is revealed, buying a security worth  $R_L^n$  for a price of  $R_L^n$ . Thus, in expectation she makes a loss, given she loses at  $X \in \{0, 1\}$ . ■

Following the lemma, there are four possible pure-strategy equilibria, just as in the previous subsection:  $NT$ ,  $T$ ,  $SNB$ , and  $BNS$ . However, the conditions for these equilibria to hold are now tighter. The reason that the positively-informed speculator never sells *in equilibrium* is that if the market maker and the manager believe that she sells, she cannot make a profit from selling. However, she still might be tempted to *deviate* to selling in any of the four equilibria mentioned above. When she sells, she potentially misleads the market maker and the manager to believe that the negatively-informed speculator is present, and so to abandon the investment. Since abandonment is suboptimal if  $\theta = H$ , this decision reduces firm value and causes the speculator to make a profit on her short position. Hence, for any of the above four equilibria to hold, an additional condition must be satisfied to ensure that the positively-informed speculator does not have an incentive to deviate to selling. Interestingly, the same issue does not arise with the negatively-informed speculator, as she never has an incentive to deviate to buying. If she does so, she misleads the market maker and the manager to believe that the positively-informed speculator is present, and so to (incorrectly) take the investment. Again, this decision reduces firm value, but because the speculator has a long position, she incurs a loss.<sup>6</sup>

In analyzing deviations from the equilibrium, another issue that arises in this subsection is the specification of off-equilibrium beliefs. In Case 1, due to monotonicity, the only assumption that satisfied the intuitive criterion was that an off-equilibrium order flow of  $X = 2$  is due to the positively-informed speculator (and so the posterior is  $q = 1$ ), while an off-equilibrium order flow of  $X = -2$  is due to the negatively-informed speculator (and so the posterior is  $q = 0$ ). In this subsection, however, the intuitive criterion is not sufficient to rule out other off-equilibrium beliefs. We nevertheless retain this assumption regarding off-equilibrium beliefs, which is reasonable given the possible equilibria in our model. Our results remain the same for any other off-equilibrium beliefs that are monotone in the order flow.<sup>7</sup>

The following proposition provides the characterization of equilibrium outcomes.

**Proposition 3** (*Equilibrium, firm value is non-monotone in the state, investment is ex-ante desirable*). *Suppose that  $R_H^n < R_L^n$  and  $\gamma < \frac{1}{2}$ , and suppose that the belief of the market maker and the manager is that an off-equilibrium order flow of  $X = -2$  ( $X = 2$ ) is associated with the presence of negatively-informed (positively-informed) speculator. Then, if  $\frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)}$  is sufficiently high (formally,  $\frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)} \geq \frac{3-\lambda}{3-2\lambda}$ ), the characterization of equilibrium outcomes is identical to that in Proposition 1.*

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<sup>6</sup>Goldstein and Guembel (2008) also derive conditions to ensure that the speculator does not deviate from the equilibrium to trade against her information.

<sup>7</sup>Other papers that use similar monotonicity assumptions for off-equilibrium beliefs include Gul and Sonnenschein (1988) and Bikhchandani (1992).

More specifically, the following **additional** conditions are required for the various equilibria to hold:

*Equilibrium NT and SNB:*  $\kappa \geq \frac{1}{3}(- (R_H^i - R_L^i) + (R_L^n - R_H^n))$ ;

*Equilibrium BNS:* in the case of feedback ( $\frac{1-\lambda}{2-\lambda} \leq \gamma$ ),  $\frac{6-3\lambda}{6-2\lambda} \frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)} \geq 1$ ; in the case of no feedback ( $\frac{1-\lambda}{2-\lambda} > \gamma$ ),  $\frac{8-3\lambda}{4-2\lambda} \frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)} \geq 1$ .

*Equilibrium T:* in the case of feedback ( $\frac{1-\lambda}{2-\lambda} \leq \gamma$ ),  $\frac{3-2\lambda}{3-\lambda} \frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)} \geq 1$ ; in the case of no feedback ( $\frac{1-\lambda}{2-\lambda} > \gamma$ ),  $2 \frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)} \geq 1$ .

The condition  $\frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)} \geq \frac{3-\lambda}{3-2\lambda}$  is sufficient for all of the above conditions to be satisfied.

**Proof.** The calculations of the posterior  $q$ , the manager's decision  $d$  and the price  $p$  for different order flows  $X$  in the various possible equilibria are identical to those provided in the proof of Proposition 1. Hence, the conditions for the positively-informed speculator to choose between buying and not trading and for the negatively-informed speculator to choose between selling and not trading are identical to those derived in the proof of Proposition 1. Analyzing the possible trading profits for the negatively-informed speculator from deviating to buying in each of the four possible equilibria, it is straightforward to see that she always loses from buying and hence will never deviate. Appendix A calculates the possible trading profits for the positively-informed speculator from deviating to selling in each of the four possible equilibria, which yields the additional conditions stated in the body of the proposition. These conditions are binding only when  $\frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)}$  is not sufficiently high. When  $\frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)} > \frac{3-\lambda}{3-2\lambda}$ , all the inequalities for the *BNS* and *T* equilibria are satisfied. In addition,  $\frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)} > \frac{3-\lambda}{3-2\lambda}$  implies  $\frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)} > 1$ ; thus, the RHS of  $\kappa > \frac{1}{3}(- (R_H^i - R_L^i) + (R_L^n - R_H^n))$  is negative and so the condition for the *NT* and *SNB* equilibria is automatically satisfied. ■

As the proposition demonstrates, the main force identified in the previous subsection for the case where  $R_H^n > R_L^n$ , exists also in the case where  $R_H^n < R_L^n$ . That is, the feedback effect deters the negatively-informed speculator, but not the positively-informed speculator, from trading on her information. In this subsection, this force is even stronger because the range of transaction costs  $\kappa$  between  $\kappa_1$  and  $\kappa_2$ , in which the *BNS* equilibrium exists due to feedback but the *SNB* equilibrium does not exist, is higher when  $(R_H^n - R_L^n)$  is negative: see equation (10). A strong feedback effect, in which correction not only mitigates the effect of the low state but also overturns it, implies that the negatively-informed speculator can make a loss – even before transaction costs – when selling on bad news. This result is in contrast to standard informed trading models where a speculator can never make a loss (before transactions costs) if she trades in the direction of her information. This loss occurs at the  $X = -1$  node; again, the key to this result is  $\lambda < 1$ . Even though both the speculator and market maker know that abandonment will occur if  $X = -1$ , they have differing views on firm value conditional on abandonment. The speculator knows that the corrective action will be taken, *and* that correction is desirable

for firm value (since she knows that  $\theta = L$ ), and so firm value is  $R_L^n$ . In contrast, the market maker knows the corrective action will be taken but is not certain that correction is desirable for firm value, because she is unsure of the underlying state  $\theta$ . Order flow  $X = -1$  is consistent with a negatively-informed speculator, but also with an absent speculator and selling by the noise trader. Hence, it is possible that  $\theta = H$ , in which case the manager's corrective action is undesirable, leading to firm value of  $R_H^n$ . Therefore, the price set by the market maker is only  $\frac{1-\lambda}{2-\lambda}R_H^n + \frac{1}{2-\lambda}R_L^n$ , since he puts weight on the possibility that correction may be undesirable, and so the speculator loses  $\frac{1-\lambda}{2-\lambda}(R_H^n - R_L^n)$  before transaction costs.

However, the proposition also shows that another force that arises from the feedback effect exists in this subsection, and that this force has implications on the characterization of equilibrium outcomes. This force is the desire of the positively-informed speculator to deviate from her equilibrium behavior and manipulate the price by selling, even though she has good news. She can potentially profit from leading the manager to take the wrong decision, which enables her to profit from her short position. The manipulation incentive is not strong enough to interfere with equilibrium conditions as long as  $\frac{(R_H^i - R_L^i)}{(R_L^n - R_H^n)}$  is sufficiently high. In this case, the loss from trading against good news (which is proportional to  $(R_H^i - R_L^i)$ ) is high relative to the benefit from manipulation (which is proportional to  $(R_L^n - R_H^n)$ ). Otherwise, there are additional conditions for the various possible equilibria, making it relatively more difficult to obtain the *BNS* equilibrium due to feedback.

Finally, we analyze the case where  $\gamma \geq \frac{1}{2}$ . It turns out that this case is the exact mirror image of the case where  $\gamma < \frac{1}{2}$ . Now, effectively,  $\theta = H$  represents bad news and  $\theta = L$  represents good news. This reversal occurs because the default decision is to abandon the investment; under this decision, firm value is lower in state  $H$  than in state  $L$ . Thus, the speculator now sells if  $\theta = H$  and buys if  $\theta = L$ . The next lemma is the mirror image of Lemma 1:

**Lemma 2** *Suppose that  $R_H^n < R_L^n$  and  $\gamma \geq \frac{1}{2}$ , then:*

(i) *The trading game has no pure-strategy equilibrium where the speculator sells when she knows that  $\theta = L$ .*

(ii) *The trading game has no pure-strategy equilibrium where the speculator buys when she knows that  $\theta = H$ .*

**Proof.** The proof is symmetric to the proof of Lemma 1 and hence is not repeated here. ■

Hence, the possible pure-strategy equilibria here are:

1. No Trade Equilibrium *NT*: the speculator does not trade,
2. Trade Equilibrium *T'*: the speculator buys when she knows that  $\theta = L$  and sells when she knows that  $\theta = H$ ,
3. Partial Trade Equilibrium *BNS'* (Buy - Not Sell): the speculator buys when she knows that  $\theta = L$  and does not trade when she knows that  $\theta = H$ .

4. Partial Trade Equilibrium  $SNB'$  (Sell - Not Buy): the speculator does not trade when she knows that  $\theta = L$  and sells when she knows that  $\theta = H$ .

The characterization of equilibrium outcomes in the following proposition is symmetric to that in Proposition 3:

**Proposition 4** (*Equilibrium, firm value is non-monotone in the state, investment is ex-ante undesirable*). Suppose that  $R_H^n < R_L^n$  and  $\gamma \geq \frac{1}{2}$ , and suppose that the belief of the market maker and the manager is that an off-equilibrium order flow of  $X = -2$  ( $X = 2$ ) is associated with the positively-informed (negatively-informed) speculator. Then, the characterization of equilibrium outcomes is symmetric to that in Proposition 3: parameters  $R_H^i, R_L^i, R_H^n, R_L^n$  are replaced with parameters  $R_L^n, R_H^n, R_L^i, R_H^i$ , respectively, and equilibria  $T, BNS, SNB$  are replaced with equilibria  $T', BNS', SNB'$ , respectively.

**Proof.** The proof is symmetric to the proof of Proposition 3 and hence is not repeated here.

■

Overall, the result is identical to that of the case of  $\gamma < \frac{1}{2}$ . Due to feedback, the speculator is deterred from selling when she has bad news, but not from buying when she has good news. The only difference is that now, bad news entails  $\theta = H$  and good news entails  $\theta = L$ .

In Case 1 ( $R_H^n > R_L^n$ ), for the sub-case of  $\gamma \geq \frac{1}{2}$ , the role of the feedback effect is seen in the  $SNB$  equilibrium: the feedback effect increases the profits that the speculator who observes  $\theta = H$  would earn by deviating to buying, and so the  $SNB$  is sustainable over a narrower range of parameters. In the current scenario of  $\gamma \geq \frac{1}{2}$  within Case 2 ( $R_H^n < R_L^n$ ), just as in the scenario of  $\gamma < \frac{1}{2}$  (for both Case 1 and Case 2), the role of the feedback effect is seen in the  $BNS/BNS'$  equilibrium: it deters the speculator from deviating to sell on bad news ( $\theta = H$  in this case).

### 3.3 Summary and Discussion of Model Assumptions

The above analysis has shown that the feedback effect discourages speculators from selling on bad news, but encourages them to buy on good news. Several key features are important for our mechanism to arise. In this section, we discuss them, and so highlight the conditions under which the asymmetric limit to arbitrage likely exists in the real world.

First, trading in the market has to convey sufficient information to influence the manager's decision. For example, consider the result in Proposition 1: for the asymmetry to arise, we require  $\frac{1-\lambda}{2-\lambda} \leq \gamma$ . Hence, it is important that the probability  $\lambda$  that the speculator is present is sufficiently high so that the order flow is sufficiently informative to change managerial decisions. In turn,  $\frac{1-\lambda}{2-\lambda} \leq \gamma$  is more likely to be satisfied the closer  $\gamma$  is to  $\frac{1}{2}$ , i.e. the closer the NPV of the project is to 0. When  $\gamma$  is close to  $\frac{1}{2}$ , the desirability of the investment is sufficiently uncertain that the manager's decision will be influenced by the trading in the financial market. If  $\gamma$  is very low, the ex-ante NPV of the project is so high that the manager will almost always undertake

the investment, regardless of order flow. The extent to which the manager will change his decision in response to trading will also depend on additional factors outside the model. If the investment is difficult to reverse (e.g., an M&A deal in which there is a formal merger agreement or a termination fee, or an irreversible physical investment), or the manager is less likely to reverse it due to agency problems (e.g., weak governance allows him to pursue negative-NPV investment to maximize his private benefits), the feedback effect from financial markets to the real economy will be lower and so the limit to arbitrage will be weaker.

Hewlett Packard's (HP) acquisition of Compaq illustrates the circumstances under which the feedback effect arises. HP's stock price fell 19% upon announcement on September 4, 2001. That HP's CEO conveyed the unanimous support of its high-profile board for the deal contributed to the magnitude of the decline, as traders did not fear that their selling would lead to the deal being canceled. To everyone's surprise, Walter Hewlett, who earlier voted in favor of the deal as a board member, announced opposition to the merger on behalf of the Hewlett Foundation in the wake of the stock price drop. As a chairman of the second-largest shareholder and the son of the company's founder, he posed a credible threat to the consummation of the deal. Shares of HP rose 17% in response, suggesting that the speculators would not have sold so aggressively had they known that the negative price impact could trigger an attempt at a corrective action. The combination of rational investor expectation at the time of deal announcement and the expectation being ex post incorrect (due to the unexpected behavior of Walter Hewlett) offers a unique opportunity to observe the feedback effect.

Second, another important assumption is that  $\lambda < 1$ , so there is uncertainty on whether there is an informed speculator in the market. To see this, note that the feedback effect only affects trading profits for the nodes of  $X = \{-1, 1\}$ : if  $X = \{-2, 2\}$ , the speculator is fully revealed and makes no profit; if  $X = 0$ , there is no feedback effect as the price is uninformative. (Thus, for  $X = 0$ , the profits from informed buying equal the profits from informed selling and there is no asymmetry.) In turn,  $\lambda < 1$  is necessary for the speculator not to be fully revealed at  $X = \{-1, 1\}$  and thus for trading profits to be non-zero. For example, consider the market maker's inference from seeing  $X = -1$  for the case in which investment is ex-ante optimal ( $\gamma < \frac{1}{2}$ ). This order flow is consistent with either the speculator being absent (in which case the state may be  $H$  or  $L$ ), or the speculator being present and negatively informed. If  $\lambda = 1$ , the first case is ruled out, and so the market maker knows for certain that  $\theta = L$ . Thus,  $X = -1$  is fully revealing: the market maker knows *both* that correction will occur, *and* that the state is  $L$ , and so sets the price exactly equal to the fundamental value of  $R_L^n$ . The speculator's profits are zero, and thus automatically unaffected by the manager's decision and the feedback effect. Indeed, if  $\lambda = 1$ , then  $\kappa_1 = \kappa_2$  and there is no range of parameter values in which there is a *BNS* equilibrium but no *SNB* equilibrium.

By contrast, if  $\lambda < 1$ , the market maker predicts the manager's action but does not know the state. Since  $X = -1$  can be consistent with the speculator being absent and the state being  $H$ , the market maker allows for the possibility that  $\theta = H$  and sets a price of  $\frac{1-\lambda}{2-\lambda}R_H^d +$

$\frac{1}{2-\lambda}R_L^d$ . Because the speculator knows the state in addition to the action, she makes a profit of  $\frac{1-\lambda}{2-\lambda}(R_H^d - R_L^d)$ . This profit is non-zero and depends on the decision  $d$  and thus the feedback effect, because the action affects the value of the speculator's superior knowledge on the state. We would achieve the same result by instead assuming that the speculator is always present and informed, but can only trade with probability  $\lambda$  – for example, if with probability  $1 - \lambda$  she receives a liquidity shock that prevents her from trading.<sup>8</sup>

Third, the reason that the speculator loses from increasing the firm's value is that she ends up with a short position. Hence, it is important that the speculator short sells rather than just sells stocks she previously owned, which in turn requires the speculator's initial position to be zero (or, at least, less than the amount sold) and short-sales to be possible. Thus, the model delivers the result that investors are more likely to engage in sales rather than short-sales, even in the absence of a short-sales constraint. However, if the speculator maximizes returns relative to other speculators or market indices rather than absolute returns (e.g., she is a mutual fund benchmarked against the performance of other mutual funds), then our limit to arbitrage may exist even if her initial position is strictly positive. For example, if she sells half of her portfolio, she increases the value of the remaining half, but increases the value of the entire portfolio held by her competitors, and so loses in relative terms if her final position is smaller than her rivals' (unchanged) positions.

Fourth, the real decision is a corrective action in that it improves firm value in the low state. This case prevails when the decision maker maximizes firm value. This is a natural assumption if the decision maker is the firm's manager who attempts to maximize firm value via an investment decision; other potential applications include a board of directors firing of an underperforming manager in the bad state or an outside blockholder engaging in activism to restore shareholder value. The model does not apply to amplifying actions, where the decision maker's objective is something other than firm value, and maximizing this objective leads him to worsen firm value in the low state. For example, capital providers may withdraw their investment in the low state, reducing firm value further (as in Goldstein, Ozdenoren, and Yuan (2011)), or customers or employees could terminate their relationship with a troubled firm (Subrahmanyam and Titman (2001)). In a model with amplifying actions, the speculator will no longer be reluctant to sell on bad news, since the information will reduce firm value further, enabling her to profit more on her short position.

Fifth, the asymmetry in trading due to the feedback effect requires that the trading cost is not too small (e.g.,  $\kappa \geq \kappa_1$  in Proposition 1). Given that the trading cost in our model captures direct (commissions and fees) as well as indirect (borrowing or opportunity) costs, it should be significant even in a well-developed financial market. Hence, such high trading costs are realistic. A more subtle issue is that sometime the trading cost is in fact not necessary for deterring the negatively-informed trader from trading. Recall that the negatively-informed

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<sup>8</sup>An alternative assumption would be that the speculator is always present, but sometimes she is uninformed. This, however, may introduce other complications, as the uninformed speculator may choose to trade to manipulate the price and the firm's decision, as in Goldstein and Guembel (2008).



speculator’s profit can be negative (as in Proposition 2), and therefore she would refrain from trading even if the trading cost is zero. However, if the trading cost is too low then another trading motive, manipulative short-selling by the positively-informed speculator, would arise. As a result we need a strictly positive trading cost only to rule out the manipulation equilibrium. The latter is studied in Goldstein and Guembel (2008), and is not the focus of our model.

Several other assumptions are made only for tractability and can be substantially weakened at the cost of complicating the model with little additional insight. The first such assumption is that the manager has no signal and the speculator has a perfect signal about the state of nature  $\theta$ . All that is required for our results to go through is that the speculator has some decision-relevant information that the manager does not have – it is not even necessary that the speculator be more informed than the manager.<sup>9</sup> Another non-critical assumption is discrete trading volumes (i.e., the speculator cannot trade an amount between 0 and 1). The results will likely continue to hold with continuous trading volumes. The speculator may be able to sell a small amount (rather than zero) on negative information without significantly increasing the probability of correction, but she will buy a greater amount upon good information and so the asymmetry remains. Finally, while we assume that there is only one speculator, the results will likely continue to hold in a model with multiple speculators as long as each of them is large enough to have an effect on the total order flow (and hence on the firm’s decision).

## 4 Effect of Information on Beliefs and Prices

The previous section demonstrated that the feedback effect gives rise to an equilibrium in which a speculator buys on good news and does not trade on bad news. In this section, we study the implications of this equilibrium. The analysis that follows focuses on the *BNS* equilibrium in which investment is ex-ante desirable ( $\gamma < \frac{1}{2}$ ) and there is feedback ( $\frac{1-\lambda}{2-\lambda} \leq \gamma$ ), and considers both Case 1 and Case 2 together. Section 4.1 calculates the effect of good and bad news about the state on the posterior beliefs  $q$ , in order to study the extent to which information reaches the manager and affects real decisions. Section 4.2 analyzes the impact of news on prices to generate stock return predictions.

### 4.1 Beliefs

Since the manager uses the posterior belief  $q$  to guide his investment decision, we can interpret  $q$  as measuring the extent to which information reaches the manager and affects his actions. In

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<sup>9</sup>For example, assume that the optimal decision  $d$  depends on both an internal state variable  $\theta_i$  about the firm, and an external state variable  $\theta_e$  about the industry’s future prospects. Assume also that the manager has a perfect signal about  $\theta_i$  and the speculator is completely uninformed about  $\theta_i$ . In addition, the manager has a noisy signal about  $\theta_e$  and the speculator has a less precise signal about  $\theta_e$  which is uncorrelated with the manager’s signal. Even though the manager is more informed than the speculator about both  $\theta_i$  and  $\theta_e$ , his decision will still be influenced by market prices as the speculator’s information about  $\theta_e$  is incremental and relevant for his decision.

a world in which no agent observes the state, or in which the manager does not learn from prices or order flows, the posterior  $q$  would equal the prior  $y = \frac{1}{2}$ . Conversely, in a world of perfect information transmission,  $q = 1$  if  $\theta = H$  and  $q = 0$  if  $\theta = L$ . Our model, in which information is partially revealed through prices, lies in between these two polar cases. The absolute distance between  $q$  and  $\frac{1}{2}$  measures the extent to which information reaches the manager.

Thus far, we have shown that good news received by the speculator has a different impact on her trades (and thus the total order flow) than bad news. However, it is not obvious that this difference will translate into a differential impact on the manager's beliefs. The manager is rational and takes into account the fact that the speculator does not sell on negative information: he updates his beliefs using the asymmetric equilibrium trading strategy. In the *BNS* equilibrium in the proof of Proposition 1, the manager recognizes that  $X = 1$  could be consistent with a negatively-informed speculator who chooses not to trade, and so  $q(1)$  is no higher than  $q(0)$  (where  $q(X)$  denotes the posterior at  $t = 1$  upon observing order flow  $X$ ). Thus, even though bad news can lead to a positive order flow of  $X = 1$ , the manager knows that such an order flow can stem from a negatively-informed and non-trading speculator, and will decrease his posterior accordingly. Put differently, although negative information does not cause a negative order flow (on average), it can still have a negative effect on beliefs and be fully conveyed to the manager. Thus, it may still seem possible for good and bad news to be conveyed symmetrically to the manager – by taking into account the speculator's asymmetric trading strategy, he can “undo” the asymmetry. Indeed, we start by showing that, if we do not condition on the presence of the speculator, the effects on beliefs of the high and low states being realized are symmetric. This is a direct consequence of the law of iterated expectations: the expected posterior must equal the prior.

**Lemma 3** *Consider the BNS equilibrium where  $\gamma < \frac{1}{2}$  and  $\frac{1-\lambda}{2-\lambda} \leq \gamma$  (i.e., there is feedback). (i) If  $\theta = H$ , the manager's expected posterior probability of the high state is  $q^H = \frac{(1-\lambda)^2}{6-3\lambda} + \frac{1}{3} + \frac{\lambda}{3}$  and is increasing in  $\lambda$ . (ii) If  $\theta = L$ , the manager's expected posterior probability of the high state is  $q^L = \frac{1-\lambda}{6-3\lambda} + \frac{1}{3}$  and is decreasing in  $\lambda$ . (iii) We have  $\frac{q^H + q^L}{2} = \frac{1}{2}$ : thus, the realization of state  $H$  has the same absolute impact on beliefs as the realization of state  $L$ .*

**Proof.** See Appendix A. ■

Of greater interest is to study the effect of the state realization conditional upon the speculator being present. We use the term “good news” to refer to  $\theta = H$  being realized and the speculator being present, since in this case there is an agent in the economy who directly receives news on the state; “bad news” is defined analogously. While the above analysis studied the effect of the state being realized (regardless of whether the state is learned by any agent in the economy), this analysis studies the impact of the speculator receiving information about the state. The goal is to investigate the extent to which the speculator's good and bad news is conveyed to the manager at  $t = 1$ . The results are given in Proposition 5 below:

**Proposition 5** (*Asymmetric effect of good and bad news on beliefs at  $t = 1$ .*) Consider the BNS equilibrium where  $\gamma < \frac{1}{2}$  and  $\frac{1-\lambda}{2-\lambda} \leq \gamma$  (i.e., there is feedback). (i) If  $\theta = H$  and the speculator is present, the manager's expected posterior probability of the high state is  $q^{H,spec} = \frac{2}{3}$  and is independent of  $\lambda$ . (ii) If  $\theta = L$  and the speculator is present, the manager's expected posterior probability of the high state is  $q^{L,spec} = \frac{1-\lambda}{6-3\lambda} + \frac{1}{3}$  and is decreasing in  $\lambda$ . (iii) We have

$$\frac{q^{H,spec} + q^{L,spec}}{2} = \frac{1 + \frac{1-\lambda}{6-3\lambda}}{2}, \quad (15)$$

which is decreasing in  $\lambda$ . Since  $\frac{1 + \frac{1-\lambda}{6-3\lambda}}{2} > \frac{1}{2}$ , (15) implies that  $\text{abs}(q^{H,spec} - y) - \text{abs}(q^{L,spec} - y) > 0$ , i.e. the absolute increase in the manager's posterior if the speculator receives good news exceeds the absolute decrease in his posterior if the speculator receives bad news. The difference is decreasing in  $\lambda$ .

**Proof.** See Appendix A. ■

Proposition 5 shows that, conditional upon the speculator being present, the impact on beliefs of good news is greater in absolute terms than the impact of bad news, and the asymmetry is monotonically decreasing in the frequency of the speculator's presence  $\lambda$ . Even though the manager takes the speculator's asymmetric trading strategy into account, he cannot distinguish the case of a negatively-informed (and non-trading) speculator from that of an absent speculator (i.e. no information) – both of these cases lead to the order flow being  $\{-1, 0, 1\}$  with uniform probability. Thus, negative information has a smaller effect on his belief. By contrast, if the speculator is always present ( $\lambda = 1$ ), the manager has no such inference problem and there is no asymmetry.

The above analysis considered the change in the manager's posterior at  $t = 1$ . At  $t = 2$ , the state is realized and the posterior becomes either 1 (if  $\theta = H$ ) or 0 (if  $\theta = L$ ). Since bad news is conveyed to the manager to a lesser extent at  $t = 1$ , it seeps out to a greater extent ex post, between  $t = 1$  and  $t = 2$ . Thus, bad news causes a greater change in the posterior between  $t = 1$  and  $t = 2$  than good news. This result is stated in Corollary 1 below:

**Corollary 1** (*Asymmetric effect of high and low state realization on beliefs at  $t = 2$ .*) Consider the BNS equilibrium where  $\gamma < \frac{1}{2}$  and  $\frac{1-\lambda}{2-\lambda} \leq \gamma$  (i.e., there is feedback). The absolute impact on beliefs between  $t = 1$  and  $t = 2$  of the realization of the state is greater for the low state  $\theta = L$  than for the high state  $\theta = H$ , i.e.

$$\text{abs}(0 - q^{L,spec}) - \text{abs}(1 - q^{H,spec}) > 0.$$

The asymmetry is monotonically decreasing in the frequency of the speculator's presence  $\lambda$ .

**Proof.** Follows from simple calculations ■

The smaller effect of bad news on the posterior at  $t = 1$  is counterbalanced by its larger effect at  $t = 2$ . As we will show in Section 4.2, surprisingly this result need not hold when we examine the effect of news on prices rather than posteriors.

## 4.2 Stock Returns

We now calculate the impact of the state realization and news on prices, in order to generate stock return implications. We study short-run stock returns between  $t = 0$  and  $t = 1$ , and long-run drift between  $t = 1$  and  $t = 2$ . While this analysis is similar to Section 4.1 but studying prices rather than beliefs, we will show that not all the results remain the same.

### 4.2.1 Short-Run Stock Returns

Lemma 4 is analogous to Lemma 3 and shows that, unconditionally, the good and bad states have the same absolute impact on prices, since the market maker takes the speculator's asymmetric trading strategy into account when devising his pricing function. Let  $p_0$  denote the “ex ante” stock price at  $t = 0$ , before the state has been realized.

**Lemma 4** *Consider the BNS equilibrium where  $\gamma < \frac{1}{2}$  and  $\frac{1-\lambda}{2-\lambda} \leq \gamma$  (i.e., there is feedback):*

- (i) *The stock price impact of the high state being realized is  $p_1^H - p_0 = \frac{\lambda}{6} [p(2) - p(-1)] > 0$ .*
- (ii) *The stock price impact of the low state being realized is  $p_1^L - p_0 = \frac{\lambda}{6} [p(-1) - p(2)] = -(p_1^H - p_0) < 0$ .*

**Proof.** See Appendix A. ■

We have  $p_1^H - p_0 = -(p_1^L - p_0)$ : the negative effect of the low state equals the positive effect of the high state. Thus, the unconditional expected return is zero. This is an inevitable consequence of market efficiency. The price at  $t = 0$  is an unbiased expectation of the  $t = 1$  expected price in the high state and the  $t = 1$  expected price in the low state. Since both states are equally likely, the absolute effect of the high state must equal the absolute effect of the low state. An uninformed investor cannot trade the stock at  $t = 0$  and expect a non-zero average return at  $t = 1$ .

Proposition 6 is analogous to Proposition 5 and shows that, conditional on the speculator being present, good news has a greater effect than bad news:

**Proposition 6** *(Asymmetric effect of good and bad news on returns between  $t = 0$  and  $t = 1$ .) Consider the BNS equilibrium where  $\gamma < \frac{1}{2}$  and  $\frac{1-\lambda}{2-\lambda} \leq \gamma$  (i.e., there is feedback):*

- (i) *If  $\theta = H$  and the speculator is present, the average return between  $t = 0$  and  $t = 1$  is  $p_1^{H,spec} - p_0 = \frac{1}{3} (1 - \frac{\lambda}{2}) (p(2) - p(-1)) > 0$ .*
- (ii) *If  $\theta = L$  and the speculator is present, the average return between  $t = 0$  and  $t = 1$  is  $p_1^{L,spec} - p_0 = \frac{\lambda}{6} (p(-1) - p(2)) < 0$ .*

(iii) The difference in the absolute average returns between the speculator learning  $\theta = H$  and  $\theta = L$  is given by:

$$\text{abs} \left( p_1^{H,spec} - p_0 \right) - \text{abs} \left( p_1^{L,spec} - p_0 \right) = \frac{1}{3} (1 - \lambda) (p(2) - p(-1)) > 0, \quad (16)$$

i.e. the stock price increase upon good news exceeds the stock price decrease upon bad news. This difference is decreasing in  $\lambda$ .

(iv) The average return, conditional on the speculator being present, is positive:

$$p_1^{spec} - p_0 = \frac{1}{3} \frac{1 - \lambda}{2} (p(2) - p(-1)) > 0. \quad (17)$$

This difference is decreasing in  $\lambda$ .

**Proof.** See Appendix A. ■

Proposition 6 states that the average return, *conditional* on the speculator being present, is positive – i.e., the stock price increase upon positive information exceeds the stock price decrease upon negative information (part (iii)). Put differently, positive news is impounded into prices to a greater degree than negative information, as found by Hong, Lim, and Stein (2000). Since good and bad news are equally likely, this means that the average return, conditional on the speculator being present, is positive (part (iv)). As with Proposition 5, the key to this result is that, even though the market maker is rational, he is unable to distinguish the case of a negatively-informed speculator from that of an absent speculator (i.e., no information). If  $\lambda = 1$ , equations (16) and (17) become zero and there is no asymmetry; the asymmetry is monotonically decreasing in  $\lambda$ . Note that the positive average return given in part (iv) is not inconsistent with market efficiency, because it is conditional upon the speculator being present, which is private information. An uninformed investor cannot buy the stock at  $t = 0$  and expect to earn a positive return at  $t = 1$  because she will not know whether the speculator is present.

#### 4.2.2 Long-Run Drift

We now move from short-run returns to calculating the long-run drift of the stock price, to analyze the stock return analog of Corollary 1, i.e., the impact of the state realization on prices between  $t = 1$  and  $t = 2$ .

**Corollary 2** (*Asymmetric effect of good and bad news on returns between  $t = 1$  and  $t = 2$ ). Consider the BNS equilibrium where  $\gamma < \frac{1}{2}$  and  $\frac{1-\lambda}{2-\lambda} \leq \gamma$  (i.e., there is feedback):*

(i) If  $\theta = H$  and the speculator is present, the average return between  $t = 1$  and  $t = 2$  is  $p_2^{H,spec} - p_1^{H,spec} = \frac{1}{3} (R_H^i - R_L^i) > 0$ .

(ii) If  $\theta = L$  and the speculator is present, the average return between  $t = 1$  and  $t = 2$  is

$$p_2^{L,spec} - p_1^{L,spec} = -\frac{1}{3} (R_H^i - R_L^i) - \frac{1}{3} \left( \frac{1 - \lambda}{2 - \lambda} (R_H^n - R_L^n) \right), \quad (18)$$

which is negative in Case 1, but can be positive or negative in Case 2.

(iii) If (18) < 0, the difference in the absolute average returns between the speculator learning  $\theta = H$  and  $\theta = L$  is given by:

$$\text{abs} \left( p_2^{H,spec} - p_1^{H,spec} \right) - \text{abs} \left( p_2^{L,spec} - p_1^{L,spec} \right) = \frac{1}{3} \left( \frac{1-\lambda}{2-\lambda} (R_L^n - R_H^n) \right),$$

which is positive in Case 2 and negative in Case 1. The magnitude of the difference is decreasing in  $\lambda$ .

(iv) Expected firm value at  $t = 2$ , conditional upon the speculator being present, is:

$$p_2^{spec} = \frac{1}{2}R_H^i + \frac{1}{3}R_L^i + \frac{1}{6}R_L^n,$$

and the average return between  $t = 1$  and  $t = 2$  if the speculator is present is:

$$p_2^{spec} - p_1^{spec} = \frac{1}{6} \frac{1-\lambda}{2-\lambda} (R_L^n - R_H^n),$$

which is positive in Case 2 and negative in Case 1. The magnitude of the difference is decreasing in  $\lambda$ .

**Proof.** See Appendix A. ■

Corollary 1 showed that the smaller effect of bad news on beliefs at  $t = 1$  is counterbalanced by a larger effect on beliefs at  $t = 2$ , and so the average increase in beliefs in the short-run is reversed by an average decrease in beliefs in the long-run. Corollary 2 shows that this need not be the case for returns: it is possible for bad news to have a smaller effect than good news at both  $t = 1$  and  $t = 2$ , and so the speculator's presence can lead to positive average returns in both the short-run and long-run.

The above result arises because the stock price depends not only on beliefs about the state, but also the manager's action. Thus, there is an additional effect of the speculator on prices that does not exist in the analysis of beliefs: not only does she convey information about the state, but also this information affects the manager's decision. In Case 2 ( $R_H^n < R_L^n$ ), this feedback effect is sufficiently strong to turn the average return between  $t = 1$  and  $t = 2$  positive. In state  $L$ , little bad news emerges in the short-run, meaning there is more to come out in the long-run; this in turn leads to the large downward revision in beliefs in Corollary 1. However, the effect on prices in Corollary 2 is muted because the damage to firm value caused by state  $L$  can be mitigated by taking the corrective action. Thus, the negative effect of bad news is smaller than the positive effect of good news in the long-run as well as short-run. This result contrasts with underreaction models where, if bad news has a smaller effect on short-run returns than good news, it must be counterbalanced by a larger long-run drift. Indeed, if the feedback effect is sufficiently strong, i.e.  $R_L^n$  is much higher than  $R_H^n$ , the return to bad news between  $t = 1$  and  $t = 2$  can be positive ((18) > 0). By contrast, in Case 1 ( $R_H^n > R_L^n$ ), the long-run drift to the

low state is larger in magnitude, analogous to Corollary 1. Since state  $L$  is bad for firm value regardless of whether the manager takes the corrective action or not, the realization of state  $L$  at  $t = 2$  leads to a large decrease in the price. Thus, prices are too high at  $t = 1$ . Miller (1977) similarly shows that prices are too high if bad news is not traded upon. However, in his model, the lack of trading on bad news results from exogenous short-sales constraints; here, the reluctance to short-sell is generated endogenously.

The analysis thus far has considered the impact of news on prices. We now consider the impact of investment (a real variable) on prices; specifically, the extent to which it is impounded into prices at  $t = 1$  or at  $t = 2$ . While Section 4.2.1 showed that good news received by the speculator has a greater price impact than bad news in the short run (at  $t = 1$ ), Proposition 7 now demonstrates a related result: the proportion of the total returns to an investment that is realized in the short-run (at  $t = 1$ ) rather than the long-run (at  $t = 2$ ) is greater for a good investment ( $\theta = H$ ) than a bad investment ( $\theta = L$ ). In other words, the price impact of a good investment is more front-loaded than for a bad investment.

**Proposition 7** (*Faster incorporation into prices of good investment than bad investment.*)  
*Consider the BNS equilibrium where  $\gamma < \frac{1}{2}$  and  $\frac{1-\lambda}{2-\lambda} \leq \gamma$  (i.e., there is feedback):*

(i) *If investment is undertaken in state H:*

(ia) *The average return between  $t = 0$  and  $t = 1$  is*

$$p_1^{i,H} - p_0 = \frac{1}{6(2+\lambda)} [(2+2\lambda-\lambda^2)R_H^i + (2-2\lambda)R_L^i - (2-\lambda-\lambda^2)R_H^n - (2+\lambda)R_L^n] > 0. \quad (19)$$

(ib) *The average return between  $t = 1$  and  $t = 2$  is*

$$R_H^i - p_1^{i,H} = \frac{R_H^i - R_L^i}{2+\lambda} > 0. \quad (20)$$

(ii) *If investment is undertaken in state L:*

(iia) *The average return between  $t = 0$  and  $t = 1$  is*

$$\frac{1}{6} [(1-\lambda)(R_H^i - R_H^n) + R_L^i - R_L^n] < 0. \quad (21)$$

(iib) *The average return between  $t = 1$  and  $t = 2$  is*

$$R_L^i - p_1^{i,H} = -\frac{1}{2}(R_H^i - R_L^i) < 0. \quad (22)$$

(iii) *The returns to a good investment manifest more rapidly (i.e., to a greater degree at  $t = 1$ ) than the returns to a bad investment, i.e.,  $\text{abs}((22) - (21)) > \text{abs}((20) - (19))$ .*

**Proof.** See Appendix A. ■

Parts (i) and (ii) of Proposition 7 show that investing in the high state leads to both positive short-run returns between  $t = 0$  and  $t = 1$  and positive long-run drift between  $t = 1$

and  $t = 2$ . Investing in the low state leads to negative short-run returns and negative long-run drift. Part (iii) demonstrates that the returns to a good investment are realized to a greater extent at  $t = 1$  rather than  $t = 2$ , compared to a bad investment. Thus, the returns to a good investment manifest more rapidly than the returns to a bad investment, i.e., are more front-loaded. To our knowledge, this prediction has not yet been tested. Note that the long-run drift is conditional upon the quality of investment which is only known to uninformed investors ex post at  $t = 2$ . Thus, there is no profit opportunity for an uninformed investor, consistent with market efficiency.

The intuition behind the asymmetry is different from Proposition 6. In both Propositions 6 and 7, the asymmetry occurs because the low state has a lesser impact on prices than the high state. In Proposition 6, this difference arises from the fact that  $\lambda < 1$ , which means that the market maker cannot distinguish the case of a negatively-informed speculator from the absence of a speculator. Here, the intuition is as follows. If the investment is bad, the negative returns cannot manifest too strongly at  $t = 1$ , otherwise the decline in the stock price will have led to the investment being canceled. Thus, the negative returns must manifest predominantly at  $t = 2$ . Put differently, there are bad investments that do not lead to a sharply negative reaction at  $t = 1$  because the speculator did not trade on the bad news. Instead, the value-destructiveness of the investment seeps out ex post. Note that the long-term drift in returns does not violate market efficiency. The key to reconciling this result with market efficiency is that firm value is endogenous to trading. If the speculator sold aggressively in response to a bad investment, the decline in the stock price will lead to the investment being canceled. The market is not strong-form efficient in the Fama (1970) sense, since the speculator's private information is not incorporated into prices, but is strong-form efficient in the Jensen (1978) sense as the speculator cannot make profits on her information, due to the feedback effect. Since she does not trade on her information, the negative returns must manifest predominantly at  $t = 2$ .

## 5 Conclusion

This paper has modeled a limit to arbitrage that stems from the fact that firm value is endogenous to the act of exploiting the arbitrage. Even if a speculator has negative information on the state, she may strategically refrain from trading on it, because doing so conveys her information to the manager. The manager may then take a corrective action that improves firm value but reduces the profits from her short position below the cost of trading, and sometimes causes her to realize a loss. There are several important differences between the feedback-driven limit to arbitrage that we study, and the limits to arbitrage identified by prior literature. First, the effect is asymmetric. Trading in either direction impounds information into prices, which improves the manager's decision-making and increases fundamental value. This feedback effect increases the profitability of a long position but reduces the profitability of a short position, thus encouraging buying on good news but discouraging selling on bad news. Second, the effect



does not rely on exogenous forces or agency problems, but is instead generated endogenously as part of the arbitrage process. Thus, even if speculators have perfect private information and no wealth constraints or trading restrictions, they may choose not to trade on their information.

The asymmetry of our effect has implications for both stock returns and real investment. In terms of stock returns, bad news has a smaller effect on short-run prices than good news, even though the market maker is rational and takes the speculator's trading strategy into account when devising his pricing function. Interestingly, in contrast to underreaction models, the smaller short-run reaction to bad news may also coincide with smaller long-run drift, since the manager can take a corrective action to attenuate the negative effect of the state on firm value. In terms of real investment, the manager may overinvest in negative-NPV projects, even though there are no agency problems and he is attempting to learn from the market to take the efficient decision. Even though there is an agent in the economy who knows with certainty that the investment is undesirable, and the manager is aware of the speculator's asymmetric trading strategy, this information is not conveyed to the manager and so the project is not abandoned.

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