The Price Impact of Institutional Herding*

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Abstract

In this paper we develop a simple theoretical model to analyze the impact of institutional herding on asset prices. In our model, career-concerned money managers interact with profit-motivated proprietary traders and security dealers endowed with market power. The interaction between these three classes of traders generates rich implications. First, we show that the reputational concerns of fund managers imply an endogenous tendency to imitate past trades, which, in turn, impacts the prices of the assets they trade. Second, our model predicts a negative correlation between institutional herding and long-term returns. We show that, in markets dominated by fund managers, assets persistently bought (sold) by fund managers trade at prices that are too high (low) and thus experience negative (positive) long-term returns, after uncertainty is resolved. Third, our model can generate a positive correlation between institutional herding and short-term returns. Our theory thus provides a simple and unified framework within which to interpret the empirical literature on the price impact of institutional herding. In addition, our paper generates several new testable predictions linking institutional herding behavior, contractual incentives, trading volume, and prices.

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1 Introduction

Professional money managers are the majority owners and traders of equity in today's markets. Leading market observers commonly allege that money managers "herd" and that such herding destabilizes markets and distorts prices. For example, Jean-Claude Trichet, President of the European Central Bank, commented on the incentives and behavior of fund managers as follows: "Some operators have come to the conclusion that it is better to be wrong along with everybody else, rather than take the risk of being right, or wrong, alone... By its nature, trend following amplifies the imbalance that may at some point affect a market, potentially leading to vicious circles of price adjustments and liquidation of positions."[1]

There is extensive empirical evidence of herding behavior among institutional investors (i.e., money managers tend to trade excessively in the direction of the recent trades of other managers).[2] However, the literature has reached less clear conclusions regarding the impact of institutional herding behavior on stock prices. Studies examining the short-term impact of institutional trade generally find that herding has a stabilizing effect on prices, while studies focusing on longer horizons often find that herding predicts reversals in returns, thus providing empirical evidence in favor of Trichet's view.[3]

The theoretical literature lags behind its empirical counterpart in this area. While the well-known model of Scharfstein and Stein (1990) shows that money managers may herd due to reputational concerns, there is no systematic theoretical analysis of the effects that institutional herding may have on equilibrium prices.

In this paper we present a simple yet rigorous model of the price impact of institutional herding. Our model analyzes the interaction among three classes of traders: career-concerned fund managers, profit-motivated proprietary traders, and security dealers endowed with market power. Our results provide a simple and unified framework to interpret the empirical evidence on the effect of herding and returns, both at long and short horizons. First, we show theoretically that money managers tend to imitate past institutional trades due to their reputational concerns, despite the fact that such trading behavior has a first-order im-

[1] Jean-Claude Trichet, then Governor of the Banque de France. Keynote speech delivered at the Fifth European Financial Markets Convention, Paris, 15 June 2001: "Preserving Financial Stability in an increasing globalised world."

[2] See, among others, Lakonishok, Shleifer and Vishny (1992), Grinblatt, Titman and Wermers (1995), Wermers (1999), and Sias (2004).

[3] For evidence on short-term return continuation following institutional herding see, for example, Wermers (1999) and Sias (2004). Dasgupta, Prat, and Verardo (2007) find evidence of long-term return reversals after institutional herding. Brown, Wei, and Wermers (2007) show that institutional herding following analyst recommendations is associated with return continuation in the short term and return reversals in the longer term.

pact on the prices of the assets that they trade. Second, we show that, in markets dominated by institutional traders, assets persistently bought (sold) by institutions trade at prices that are too high (low), generating return-reversals in the long term, when uncertainty is resolved. Thus, consistent with recent empirical findings, our model predicts a negative correlation between the net trade of institutional investors and long-term returns. Third, our results can explain a positive correlation between institutional herding and short-term returns, in line with existing empirical evidence. Finally, our theory develops a number of new predictions that establish a link between herding, contractual incentives, trading volume, and prices, and represent potential directions for future empirical analysis.[4]

The building blocks of our theory can be traced back to Scharfstein and Stein (1990), who study a sequential choice setting with exogenous (fixed) prices in which decision makers have career concerns. We embed a related model of career concerns into a multi-period sequential trade market with endogenous price determination, in which some traders (fund managers) have career concerns, while their trading counterparties (security dealers) are endowed with some degree of market power. We describe the model below.

A number of career-concerned fund managers and profit-motivated proprietary traders trade with dealers endowed with market power over several trading rounds before uncertainty over asset valuation is resolved. Fund managers and proprietary traders receive private signals about the liquidation value of the stock and they differ in the accuracy of their signal. Fund managers are evaluated by their investors based on their trades and the eventual liquidation value of their portfolios. The future income of a manager depends on how highly investors think of his signal accuracy. In contrast, proprietary traders are motivated purely by trading profits.

In equilibrium, if most managers have bought the asset in the recent past, a manager with a negative signal is reluctant to sell, because he realizes that: (i) his negative realization is in contradiction with the positive realizations observed by his colleagues; (ii) this is probably due to the fact that his accuracy is low; and (iii) by selling, he is likely to appear like a low-accuracy type to investors. The manager faces a tension between his desire to maximize expected profit (which induces him to follow his private information and sell) and his reputational concerns (which make him want to pretend his signal is in accordance with those of the others). This tension drives a wedge between the price at which the manager is willing to sell and the maximum price at which a profit-motivated dealer will trade with him. Thus, this pessimistic manager does not trade.

Conversely, a manager with a positive signal who trades after a sequence of buys is even

[4] Our paper is related to the large literature on herding (e.g., Banerjee (1990), Bikhchandani, Hirshleifer, and Welch (1990), and Avery and Zemsky (1998)) and to the growing literature on the agency conflicts and asset pricing (e.g., Allen and Gorton (1993), He and Krishnamurthy (2007), and Kondor and Guerrieri (2007)).

more willing to buy the asset, because his profit motive and his reputational incentive go in the same direction. Dealers utilize their market power to take advantage of this manager's reputational motivation and offer to trade with him at prices that are above expected liquidation values based on available information. In turn, the manager is willing to buy at such excessively high prices because buying provides him with an expected reputational reward. When a number of traders have bought, indicating that the asset value is likely to be high, fund managers will either buy at unfavorable prices, or not trade. Purely profit-motivated proprietary traders will choose not to buy even if they receive the positive signal, because the price is too high. On the other hand, if proprietary traders receive the negative signal, they will sell.

In equilibrium, therefore, money managers trade in the direction of past trades or not at all (thus exhibiting herding behavior), while proprietary traders trade against the direction of past trades or not at all (thus exhibiting contrarian behavior). Our results on the trading behavior of fund managers are supported by the empirical evidence on herding by institutional investors. There is also extensive evidence on the contrarian trading behavior of individual investors, who can be viewed as the proprietary traders in our model.[5]

What is the effect of these trading decisions on asset prices? The willingness to pay for an asset on the part of career-driven investors can differ systematically from the expected liquidation value of the asset. It is higher (lower) if past trade by other managers has been persistently positive (negative). If there are enough money managers in the market, this discrepancy between their willingness to pay and the fair price is incorporated into average transaction prices. Each stock develops a *reputational premium*. Stocks that have been persistently bought (sold) trade at prices that are higher (lower) than their fair value, leading to a correction when the true value is revealed. Our theory, therefore, predicts a negative correlation between the net trade of institutional investors and long term returns.

Our theory can also generate a positive correlation between the balance of fund manager trade and the short-term returns. To see this, note that when a number of managers have bought, market beliefs about the asset become quite positive. At this point, in a market dominated by fund managers, the next trader to face the market maker is likely to be a manager, and, as we have already argued, his tendency to imitate past trade indicates that he will not sell. Thus, average transaction prices are likely to be higher in the immediate aftermath of a managerial buy-sequence. Measured during an institutional herd, or immediately following one, short-term transaction price paths are likely to be increasing when institutions have been net buyers, and decreasing when they have been net sellers.

Our model generates a number of further implications. We show that the degree of

[5] We refer to the relevant literature in Section 3.

asset mispricing based on career concerns is an increasing function of both the contractual incentives of institutional traders and the degree of institutional presence in the market. Money managers who care more about reputation (relative to profits) will be willing to buy at even higher prices and to sell at even lower prices, leading to greater mispricing. Moreover, as long as the market is dominated by money managers and these money managers are sufficiently concerned about their reputation, the expected mispricing increases monotonically along a buy or sell sequence.

Finally, we link institutional herding and price reversals to trading volume. Price run-ups due to institutional buying are reversible in our model: they can be reversed by sufficiently many fund managers receiving negative signals, leading them not to trade and thus revealing to the market the existence of negative news, and leading to a drop in public beliefs about asset values. However, as this informal discussion suggests, for such a reversal to occur, a number of fund managers must choose not to trade in a sequence: thus, price reversals following a managerial herd are likely to be preceded by episodes of reduced trading volume.

Our core qualitative results arise from the interaction of two crucial ingredients. On the one hand, fund managers are career concerned. As a result, their valuation for a given asset (conditional on a given history of trades) may differ from that of traders without career concerns. On the other, the security dealers who buy and sell from fund managers have a degree of market power, which leads to some of this difference in valuations to be reflected in prices. There is extensive empirical evidence in support of both ingredients. A large empirical literature (e.g., Brown, Harlow, and Starks (1996), Chevalier and Ellison (1997, 1999)) documents that the reward structure of portfolio managers is sensitive to their perceived ability. Furthermore, a number of studies show that OTC markets for several assets tend to be concentrated among relatively few dealers who exercise market power (see, for example, Ellis, Michaely and O'Hara (2002) and Schultz (2003) for stocks traded on the Nasdaq, and Green, Hollifield, and Schurhoff (2007) for corporate debt and municipal bonds).

The rest of the paper is organized as follows. In the next section we present the model and derive the equilibrium. In section 3 we delineate the properties of the equilibrium and discuss the connection with existing empirical results. Section 4 discusses possible micro-foundations for the payoff structure assumed in the baseline model. Section 5 concludes.

2 Model

The first ingredient of our analysis is a model of financial markets with asymmetric information. Consider a sequential trade market in which in each period there is a large number N_F of delegated traders (*fund managers*) and a large number N_P of non-delegated speculators (*proprietary traders*), where $\eta = \frac{N_F}{N_F + N_P}$ represents the proportion of fund managers in each period. There are T trading periods. Each trader is able to trade at most once, if he is randomly selected to trade in one of the T rounds. In any given period t, the probability that the trader selected to trade is a fund manager is η.

There is a single Arrow asset, with equi-probable liquidation values $v = 0$ or 1. The realized value of v is revealed at time $T + 1$. The trader who is selected at t faces a short-lived monopolistic market maker (MM), who trades at time t only, and posts a bid (p_t^b) and an ask price (p_t^a) to buy or sell one unit of the asset.[6] Each trader has three choices: he can buy one unit of the asset from the MM ($a_t = 1$), sell one unit of the asset to the MM ($a_t = -1$), or not trade ($a_t = 0$).[7]

We comment briefly on the market structure underlying our model. We consider a pure quote-driven dealer market (e.g., the London SEAQ system and Nasdaq) where the market maker is a monopolist. The assumption of a monopolistic market maker is a simplification for imperfect competition amongst dealers. As long as dealers are not perfectly competitive, they will enjoy some degree of market power. Only a degree of market power on the part of dealers is necessary to support our qualitative results. As we have noted in the introduction, there is ample empirical evidence for imperfect competition amongst dealers in several asset markets. Further discussion of this point is provided in Section 4.

Regardless of whether he is a fund manager or a proprietary trader, the trader chosen to trade at t can be either good (type $\theta = g$) with probability γ or bad (type $\theta = b$), with probability $1 - \gamma$.[8] The traders do not know their own types.[9] The good trader observes a perfectly accurate signal: $s_t = v$ with probability 1. The bad trader observes a purely noisy signal: $s_t = v$ with probability $\frac{1}{2}$. Signals are independent conditional on the state.

As in many signalling games, the presence of potential out-of-equilibrium actions can result in implausible equilibria supported by arbitrary out-of-equilibrium beliefs. To ameliorate this problem, we assume that in every period t there is an exogenous probability

[6] Formally, our model has features of both Glosten and Milgrom (1985), which is a multi-period model with a competitive market maker, and Copeland and Galai (1983) which is a single-period model with a monopolistic market maker. Needless to say, it is complex to model a monopolistic market maker in a multi-period setting, and our assumption of short-livedness simplifies the problem.

[7] We note in passing that there is no noise trade in our set-up. However, noise traders could be added to our model without modifying the qualitative properties of our price dynamics, at the cost of substantial algebraic complexity. We briefly outline how this can be done in Section 4.

[8] We are thus implicitly assuming equal quality of average information in the population of delegated and non-delegated traders. This assumption simplifies the algebra without reducing the generality of our core message.

[9] Dasgupta and Prat (2008) consider a related model in which managers receive informative signals about their types, and show that the core effects of career concerns are unaffected as long as self-knowledge is not very accurate.

$\rho \in (0,1)$ that the trader (manager or proprietary trader) is unable to trade, in which case he is immediately replaced by another trader. This guarantees that non-trading occurs on the equilibrium path. ρ can be as small as desired. When the investor observes a manager who does not trade, she cannot tell whether the manager was unable or unwilling to trade.

Proprietary trader t maximizes his trading profits (χ_t), while manager t maximizes a linear combination of his trading profits (χ_t) and his reputation (γ_t), which are defined below.

Trading profit is given by:

$$\chi_t = \begin{cases} v - p_t^a & \text{if } a_t = 1 \\ p_t^b - v & \text{if } a_t = -1 \\ 0 & \text{if } a_t = 0 \end{cases}$$

The reputational benefit is given by the posterior probability (at $T+1$) that the manager is good given his actions and the liquidation value:

$$\gamma_t = \Pr\left[\theta_t = g | a_t, h_{T+1}, v\right]$$

The manager's total payoff is

$$\chi_t + \beta\gamma_t$$

where $\beta > 0$ measures the importance of career concerns.

Let us first introduce some notation. Let h_t denote the history of prices and trades up to period t (excluding the trade that occurs at t). Let $v_t = E\left[v|h_t\right]$ denote the public expectation of v. Finally, let $v_t^0 = E\left[v|h_t, s_t = 0\right]$ and $v_t^1 = E\left[v|h_t, s_t = 1\right]$ denote the private expectations of v of a trader at t who has seen signal $s_t = 0$ or $s_t = 1$ respectively. Simple calculations show that

$$v_t^1 = \frac{(1+\gamma)v_t}{2\gamma v_t + 1 - \gamma} \text{ and } v_t^0 = \frac{(1-\gamma)v_t}{1+\gamma-2\gamma v_t}.$$

It is clear that $v_t^0 < v_t < v_t^1$ and

$$\Pr(s_t = 1|h_t)v_t^1 + \Pr(s_t = 0|h_t)v_t^0 = v_t.$$

As a benchmark, we first analyze the case in which $\beta = 0$, that is, there are no career concerns. In this case, it is easy to see that the only possibility is that all traders trade sincerely in equilibrium, that is, buy if they see $s_t = 1$ and sell if they see $s_t = 0$. The MM, in turn, sets prices to extract the full surplus: bid price $p_t^b = v_t^0$ and ask price $p_t^a = v_t^1$. We summarize:

Proposition 1 *When $\beta = 0$, managers and proprietary traders trade as follows:*

$$a_t = \begin{cases} -1 & \text{if } s_t = 0 \\ 1 & \text{if } s_t = 1 \end{cases}$$

and the market maker sets prices $p_t^b = v_t^0$ and $p_t^a = v_t^1$.

Thus the *average transaction price* when $\beta = 0$ is v_t.

We now analyze the more general case when $\beta > 0$. We first introduce some additional notation for useful equilibrium quantities. Let

$$w_{a_t}^{s_t} = E[\gamma_t(a_t)|s_t, h_t],$$

the expected posterior reputation of a manager who observes signal s_t and takes action a_t. This is clearly an equilibrium quantity, and turns out to be useful in summarizing prices when $\beta > 0$. The following is an equilibrium of the game with $\beta > 0$.

Proposition 2 *There exists an equilibrium in which, if selected to trade at t a manager trades as follows:*

(1) If $v_t \geq \frac{1}{2}$ *then* $a_t = \begin{cases} 1 & \text{if } s_t = 1 \\ 0 & \text{otherwise} \end{cases}$

(2) If $v_t < \frac{1}{2}$ *then* $a_t = \begin{cases} -1 & \text{if } s_t = 0 \\ 0 & \text{otherwise} \end{cases}$

If selected to trade at t a proprietary trader trades as follows:

(1) If $v_t \geq \frac{1}{2}$ *then* $a_t = \begin{cases} -1 & \text{if } s_t = 0 \\ 0 & \text{otherwise} \end{cases}$

(2) If $v_t < \frac{1}{2}$ *then* $a_t = \begin{cases} 1 & \text{if } s_t = 1 \\ 0 & \text{otherwise} \end{cases}$

The market maker quotes the following prices at t:

(1) $v_t \geq \frac{1}{2}$

$$\begin{aligned} p_t^a &= v_t^1 + \beta\left(w_1^1 - w_0^1\right) \\ p_t^b &= v_t^0 \end{aligned}$$

(2) $v_t < \frac{1}{2}$

$$\begin{aligned} p_t^a &= v_t^1 \\ p_t^b &= v_t^0 + \beta\left(w_0^0 - w_{-1}^0\right) \end{aligned}$$

The proof of this result is lengthy, and is presented in full detail in the appendix. Here, we comment on the main ingredients that drive the result. We focus on the case in which $v_t > \frac{1}{2}$. The intuition for $v_t < \frac{1}{2}$ is symmetric.[10]

When $v_t > \frac{1}{2}$, the market is optimistic about the asset payoff, and the equilibrium strategies prescribe that the manager with $s_t = 1$ should buy while the manager with $s_t = 0$ should decline to trade. The equilibrium also specifies that, in this scenario, the ask price is higher

[10] At $v_t = \frac{1}{2}$, trades and prices specified as above for $v_t < \frac{1}{2}$ can also be sustained as an equilibrium.

than expected liquidation value conditional on a buy order, while the bid price is equal to expected liquidation value conditional on a sell order.

When $v_t > \frac{1}{2}$, it seems to fund managers that there are reputational rewards to be reaped (in equilibrium) from buying. Thus, the fund manager who receives $s_t = 1$ wishes to buy this asset from profit motivations, and for reputational reasons. Thus he is willing to pay a price above the fair informational value of the asset at t in order to own it. The monopolistic market maker sees this as an opportunity for extracting rents, and sets ask prices strictly above expected liquidation value to make positive profits. The fund manager who receives $s_t = 0$ wishes to sell for profit reasons, but to buy for reputational reasons. The price at which he would sell will be higher than v_t^0, which is the highest price the market maker would ever be willing to pay him. Thus, this manager does not trade.

The market maker is indifferent between trading and not trading with proprietary traders, since, conditional on wishing to trade, their asset valuations coincide in equilibrium. The high willingness to pay of the fund manager with $s_t = 1$ drives up the ask price above expected liquidation value for the most optimistic trader (v_t^1), and at such high prices proprietary traders would never wish to buy. On the other hand, as we have argued above, there is no incentive compatible price at which the market maker can buy from a fund manager, so the market maker's only trading counterparty on the bid side are proprietary traders. The market maker is indifferent to trading or not, and is thus willing to set a bid price at v_t^0, at which point the proprietary traders who receive signal $s_t = 0$ are indifferent between selling and not trading.

Could the market maker deviate to increase his profits? It is clear that he would never wish to make fund managers with $s_t = 1$ change their behavior, since he can already extract maximal surplus from these traders. However, as long as fund managers with $s_t = 1$ buy, it is also not optimal for him to induce fund managers with $s_t = 0$ to also buy (for which he would have to lower prices). Intuitively, the market maker makes profits by "selling reputation" to fund managers. However, if he persuades all managers to always buy, there is no reputational benefit to buying. In turn, therefore, the market maker cannot extract any positive rents from his trades with fund managers, and therefore makes zero profits. It will generally be in the interest of the market maker to extract reputational rents only from a strict subset of the group of fund managers.

3 Equilibrium Trades and Prices

In this section we delineate the properties of the equilibrium identified in Section 2 and relate them to existing empirical findings.

3.1 Institutional Herding and Contrarian Trading

Fund managers never trade "against popular opinion". If their private information agrees with the public belief (for example, if $s_t = 1$ when $v_t > \frac{1}{2}$) then they trade in the direction of the public belief (e.g., buy when $v_t > \frac{1}{2}$). If their private information contradicts the public belief (for example, if $s_t = 0$ when $v_t > \frac{1}{2}$) then they choose not to trade.[11]

In sharp contrast, proprietary traders never trade in the direction of popular opinion. If their private information agrees with the public belief (for example, if $s_t = 1$ when $v_t > \frac{1}{2}$) then they choose not to trade. If their private information contradicts the public belief (for example, if $s_t = 0$ when $v_t > \frac{1}{2}$) then they choose to trade in a contrarian manner.

The contrasting behavior of fund managers and proprietary traders can be explained by the existence of a *reputational premium* (defined below) – trading in the direction of popular opinion implies buying "too high" or selling "too low". Fund managers are willing to do so because trading in the direction of popular opinion is, on balance, likely to enhance their reputation. Proprietary traders have pure profit-based compensation, face no career concerns, and therefore are unwilling to trade at unfavorable prices. The willingness of fund managers to trade at unfavorable prices, in turn, supports these prices, and therefore the reputational premium in equilibrium.

The empirical evidence on institutional trading behavior shows that institutional investors tend to herd, or trade in the direction of recent institutional trades. Lakonishok, Shleifer and Vishny (1992) show that the trades of a sample of pension funds tend to be correlated over a given quarter, especially among small stocks. Grinblatt, Titman and Wermers (1995) and Wermers (1999) examine a larger sample of holdings by mutual funds and find evidence of herding in small stocks. Sias (2004) finds stronger evidence of herding behavior among institutional investors. He estimates a strong and positive correlation between the fraction of institutions buying the same stock over adjacent quarters.

There is also evidence that non-institutional traders, i.e., individuals, tend to trade as contrarians. Kaniel, Saar, and Titman (2008), for example, examine NYSE trading data by individual investors and find that individuals buy stocks after prices decrease and sell stocks after prices increase. Griffin, Harris, and Topaloglu (2003) show evidence of short-horizon contrarian behavior by Nasdaq traders who submit orders through retail brokers. Goetzmann and Massa (2002) find that individuals who invest in an index fund are more likely to be contrarians.[12]

[11] Thus, in a sense, portfolio managers under-react to private information that contradicts the market's opinion. A very different mechanism for under-reaction to information of short-term traders (who can be interpreted to be institutions) is offered in Vives (1995). In that model, risk-averse short-term traders bear price risk by holding risky assets, and thus may under-react to private information.

[12] In markets outside the U.S., Choe, Kho, and Stulz (1999) find evidence of short-horizon contrarian trading

We turn next to defining the reputational premium and delineating its properties.

3.2 The Reputational Premium

The willingness of fund managers to trade at unfavorable prices in order to enhance their reputation can lead to prices deviating from expected liquidation value. We define the reputational premium as the difference in expected transaction prices, conditional on trade taking place, in the presence and absence of career concerns.

When $\beta = 0$, $p_t^a = v_t^1$, $p_t^b = v_t^0$, and trade always occurs. Thus, the expected transaction price is v_t.

When $\beta > 0$, prices and equilibrium behavior depend on the public belief v_t. For concreteness, we focus on the case where $v_t > \frac{1}{2}$ (the case where $v_t < \frac{1}{2}$ is symmetric). Trade occurs only if a fund manager is selected to trade and observes $s_t = 1$ (in which case there is a buy order) or if a proprietary trader is selected to trade and observes $s_t = 0$ (in which case there is a sell order). Thus, the probability of trade is

$$\eta \Pr(s_t = 1|h_t) + (1-\eta)\Pr(s_t = 0|h_t).$$

Therefore, the expected transaction price with $\beta > 0$, conditional on a trade taking place, is:

$$\frac{1}{1 + \frac{1-\eta}{\eta}\frac{\Pr(s_t=0|h_t)}{\Pr(s_t=1|h_t)}}\left(v_t^1 + \beta\left(w_1^1 - w_0^1\right)\right) + \frac{1}{\frac{\eta}{1-\eta}\frac{\Pr(s_t=1|h_t)}{\Pr(s_t=0|h_t)} + 1}v_t^0.$$

Thus, the reputational premium is given by:

$$RP(\eta, \beta, v_t) = \frac{1}{1 + \frac{1-\eta}{\eta}\frac{\Pr(s_t=0|h_t)}{\Pr(s_t=1|h_t)}}\left(v_t^1 + \beta\left(w_1^1 - w_0^1\right)\right) + \frac{1}{\frac{\eta}{1-\eta}\frac{\Pr(s_t=1|h_t)}{\Pr(s_t=0|h_t)} + 1}v_t^0 - v_t.$$

We now consider some properties of $RP(\eta, \beta, v_t)$.

3.2.1 The proportion of fund managers

The weight of delegated portfolio managers in a financial market has a direct impact on the reputational premium. To see this, note that

$$v_t^1 + \beta\left(w_1^1 - w_0^1\right) > v_t^1 > v_t^0,$$

$$\frac{1}{1 + \frac{1-\eta}{\eta}\frac{\Pr(s_t=0|h_t)}{\Pr(s_t=1|h_t)}} \text{is increasing in } \eta,$$

by Korean individual investors, and Grinblatt and Keloharju (2000) report contrarian trading behavior by Finnish investors.

$$\frac{1}{\frac{\eta}{1-\eta}\frac{\Pr(s_t=1|h_t)}{\Pr(s_t=0|h_t)}+1} \text{is decreasing in } \eta,$$

while all other expressions are unaffected by η. Thus, increasing η increases $RP(\eta, \beta, v_t)$. It is clear that

$$\lim_{\eta \to 0} RP(\eta, \beta, v_t) < 0 \ ; \ \lim_{\eta \to 1} RP(\eta, \beta, v_t) > 0.$$

Therefore, there exists some threshold level of the presence of delegated portfolio managers (η^*) such that if $\eta > \eta^*$, then the average transaction price for an asset with $v_t > \frac{1}{2}$ is higher than expected liquidation value in the presence of career concerns. It is easy to check that $\eta^* \leq \frac{1}{2}$.

A cross-sectional implication of this result is that the effect of institutional herding on prices should be stronger among stocks with higher levels of institutional ownership. The findings in Dennis and Strickland (2002) indirectly offer support to this implication. The authors do not specifically measure herding behavior, but examine returns on days of large market movements for stocks with different levels of institutional ownership. They find that, after a market drop, stocks that are mostly owned by institutions exhibit large return reversals during the following six-month period.

The theoretical result presented in this section is also supported by empirical evidence showing that the effect of institutonal herding on stock returns has become stronger in recent years, i.e. during a sample period in which institutions have substantially increased their presence in the market and are the majority owners and traders of equity (see, for example, Dasgupta, Prat, and Verardo (2007) and Brown, Wei, and Wermers (2007)).

3.2.2 The effect of contractual incentives

The degree of reputational concerns for fund managers depends on their contractual incentives. In our model, this is measured by β. When $v_t > \frac{1}{2}$, increasing β clearly increases $RP(\eta, \beta, v_t)$, because it increases the ask price in the presence of career concerns without affecting either the probability of trade or any other prices. Similarly, when $v_t < \frac{1}{2}$, increasing β clearly decreases $RP(\eta, \beta, v_t)$, i.e., increases the reputational discount.

This result suggests that contractual incentives can affect the trading behavior of career concerned managers, which, in turn, can affect asset prices. Dass, Massa, and Patgiri (2008) study the effect of contractual incentives in the mutual fund industry during the financial bubble of the late 1990s. They find that incentives in the compensation structure of mutual fund managers significantly affect their propensity to herd (although they do not examine the price effect of such link).

3.2.3 The effect of the public belief

As we have already seen, when $\eta > \eta^*$, $RP(\eta, \beta, v_t) > 0$ whenever $v_t > \frac{1}{2}$. (The symmetry of the model implies that when $\eta > \eta^*$, $RP(\eta, \beta, v_t) < 0$ whenever $v_t < \frac{1}{2}$.) Fixing $v_t > \frac{1}{2}$, how does $RP(\eta, \beta, v_t)$ change as a function of v_t?

In general, the relationship is complex, because v_t affects both the trade prices and the conditional probabilities of buy and sell orders. However, when most of the traders in the market are fund managers, and the career concerns of these fund managers are sufficiently strong, the reputational premium will be strictly increasing in v_t. To see this, note that

$$\begin{aligned}\lim_{\eta \to 1} RP(\eta, \beta, v_t) &= v_t^1 + \beta \left(w_1^1 - w_0^1\right) - v_t \\ &= \left(v_t^1 - v_t\right) + \beta \left(w_1^1 - w_0^1\right)\end{aligned}$$

While the expression $v_t^1 - v_t$ may be non-monotone, it is easy to see that $w_1^1 - w_0^1$ is strictly increasing in v_t, because w_1^1 increases while w_0^1 decreases in v_t. Thus, the overall expression strictly increases in v_t as long as β is large enough. Strong public beliefs (following, for example, a long sequence of institutional buys or sells) imply a stronger effect of herding behavior on prices, and can thus contribute to exacerbating the degree of asset mispricing.

3.3 The cost of herding

As our discussion above has made clear, fund managers only trade in the direction of the public belief, and do so at prices that are too high or too low, depending on whether the public belief is optimistic or pessimistic. Our model allows us to quantify the price that fund managers pay for their tendency to imitate past trades, as a function of when they buy (sell) in a given sequence of buy (sell) orders.

We restrict attention to the case where $v_t > \frac{1}{2}$. The other case is symmetric. When a fund manager (with $s_t = 1$) buys, his trading profits are given by:

$$v_t^1 - p_t^a = v_t^1 - v_t^1 - \beta(w_1^1 - w_0^1) < 0.$$

Thus, this manager makes an expected trading loss, for which he is compensated by an expected reputational benefit. Note that $w_1^1 - w_0^1$ is increasing in v_t, and thus the higher is the public belief when the manager buys, the higher are his expected trading losses. But high v_t is achieved in this equilibrium only by persistent net buying. Thus, the later a manager buys in a sequence with a set of net buy orders, the greater will be his losses.

The empirical literature on herding typically examines trading concentrated over one or two periods (quarters). Dasgupta, Prat, and Verardo (2007) focus instead on long-horizon herding sequences and find that the degree of asset mispricing (measured by the magnitude of long-term return reversals) is larger for stocks characterized by a longer sequence of institutional buying or selling. For example, the difference in two-year cumulative returns between stocks persistently sold and stocks persistently bought by institutions is 6.5% if institutional herding is measured over a period of three consecutive quarters, and becomes 17% if herding occurs persistently over five quarters.

3.4 Institutional herding, price reversals, and market inactivity

It is clear that institutional buy or sell sequences are reversible in our model. When fund managers buy in a sequence following a neutral public belief of $v_t = \frac{1}{2}$, this ensures that $v_t > \frac{1}{2}$, and the price rises. However, following such purchases, fund managers or proprietary traders with $s_t = 0$ may arrive, and they will choose not to trade or to sell respectively. Either of these actions will lead to a reversal of the price pattern. Our analysis has important joint implications for the degree of market activity (as measured by the number of transactions per period for a given asset) and reversals in *realized* transaction prices, which we comment on here. It is easiest to delineate such an implication in a market that is dominated by fund managers, i.e., when $\eta \approx 1$.

Consider a market dominated by fund managers ($\eta \approx 1$) and suppose that two or more fund managers have bought in a sequence up to and including period t, leading to a pattern of increasing public beliefs ($\frac{1}{2} \leq v_{t-1} < v_t$) and realized transaction prices ($p^a_{t-1} < p^a_t$).[13] How can such a pattern be reversed? That is, when is it possible to see a transaction occur at a price smaller than p^a_t, the most recent transaction price?

Since $v_{t+1} > \frac{1}{2}$, the equilibrium strategies dictate that no fund manager will sell, and since $\eta \approx 1$, the only possible cases are (a) there is a further purchase at $t+1$ (which continues the pattern of increasing prices, so that $v_{t+2} > v_{t+1}$ and $p^a_{t+1} > p^a_t$) or (b) there is no trade at $t+1$. Since $\eta \approx 1$, this reveals that a fund manager with $s_{t+1} = 0$ faced the market maker. This, in turn, lowers public beliefs to $v_{t+2} = v_t > \frac{1}{2}$ so that quoted prices at $t+2$ are identical to the prices in the most recent period (t) in which a transaction took place: $p^a_{t+2} = p^a_t$ and $p^b_{t+2} = p^b_t$. Now, since $v_{t+2} > \frac{1}{2}$ and $\eta \approx 1$, again the only possibilities are (a) a further buy order at $t+2$, which implies that realized transaction prices do not fall, or (b) no trade at $t+2$, which leads to $v_{t+3} < v_t$, and thus lowers the potential transaction prices below the most recent transaction price. Thus, only following two periods of no-trade at $t+1$ and $t+2$, is it possible that a transaction will occur (at $t+3$) at a price *strictly lower* than the most recent transaction price, p^a_t. Thus, a reversal in transaction prices following an institutional buy-sequence must be preceded by at least two successive periods of no-trade.

[13] It is clear that this discussion remains valid for large $\eta < 1$, replacing *realized* transaction prices by *expected* transaction prices.

Market inactivity precedes transaction-price reversals.

Recent empirical studies offer support to the results presented in this section. Analyzing a cross-section of US stock returns, these studies show evidence that abnormally low trading volume can predict return reversals. For example, Connolly and Stivers (2003) document that the weekly returns of a portfolio of large U.S. stocks exhibit reversals following a period of low abnormal turnover (see also Cooper (1999)). Avramov, Chordia and Goyal (2006) find that monthly returns of low turnover stocks exhibit more reversals than the returns of high turnover stocks.

3.5 The short-term and long-term price impact of institutional herding: interpreting empirical evidence

To conclude our discussion of the properties of the equilibrium identified in Proposition 2, we now consider existing empirical evidence on the price impact of institutional herding. Our simple model provides a stylized framework within which it is possible to rationalize two important sets of existing empirical results in this area of the literature.

A core conclusion that emerges out of our theoretical analysis is that, in markets with sufficiently many fund managers, stocks that have been persistently bought (sold) by career-concerned fund managers are overpriced (underpriced), and thus are likely to have below (above) average returns in the long-term (at horizon $T+1$), once uncertainty has been resolved and prices adjust to fundamental value. This observation follows from the existence of the reputational premium: in section 3.2, we show that as long as there are sufficiently many fund managers, the reputational premium is strictly positive for persistently bought assets, and negative for persistently sold ones. This finding provides a theoretical grounding for the results of Dasgupta, Prat, and Verardo (2007). They consider the aggregate portfolio holdings of a sample of US institutional investors and identify those stocks that have been persistently bought or sold by institutions over several quarters. They examine the returns to such stocks at long (two year) horizons and find evidence of negative performance for persistently bought stocks, and positive performance for persistently sold stocks. Evidence of long-term return reversals associated with institutional trading can also be found in Braverman, Kandel, and Wohl (2005), Frazzini and Lamont (2007), and Coval and Stafford (2007).

An earlier strand of the literature has found positive return predictability from institutional herding at short horizons. In particular, Wermers (1999) and Sias (2004) find that stocks that institutions herd into (and out of) exhibit positive (negative) abnormal returns at horizons of a few quarters.[14] The results of section 3.4 show that our model can also gen-

[14] Other papers finding evidence of a positive correlation between institutional demand and future returns include Nofsinger and Sias (1999), Grinblatt, Titman and Wermers (1995), and Cohen, Gompers and

erate equilibrium outcomes consistent with these findings. Our analysis shows that, following an institutional buy (sell) sequence up to time t in a market dominated by fund managers, expected transaction prices at $t+1$ and $t+2$ could not be lower than the transaction price at t. Thus, stocks bought ex post at realized transaction prices at t and then sold at realized transaction prices at $t+1$ or $t+2$ will, on average, have positive expected returns.

Finally, a recent study by Brown, Wei, and Wermers (2007) shows evidence of both short-term positive correlation and long-term negative correlation between institutional herding and returns. The authors examine institutional trading following analyst recommendation revisions. They find that, during the quarter in which herding is measured and shortly thereafter, stocks bought (sold) by herds experience a price increase (decrease). They also find evidence of return reversals over the following year (especially from the third quarter) when funds herd in the direction of analyst recommendation revisions.

4 Discussion

In this section we provide further discussion of some of our crucial assumptions, provide microfoundations for our model, and outline how noise trading could be added to the model to explicitly ensure the optimality of delegation of portfolio management.

4.1 Monopolistic market maker

We have emphasized above that the assumption of monopolistic dealers is sufficient but not necessary for our qualitative results. In this subsection, we discuss this further. In a standard trading model like Glosten and Milgrom (1985), all traders pursue the same objective: they maximize expected returns. In our setting, things are very different. Some traders have career concerns and private information (fund managers) while their trading counterparties (security dealers) have no career concerns and, as is standard in microstructure models, no private information. Our key results is that there may be a large discrepancy between the willingness to pay of these two groups of traders for the same asset.

If portfolio managers and dealers value the same asset differently, what price will emerge in equilibrium? In general, we should expect the price to reflect the valuations of the two groups according to their respective price elasticities. Unfortunately, such a general approach leads quickly to intractability in the context of dynamic trading models. So we are left with two extreme alternatives: either portfolio managers have all the bargaining power (this would arise, for example, if dealers were competitive, as they are in Glosten and Milgrom 1985) or dealers have all the bargaining power (for example, the dealer is a monopolist). In the former

Vuolteenaho (2002).

case, the price will correspond to the valuation of dealers and our model will yield the same prices as Glosten and Milgrom.[15] In the latter case – the interesting one to explore – prices correspond to the valuations of portfolio managers. Reality is in between these two extreme cases, and we should expect prices to partly incorporate the willingness to pay of institutions. But this means that, in a reasonable model, where the dealer and portfolio managers share the bargaining power (for example, the dealer is imperfectly competitive, but not monopolistic) we should expect prices to display the properties that we discuss here.

4.2 Microfoundations and noise trading

We have seen that the presence of career concerns on the part of fund managers can be shown to have important consequences for short and long-term prices and returns of assets that they trade. To date, we have assumed that fund managers care about their reputation. In this subsection we briefly discuss a microfoundation for fund-manager payoffs. A more detailed approach to such microfoundations in related models can be found in the related models of Dasgupta and Prat (2006, 2008).

There are a large number, N_F, of islands. On each island i live an investor and two fund managers: an incumbent fund manager and a challenger. The investor cannot trade directly and must use a fund manager.

There are two long periods ("years"). In year 1, the investor is (exogenously) assigned to the incumbent fund manager. In each year, one asset is traded, with equiprobable liquidation value 0 or 1.

The trading process and the information structure in the first year are exactly as described in the reduced-form model. The number of periods of trading in the first year is small in comparison to the number of islands.

At the end of the first year, each investor i observes whether his fund manager has traded, but he does not observe whether his fund manager had the opportunity to trade. The investor is unable to distinguish between a manager who did not have the chance to trade and one who did but chose $a_t = 0$. Also at the end of the first year, a new generation of fund managers appear, one in every island. Their ability $\tilde{\gamma}$ is uniformly distributed over $[0, 1]$. In the second period, trading occurs again in the same format as the first period, with two exceptions: in this second period, (a) fund managers do not have career concerns and thus prices do not rise above or below the fair information-based levels, and (b) there are some noise traders, the presence of whom make it optimal for investors to wish to retain fund managers only if he believes that they are better than average. If the fund manager is paid a fraction of the

[15] However, the informativeness of prices may change due to changes in the behavior of portfolio managers. See Dasgupta and Prat (2008).

first year's profits along with a fixed wage, this formulation generates a payoff function that is a special case of the baseline model.

The discerning reader will have already noted that a shortcoming of the microfoundation described here is that investors who use delegated portfolio managers earn negative expected returns in the first "year". Thus delegation is not optimal for fully rational investors. There is a fair amount of evidence to suggest that retail investors place their money in actively managed funds despite the fact that the after-cost return of these funds is lower than those of index funds. For example, Gruber (1996) shows that investors buy actively managed funds even though, on average, they underperform index funds. Carhart (1997) finds evidence of mutual funds underperformance on a style-adjusted basis. Daniel, Grinblatt, and Titman (1997) use a characteristics-based measure of performance for a large sample of mutual funds and find that the amount by which the average fund beats a passive strategy is approximately equal to the average management fee. Wermers (2000) documents that mutual funds on average beat the market index, but not by enough to cover their expenses and transactions costs. Nevertheless, it is worth discussing this point from a theoretical angle. The suboptimality of delegation to fund managers is a consequence of the absence of liquidity-driven traders in our model. Such traders are standard in models of financial markets with asymmetric information, but in our setting with career concerned traders, proprietary traders, and monopolistic market makers, the introduction of this fourth class of traders would lead to substantial modelling complexity, which is beyond the scope of this paper. However, such an extension presents no conceptual difficulties, and we can sketch the basic idea here. For example, we could augment the model to include noise traders who buy from and sell to the market maker with probabilities η_b and η_s, respectively. In addition, as in Copeland and Galai (1983), we could posit that liquidity driven traders trade with lower probability when prices are unfavorable, i.e., η_b decreases in the ask-price, and η_s increases in the bid-price.[16] Finally, in order to suitably enrich the model, we could consider a continuum of types of fund managers and proprietary traders differentiated by private signals about the precision of their own information.

Now consider a situation in which $v_t > \frac{1}{2}$. Consider the set of traders who have received signal $s_t = 1$. Let $\overline{v}_t^1$ and $\underline{v}_t^1$ denote the expected values of the asset from the perspective of the most informed and least informed traders respectively. The managers' willingness to pay for the asset, however, is higher due to reputational concerns (since $v_t > \frac{1}{2}$). Let the corresponding minimal and maximal willingness to pay be denoted by $\overline{p}_t^a$ ($> \overline{v}_t^1$) and $\underline{p}_t^a$ ($> \underline{v}_t^1$). Imagine that the market maker is considering whether to increase prices above

[16] Implicitly, the assumption that supports this is that there is are differences in the willingness of noise traders to pay for liquidity, with some of them willing to pay very unfavourable prices while others stop trading at such prices.

$\underline{v}_t^1$. Raising the price has three effects at the margin: (1) it discourages noise trading, which diminishes the market maker's profits; (2) it reduces his losses against well-informed fund managers and well-informed proprietary traders; and (3) it increases his profits against badly informed career concerned traders (for example, the market maker profits from trading with managers with expected value $\underline{v}_t^1$ and willingness to pay $\underline{p}_t^a$ when the price p^a lies in $\left[\underline{v}_t^1, \underline{p}_t^a\right]$). Effect (1) discourages high prices, while effects (2) and (3) encourage them. It is clear that, under reasonable assumptions, the optimal ask price will lie in the interval $\left(\underline{v}_t^1, \overline{v}_t^1\right)$. Then, badly informed managers will make expected losses and well informed managers will make expected profits. On average, delegation will be rational, and it will be in the investor's interest to monitor their fund managers in order to learn their types. Finally, note that if we replaced a given set of fund managers by an identically informed set of proprietary traders, then effects (1) and (2) delineated above will still exist, but effect (3) will vanish. This will lead to a lower ask price. Thus, the presence of career concerned managers would lead to a reputational premium as in the baseline model. However, as the preceding discussion makes clear, the fully formal modelling of such an enriched market is very complex and is well beyond the scope of this paper.

5 Conclusion

This paper presents a simple yet rigorous model of the price impact of institutional herding. While the well-known model of Scharfstein and Stein (1990) shows that money managers may herd due to reputational concerns, there is no systematic theoretical analysis of the price impact of institutional herding. The large and growing empirical literature on the price impact of herding, on the other hand, generally finds that institutional herding is associated with return continuation in the short term and return reversals in the long term.

Our model analyzes the interaction among three classes of traders: career-concerned money managers, profit-motivated proprietary traders, and security dealers endowed with market power. The interaction among these traders generates rich implications. First, we show theoretically that money managers tend to imitate past trades (i.e., herd) due to their reputational concerns, despite the fact that such herding behavior has a first-order impact on the prices of assets that they trade.

Second, we delineate the properties of the price impact of institutional herding: we argue that, in markets dominated by institutional traders, assets persistently bought (sold) by money managers will trade at prices that are too high (low), and that this will generate return reversals in the long-term, when uncertainty is resolved. Third, we show that our equilibrium results are consistent with a positive correlation between institutional herding and short-term returns. Our analysis, therefore, provides a simple and stylized framework to interpret the empirical evidence on the price impact of institutional herding, which finds a stabilizing effect of herding in the short term and a destabilizing effect in the long term.

Finally, our model generates a number of new empirical predictions that link herding behavior, contractual incentives, trading volume, and prices. Some of these predictions are supported by existing empirical findings. Others represent potential directions for future empirical analysis.

6 Appendix

Proof of Proposition 2: We first demonstrate the proof for the case in which $v_t > \frac{1}{2}$. The case for $v_t < \frac{1}{2}$ is symmetric.

Case: $v_t > \frac{1}{2}$

Fund manager's strategy: We begin by computing some equilibrium posteriors.

$$\begin{aligned} w_1^1 &= \Pr(g|v=1,a=1)\Pr(v=1|s=1) + \Pr(g|v=0,a=1)\Pr(v=0|s=1) \\ &= \Pr(g|v=1,s=1)\, v_t^1 + \Pr(g|v=0,s=1)\left(1-v_t^1\right) \\ &= \frac{2\gamma}{1+\gamma} v_t^1 \end{aligned}$$

$$\begin{aligned} w_0^1 &= \Pr(g|v=1,a=0)\Pr(v=1|s=1) + \Pr(g|v=0,a=0)\Pr(v=0|s=1) \\ &= \frac{2\rho\gamma}{2\rho\gamma+(1+\rho)(1-\gamma)} v_t^1 + \frac{2\gamma}{2\gamma+(1+\rho)(1-\gamma)}\left(1-v_t^1\right) \end{aligned}$$

because

$$\begin{aligned} \Pr(g|v,a=0) &= \frac{\Pr(a=0|g,v)\Pr(g|v)}{\Pr(a=0|g,v)\Pr(g|v)+\Pr(a=0|b,v)\Pr(b|v)} \\ &= \frac{\Pr(a=0|g,v)\,\gamma}{\Pr(a=0|g,v)\,\gamma+\Pr(a=0|b,v)(1-\gamma)} \\ &= \frac{(\rho+(1-\rho)\Pr(s=0|g,v))\,\gamma}{(\rho+(1-\rho)\Pr(s=0|g,v))\,\gamma+(\rho+(1-\rho)\Pr(s=0|b,v))(1-\gamma)} \\ &= \begin{cases} \frac{\rho\gamma}{\rho\gamma+\left(\rho+\frac{1}{2}(1-\rho)\right)(1-\gamma)} & \text{if } v=1 \\ \frac{(\rho+(1-\rho))\gamma}{(\rho+(1-\rho))\gamma+\left(\rho+(1-\rho)\frac{1}{2}\right)(1-\gamma)} & \text{if } v=0 \end{cases} \\ &= \begin{cases} \frac{2\rho\gamma}{2\rho\gamma+(1+\rho)(1-\gamma)} & \text{if } v=1 \\ \frac{2\gamma}{2\gamma+(1+\rho)(1-\gamma)} & \text{if } v=0 \end{cases} \end{aligned}$$

The expressions for w_0^0 and w_{-1}^0 are analogous

Suppose the fund manager has received signal $s_t = 1$. If he buys, he receives:

$$v_t^1 - p_t^a + \beta w_1^1 = \beta w_0^1$$

If he does not trade, he also receives βw_0^1. Finally, if he sells (an off equilibrium action) we assume that the investor believes that it was because he received signal $s_t = 0$, so that $w_{-1}^1 = (1-v_t^1)\frac{2\gamma}{1+\gamma}$.[17] Thus, the manager's expected payoff from selling is

$$p_t^b - v_t^1 + \beta w_{-1}^1 = v_t^0 - v_t^1 + \beta w_{-1}^1 < \beta w_{-1}^1$$

[17] This is the "natural" off-equilibrium belief, that is robust to the presence of a small number of "naive" fund managers who always trade sincerely.

We show next that $w_{-1}^1 < w_0^1$, which will imply that the expected (deviation) payoff from selling is strictly smaller than the expected (equilibrium) payoff from buying. Recall that

$$w_0^1 = \frac{2\gamma}{2\gamma + \left(\frac{1}{\rho}+1\right)(1-\gamma)} v_t^1 + \frac{2\gamma}{2\gamma + (\rho+1)(1-\gamma)} \left(1 - v_t^1\right)$$

It is clear that at $\rho = 0$, $w_0^1 = w_{-1}^1$. We shall demonstrate that, for $v_t > \frac{1}{2}$, w_0^1 is increasing in ρ, which implies that for $v_t > \frac{1}{2}$ and $\rho > 0$ it must be the case that $w_0^1 > w_{-1}^1$. To do so, we take the derivative of w_0^1 with respect to ρ:

$$\begin{aligned}
\frac{\partial w_0^1}{\partial \rho} &= \frac{\partial}{\partial \rho}\left(\frac{2\gamma}{2\gamma + \left(\frac{1}{\rho}+1\right)(1-\gamma)} v_t^1 + \frac{2\gamma}{2\gamma + (\rho+1)(1-\gamma)} \left(1 - v_t^1\right)\right) \\
&= 2\gamma(1-\gamma)\left(\frac{\frac{1}{\rho^2}}{\left(2\gamma + \left(\frac{1}{\rho}+1\right)(1-\gamma)\right)^2} v_t^1 - \frac{1}{\left(2\gamma + (\rho+1)(1-\gamma)\right)^2}\left(1 - v_t^1\right)\right)
\end{aligned}$$

This expression is increasing in v_t^1. Whenever $v_t > \frac{1}{2}$, it is clear that $v_t^1 > \frac{1}{2}$. Evaluating this expression at $v_t^1 = \frac{1}{2}$ gives

$$\begin{aligned}
&\gamma(1-\gamma)\left(\frac{\frac{1}{\rho^2}}{\left(2\gamma + \left(\frac{1}{\rho}+1\right)(1-\gamma)\right)^2} - \frac{1}{\left(2\gamma + (\rho+1)(1-\gamma)\right)^2}\right) \\
=\ &\gamma(1-\gamma)\left(\frac{1}{\left(2\gamma\rho + (1+\rho)(1-\gamma)\right)^2} - \frac{1}{\left(2\gamma + (\rho+1)(1-\gamma)\right)^2}\right) > 0
\end{aligned}$$

Which then establishes that $w_{-1}^1 < w_0^1$, and thus selling is dominated for the manager with $s_t = 1$.

Suppose instead that the fund manager has received signal $s_t = 0$. His payoff from buying is:

$$\begin{aligned}
v_t^0 - p_t^a + \beta w_1^0 &= v_t^0 - v_t^1 - \beta\left(w_1^1 - w_0^1\right) + \beta w_1^0 \\
&= \left(v_t^0 - v_t^1\right) + \beta\left(w_1^0 - w_1^1\right) + \beta w_0^1 \\
&< \beta w_0^1 < \beta w_0^0
\end{aligned}$$

The penultimate inequality follows from the fact that $v_t^0 - v_t^1 < 0$ and $w_1^0 - w_1^1 < 0$. To see why the latter is true, note that $w_1^0 = \frac{2\gamma}{1+\gamma} v_t^0 < \frac{2\gamma}{1+\gamma} v_t^0 = w_1^1$. The final inequality follows from the fact that

$$w_0^0 = \frac{2\gamma}{2\gamma + \left(\frac{1}{\rho}+1\right)(1-\gamma)} v_t^0 + \frac{2\gamma}{2\gamma + (1+\rho)(1-\gamma)} \left(1 - v_t^0\right)$$

while

$$w_0^1 = \frac{2\gamma}{2\gamma + \left(\frac{1}{\rho}+1\right)(1-\gamma)} v_t^1 + \frac{2\gamma}{2\gamma + (1+\rho)(1-\gamma)} \left(1 - v_t^1\right)$$

and, clearly $\frac{2\gamma}{2\gamma+\left(\frac{1}{\rho}+1\right)(1-\gamma)} < \frac{2\gamma}{2\gamma+(1+\rho)(1-\gamma)}$ and $v_t^0 < v_t^1$. If he does not trade, his payoff is βw_0^0. Thus, buying is dominated.

Finally, if he chooses to sell (an off-equilibrium action), then, as before, the investor assumes (correctly in this case) that the signal received was $s_t = 0$, and thus the expected reputational payoff associated with selling is $w_{-1}^0 = \left(1 - v_t^0\right) \frac{2\gamma}{1+\gamma}$. His total payoff from selling is

$$p_t^b - v_t^0 + \beta w_{-1}^0 = \beta w_{-1}^0$$

To show that selling is dominated by non-trading, we need to show that $w_{-1}^0 < w_0^0$ for $v_t > \frac{1}{2}$. For this note that w_{-1}^0 and w_0^0 are both decreasing in v_t. We shall show that $w_{-1}^0 < w_0^0$ at $v_t = \frac{1}{2}$ for $\rho > 0$, and that w_0^0 decreases at a slower rate than w_{-1}^0, which will establish the required claim. For the first part, note that at $v_t = \frac{1}{2}$ and $\rho = 0$, $w_0^0 = w_{-1}^0 = \gamma$ and for $v_t = \frac{1}{2}$ and $\rho = 1$, $w_0^0 = w_{-1}^0 = \gamma$. Then note that

$$\frac{\partial w_0^0}{\partial \rho} = 2\gamma(1-\gamma)\left(\frac{\frac{1}{\rho^2}}{\left(2\gamma+\left(\frac{1}{\rho}+1\right)(1-\gamma)\right)^2} v_t^0 - \frac{\frac{1}{\rho^2}}{\left(2\gamma+\left(\frac{1}{\rho}+1\right)(1-\gamma)\right)^2}\left(1-v_t^0\right)\right)$$

Solving this for an optimum at $v_t = \frac{1}{2}$ gives the following first order condition:

$$\frac{1}{(2\rho\gamma + (1+\rho)(1-\gamma))^2} \frac{1-\gamma}{2} - \frac{1}{(2\gamma + (\rho+1)(1-\gamma))^2}\left(1 - \frac{1-\gamma}{2}\right) = 0.$$

There is clearly only one positive solution $\frac{1}{\gamma^2+3}\left(\gamma^2 + 2\sqrt{-\gamma^2+1} - 1\right)$. Finally, note that evaluating the derivative at $v_t = \frac{1}{2}$, so that $v_t^0 = \frac{1-\gamma}{2}$, and $\rho = 0$ gives

$$2\gamma(1-\gamma)\left(\frac{1}{(1-\gamma)^2}\frac{1-\gamma}{2} - \frac{1}{(2\gamma+(1-\gamma))^2}\left(1-\frac{1-\gamma}{2}\right)\right) = 2\frac{\gamma^2}{\gamma+1} > 0$$

Finally, evaluating the derivative at at $v_t = \frac{1}{2}$, so that $v_t^0 = \frac{1-\gamma}{2}$, and $\rho = 1$ gives:

$$2\gamma(1-\gamma)\left(\frac{1}{(2\gamma+(1+1)(1-\gamma))^2}\frac{1-\gamma}{2} - \frac{1}{(2\gamma+(1+1)(1-\gamma))^2}\left(1-\frac{1-\gamma}{2}\right)\right) = -\frac{1}{2}\gamma^2(1-\gamma) < 0$$

Now we shall show that w_0^0 decreases more slowly than w_{-1}^0. For this note that $\frac{\partial w_{-1}^0}{\partial v_t^0} = -\frac{2\gamma}{1+\gamma}$, while

$$\frac{\partial w_0^0}{\partial v_t^0} = \frac{2\gamma}{2\gamma + \left(\frac{1}{\rho}+1\right)(1-\gamma)} - \frac{2\gamma}{2\gamma + (1+\rho)(1-\gamma)}$$

This expression is increasing in ρ, so the smallest it can be is at $\rho = 0$, when it coincides with $\frac{\partial w_{-1}^0}{\partial v_t^0} = -\frac{2\gamma}{1+\gamma}$. Thus, the claim is proved. Therefore, it is optimal for the manager with $s_t = 0$ not to trade.

Proprietary trader's strategy: Consider the proprietary trader who observes $s_t = 1$. If he buys his payoff is

$$v_t^1 - p_t^a = v_t^1 - v_t^1 - \beta\left(w_1^1 - w_0^1\right) = -\beta\left(w_1^1 - w_0^1\right) < 0$$

where the inequality follows from three observations: (i) as we have established above, w_0^1 is increasing in ρ for $v_t > \frac{1}{2}$; (ii) for $\rho = 1$, $w_0^1 = \gamma$; and finally (iii) for $v_t > \frac{1}{2}$, it is easy to see that $w_1^1 > \gamma$. If the trader does not trade his payoff is 0. If, instead, he sells, his payoff is

$$p_t^b - v_t^1 = v_t^0 - v_t^1 < 0$$

Thus, it is optimal for the proprietary trader not to trade.

Next consider the proprietary trader who observes $s_t = 0$. If he buys, his expected payoff is strictly smaller than that of the proprietary trader who observed $s_t = 1$, which itself was negative. If he does not trade, his payoff is 0. If he sells, his expected payoff is

$$p_t^b - v_t^0 = v_t^0 - v_t^0 = 0$$

Thus, it is a best response for this proprietary trader to sell.

Market maker's strategy: Since the market maker trades with proprietary traders at fair value, he is indifferent between trading with them or not. So, the only question is whether the market maker can improve terms of trade with fund managers.

By using the equilibrium strategies, the MM can extract positive (maximal) surplus from $s_t = 1$ fund managers, but gets zero surplus from interacting with $s_t = 0$ fund managers. It is clear that he will not wish to change the behavior of $s_t = 1$ managers.

We first show that as long as $s_t = 1$ managers buy, the MM will never wish to have $s_t = 0$ managers sell with positive probability. In any putative equilibrium in which the $s_t = 1$ managers buy, and the $s_t = 0$ sell with positive probability, the posterior for non-trading is identical to the original equilibrium posterior w_0^0 (because non-trading reveals that the manager either got signal $s_t = 0$ or did not receive a trading opportunity. Similarly, the putative equilibrium posterior for selling is identical to the "sincere" off-equilibrium belief used above: w_{-1}^0 (because sales in the putative equilibrium identify the manager as having received signal $s_t = 0$). In order to sell with positive probability, the manager with $s_t = 0$ must at least weakly prefer selling to non-trading. Denoting the bid price in this putative equilibrium by $\widetilde{p}_t^b$, we now can write down:

$$\widetilde{p}_t^b - v_t^0 + \beta w_{-1}^0 \geq \beta w_0^0$$

This, in turn, implies that

$$\widehat{p}_t^b \geq v_t^0 + \beta\left(w_0^0 - w_{-1}^0\right) > v_t^0$$

since we have shown earlier that $w_0^0 > w_{-1}^0$. But bidding such a price can never be incentive compatible for the MM, which rules out this possible deviation.

The only remaining alternative is that the market maker prices to induce both $s_t = 1$ and $s_t = 0$ managers to buy. We need to check that his profits in this potential deviation are smaller than his (strictly positive) equilibrium profits. Suppose that the market maker prices to induce the $s_t = 0$ manager to buy with probability $\alpha \in (0, 1]$, and to not trade with probability $1-\alpha$. The expected reputational payoffs from buying in this putative equilibrium are as follows:

$$\begin{aligned}
\widehat{w}_1^1 &= \left(v_t^1 \frac{\gamma}{\gamma + \frac{1}{2}(1-\gamma)(1+\alpha)} + (1-v_t^1)\frac{\gamma\alpha}{\gamma\alpha + \frac{1}{2}(1-\gamma)(1+\alpha)}\right) \\
\widehat{w}_1^0 &= \left(v_t^0 \frac{\gamma}{\gamma + \frac{1}{2}(1-\gamma)(1+\alpha)} + (1-v_t^0)\frac{\gamma\alpha}{\gamma\alpha + \frac{1}{2}(1-\gamma)(1+\alpha)}\right)
\end{aligned}$$

It is easy to see that $\widehat{w}_1^1 > \widehat{w}_1^0$. By a similar set of computations, the reputational payoffs from not trading in this putative equilibrium are as follows:

$$\widehat{w}_0^1 = v_t^1 \frac{\rho\gamma}{\rho\gamma + \left(\rho + (1-\rho)(1-\alpha)\frac{1}{2}\right)(1-\gamma)} + (1-v_t^1)\frac{(\rho + (1-\rho)(1-\alpha))\gamma}{(\rho + (1-\rho)(1-\alpha))\gamma + \left(\rho + (1-\rho)(1-\alpha)\frac{1}{2}\right)(1-\gamma)}$$

$$\widehat{w}_0^0 = v_t^0 \frac{\rho\gamma}{\rho\gamma + \left(\rho + (1-\rho)(1-\alpha)\frac{1}{2}\right)(1-\gamma)} + (1-v_t^0)\frac{(\rho + (1-\rho)(1-\alpha))\gamma}{(\rho + (1-\rho)(1-\alpha))\gamma + \left(\rho + (1-\rho)(1-\alpha)\frac{1}{2}\right)(1-\gamma)}$$

It is easy to see that $\widehat{w}_0^1 < \widehat{w}_0^0$. Denote the revised ask price in such a putative equilibrium by $\widehat{p}_t^a$. Since the fund manager with $s_t = 0$ must weakly prefer buying to not trading, it must be the case that

$$\begin{aligned}
\beta\widehat{w}_0^0 &\leq v_t^0 - \widehat{p}_t^a + \beta\widehat{w}_1^0 \\
\text{i.e., } \widehat{p}_t^a &\leq v_t^0 + \beta\left(\widehat{w}_1^0 - \widehat{w}_0^0\right).
\end{aligned}$$

The MM's expected profit under the equilibrium strategy is:

$$\eta \Pr(s_t = 1)(p_t^a - v_t^1) = \eta \Pr(s_t = 1)\beta\left(w_1^1 - w_0^1\right)$$

Define

$$\pi_E \equiv \Pr(s_t = 1)\beta\left(w_1^1 - w_0^1\right)$$

The MM's expected profit under the putative deviation is:

$$\eta \Pr(s_t = 1)(\widehat{p}_t^a - v_t^1) + \eta \Pr(s_t = 0)(\widehat{p}_t^a - v_t^0)\alpha.$$

Define

$$\pi_D \equiv \Pr(s_t = 1)(\widehat{p}_t^a - v_t^1) + \Pr(s_t = 0)(\widehat{p}_t^a - v_t^0)\alpha$$

Since $\widehat{p}_t^a \leq v_t^0 + \beta\left(\widehat{w}_1^0 - \widehat{w}_0^0\right)$

$$\begin{aligned}
\pi^D &\leq \Pr(s_t = 1)(v_t^0 + \beta\left(\widehat{w}_1^0 - \widehat{w}_0^0\right) - v_t^1) + \Pr(s_t = 0)(v_t^0 + \beta\left(\widehat{w}_1^0 - \widehat{w}_0^0\right) - v_t^0)\alpha \\
&= \Pr(s_t = 1)\left(v_t^0 - v_t^1\right) + \Pr(s_t = 1)\beta\left(\widehat{w}_1^0 - \widehat{w}_0^0\right) + \Pr(s_t = 0)(\beta\left(\widehat{w}_1^0 - \widehat{w}_0^0\right))\alpha \\
&< \Pr(s_t = 1)\beta\left(\widehat{w}_1^0 - \widehat{w}_0^0\right) + \Pr(s_t = 0)(\beta\left(\widehat{w}_1^0 - \widehat{w}_0^0\right))\alpha \\
&= \beta\left(\Pr(s_t = 1) + \Pr(s_t = 0)\alpha\right)\left(\widehat{w}_1^0 - \widehat{w}_0^0\right) \\
&= \beta\Pr(a_t = 1)\left(\widehat{w}_1^0 - \widehat{w}_0^0\right) \equiv UB_D\left(\alpha\right)
\end{aligned}$$

We show below that $UB_D\left(\alpha\right) < \pi_E$ for all $\alpha \in [0, 1]$, which implies that the deviation is unprofitable for the MM. First, note that

$$\begin{aligned}
\widehat{w}_1^0 - \widehat{w}_0^0 &= \begin{pmatrix} \Pr(v = 1|s = 0)\left(\Pr\left(\theta = g|a_t = 1, v = 1; \alpha\right) - \Pr\left(\theta = g|a_t = 0, v = 1; \alpha\right)\right) \\ + \Pr(v = 0|s = 0)\left(\Pr\left(\theta = g|a_t = 1, v = 0; \alpha\right) - \Pr\left(\theta = g|a_t = 0, v = 0; \alpha\right)\right) \end{pmatrix} \\
&< \begin{pmatrix} \Pr(v = 1|a_t = 1)\left(\Pr\left(\theta = g|a_t = 1, v = 1; \alpha\right) - \Pr\left(\theta = g|a_t = 0, v = 1; \alpha\right)\right) \\ + \Pr(v = 0|a_t = 1)\left(\Pr\left(\theta = g|a_t = 1, v = 0; \alpha\right) - \Pr\left(\theta = g|a_t = 0, v = 0; \alpha\right)\right) \end{pmatrix}
\end{aligned}$$

where the inequality follows from the fact that, since managers with $s_t = 1$ also buy, $\Pr(v = 1|a_t = 1) > \Pr(v = 1|s = 0)$. The expression to the right of the inequality can, in turn, be written as follows:

$$\begin{aligned}
&\begin{pmatrix} \Pr(v = 1|a_t = 1)\Pr\left(\theta = g|a_t = 1, v = 1; \alpha\right) \\ + \Pr(v = 0|a_t = 1)\Pr\left(\theta = g|a_t = 1, v = 0; \alpha\right) \\ - \begin{pmatrix} \Pr(v = 1|a_t = 1)\Pr\left(\theta = g|a_t = 0, v = 1; \alpha\right) \\ + \Pr(v = 0|a_t = 1)\Pr\left(\theta = g|a_t = 0, v = 0; \alpha\right) \end{pmatrix} \end{pmatrix} \\
= \;&\Pr\left(\theta = g|a_t = 1; \alpha\right) - \begin{pmatrix} \Pr(v = 1|a_t = 1)\Pr\left(\theta = g|a_t = 0, v = 1; \alpha\right) \\ + \Pr(v = 0|a_t = 1)\Pr\left(\theta = g|a_t = 0, v = 0; \alpha\right) \end{pmatrix}
\end{aligned}$$

Thus, $\frac{1}{\beta}UB_D\left(\alpha\right)$ can be written as:

$$\Pr(a_t = 1)\left(\Pr\left(\theta = g|a_t = 1; \alpha\right) - \begin{pmatrix} \Pr(v = 1|a_t = 1)\Pr\left(\theta = g|a_t = 0, v = 1; \alpha\right) \\ + \Pr(v = 0|a_t = 1)\Pr\left(\theta = g|a_t = 0, v = 0; \alpha\right) \end{pmatrix}\right)$$

which, by adding and subtracting $\Pr(a_t = 0)\Pr(\theta = g|a_t = 0;\alpha)$, can be further written as:

$$\left(\begin{array}{c} \Pr(a_t=1)\Pr(\theta=g|a_t=1;\alpha) \\ +\left(\Pr(a_t=0)\Pr(\theta=g|a_t=0;\alpha)-\Pr(a_t=0)\Pr(\theta=g|a_t=0;\alpha)\right) \\ -\Pr(a_t=1)\left(\begin{array}{c} \Pr(v=1|a_t=1)\Pr(\theta=g|a_t=0,v=1;\alpha) \\ +\Pr(v=0|a_t=1)\Pr(\theta=g|a_t=0,v=0;\alpha) \end{array}\right) \end{array}\right)$$

$$\begin{aligned} &= \gamma-\left(\begin{array}{c} \Pr(a_t=0)\left(\begin{array}{c} \Pr(v=1|a_t=0)\Pr(\theta=g|a_t=0,v=1;\alpha) \\ +\Pr(v=0|a_t=0)\Pr(\theta=g|a_t=0,v=0;\alpha) \end{array}\right) \\ +\Pr(a_t=1)\left(\begin{array}{c} \Pr(v=1|a_t=1)\Pr(\theta=g|a_t=0,v=1;\alpha) \\ +\Pr(v=0|a_t=1)\Pr(\theta=g|a_t=0,v=0;\alpha) \end{array}\right) \end{array}\right) \\ &= \gamma-\Pr(\theta=g|a_t=0,v=1;\alpha)\left(\begin{array}{c} \Pr(a_t=0)\Pr(v=1|a_t=0) \\ +\Pr(a_t=1)\Pr(v=1|a_t=1) \end{array}\right) \\ &\quad -\Pr(\theta=g|a_t=0,v=0;\alpha)\left(\begin{array}{c} \Pr(a_t=0)\Pr(v=0|a_t=0) \\ +\Pr(a_t=1)\Pr(v=0|a_t=1) \end{array}\right) \\ &= \gamma-\left(\Pr(v=1)\Pr(\theta=g|a_t=0,v=1;\alpha)+\Pr(v=0)\Pr(\theta=g|a_t=0,v=0;\alpha)\right) \end{aligned}$$

Claim 3

$$\frac{\partial}{\partial\alpha}\left[\Pr(v=1)\Pr(\theta=g|a_t=0,v=1;\alpha)+\Pr(v=0)\Pr(\theta=g|a_t=0,v=0;\alpha)\right]>0$$

Proof of claim: From the expressions delineated above we know that:

$$\Pr(\theta=g|a_t=0,v=1;\alpha)=\frac{\rho\gamma}{\rho\gamma+\left(\rho+(1-\rho)(1-\alpha)\frac{1}{2}\right)(1-\gamma)}$$

and

$$\Pr(\theta=g|a_t=0,v=0;\alpha)=\frac{(\rho+(1-\rho)(1-\alpha))\gamma}{(\rho+(1-\rho)(1-\alpha))\gamma+\left(\rho+(1-\rho)(1-\alpha)\frac{1}{2}\right)(1-\gamma)}$$

Direct computation shows that

$$\frac{\partial}{\partial\alpha}\Pr(\theta=g|a_t=0,v=1;\alpha)>0,\ \frac{\partial}{\partial\alpha}\Pr(\theta=g|a_t=0,v=0;\alpha)<0$$

and that

$$\frac{\partial}{\partial\alpha}\Pr(\theta=g|a_t=0,v=1;\alpha)+\frac{\partial}{\partial\alpha}\Pr(\theta=g|a_t=0,v=0;\alpha)>0.$$

Since, for $v_t > \frac{1}{2}$, by definition, $\Pr(v=1) > \frac{1}{2} > \Pr(v=0)$, the claim is proved.■

From Claim 3 it follows that $UB_D(\alpha)$ is decreasing in α, and thus is maximized for $\alpha = 0$. But, since at $\alpha = 0$, $\widehat{w}_1^0 = v_t^0\frac{2\gamma}{1+\gamma}$, and $\widehat{w}_0^0 = w_0^0$ (the equilibrium expected posterior for a manager who does not trade when he receives signal $s_t = 0$).

$$\begin{aligned} UB_D(0) &= \beta \Pr(s_t = 1) \left(v_t^0 \frac{2\gamma}{1+\gamma} - w_0^0 \right) \\ &< \beta \Pr(s_t = 1) \left(w_1^1 - w_0^1 \right) = \pi_E \end{aligned}$$

because, it is clear that $w_1^1 = v_t^1 \frac{2\gamma}{1+\gamma} > v_t^0 \frac{2\gamma}{1+\gamma}$, and we have shown earlier than $w_0^1 < w_0^0$. Thus the deviation is unprofitable. This completes the proof for $v_t > \frac{1}{2}$.

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