Short-term Trading and Informational Cascades in Financial Markets

by

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Abstract

I propose a herding model to analyze the dynamics of financial markets in the presence of both short-term and long-term traders. I show that with the assumption of full rationality, the microstructure of markets prevent herd behavior and informational cascades. Albeit short-term traders stop trading sincerely if prices become precise enough, they are not able to manipulate long-term traders. However, in a modified model when long-term traders underestimate the myopia of the market, they engage in herd behavior, with positive probability on the wrong state. Short-term investors trade contrary to the herding mass due to the skewed distribution of returns. Prices do not converge to the true value of the asset, even on an infinite time horizon.

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Introduction

In recent decades, there has been a substantial increase in the institutional ownership of corporate equity¹, while the holding period of this class of investors has fallen significantly². Regarding these trends in the investor class that is traditionally considered to be long-termist, it seems a plausible assumption that on financial markets there are investors who base their decisions not on the fundamental value of an asset (i.e. the discounted value of all future cash flows) but on the price of the asset in a short time period. According to the efficient market hypothesis, the horizon of an investor does not matter. If every investor intends to hold an asset for only five minutes, than the price of that asset depends on the expectations on its price in five minutes, which depends on the expectations on its price in five minutes, which depends on the expectations on the fundamental value of the assures that investors speculate on the fundamental value of the asset (Froot et al., 1992).

¹For example, institutional investors held 49.8% of outstanding corporate equity on the New York Stock Exchange in 2002, while only 7.2% in 1950 (NYSE Factbook, 2003)

²According to the OECD (Della Croce et al., 2011), '(...) the average holding period [of institutional investors] has fallen between one and three years in selected OECD stock exchanges over the last twenty years. Looking further back, the drop is even greater. For instance, in the 1980s, the average holding period in the New York stock exchange was over 5 years, compared to 5 months today.'

However, there are various empirical puzzles that are hard to explain in the parsimonious and elegant framework of the efficient market models. For example, it is generally accepted in the financial economics literature that investors are prone to herding behavior, i.e to follow the public sentiment instead of their own private information and behave like 'imitative lemmings' (Avery and Zemsky, 1998, p.724). The causes of herding are still poorly understood despite the importance and frequent occurrence of such episodes. It is enough to think of the dotcom bubble, when large number of investors bought practically worthless tech stocks only because everyone was buying them. Various studies proposed different causes to explain the phenomenon, such as uncertainty of the existence and effect of a shock to the fundamentals (Avery and Zemsky, 1998), naive inference of traders (Eyster and Rabin, 2010) or career concerns of fund managers (Dasgupta and Prat, 2008).

In this paper I propose a sequential trading model to analyse herding and informational cascades in the presence of both short-term and long-term investors. I include a certain proportion of short-term traders whose profit depends not on the fundamental value of the asset, but on it's price in a short time period. I show that short-term trading only do not lead to informational cascades, as the microsturcture of financial markets prevents such anomalies. Short-term traders do not trade sincerely if prices are precise enough, but they are not able to manipulate the market by pushinhg prices up or down. I will modify the model by introducing a behavioral bias called the 'curse of knowledge', as coined by Camerer et al. (1989) and extended by Madarasz et al. (2014). In this modified model, long-term traders overestimate the investment horizon of the market by projecting their preferences on short-term traders. A simple model reveals somewhat counterintuitive insights. In my model, long-term traders do engage in herd behavior, with positive probability on the wrong state, as they attach greater information content to the history of market orders. At the same time, short-term traders are 'leaning against the wind', i.e. they are trading contrary to the herding mass due to the skewed distribution of re-

turns. Also, in this setup prices fail to aggregate private information fully. Informational cascade will occur if prices are close enough to one of the extremes. Even on an infinite time horizon, prices do not converge to the true value of the asset. Information revelation falls behind the socially optimal level. To my knowledge, my paper is the first to include short-termism directly in a herding model. Also, the behavioral bias I include have not been examined in models of centralized financial markets.

My paper connects two strands of the literature. The first strand is the theory on the effect of short-term traders on financial markets, while the second strand studies rational herding. Short-term trading is a topic that has a long tradition in economics dating back to Keynes and his well-known beauty contest metaphor, in which investors make decisions based on the anticipation of other investors' beliefs, not on the fundamental value of the asset (Keynes, 1936). He had a dismal opinion on financial markets, largely due to short-term traders³. Allen et al. (2006) showed that contrary to standard asset pricing theory, higher order expectations (guessing the publics opinion on the fundamental value of the asset, or guessing the public's opinion on the public's opinion and so on) play a role in the price of financial assets. If there is differential information between investors, average expectations fail to satisfy the law of iterated expectations. Cespa and Vives (2014) quantify those results and show that in the presence of short-term traders the market has multiple equilibria, and under certain informational properties the beauty contest metaphor is valid, implying weakly informative prices and excess volatility. I will

 $^{^3}$ 'If the reader interjects that there must surely be large profits to be gained (...) in the long run by a skilled individual who purchases investments on the best genuine long-term expectation he can frame, he must be answered (...) that there are such serious-minded individuals and that it makes a vast difference to an investment market whether or not they predominate. (...) But we must also add that there are several factors which jeopardise the predominance of such individuals in modern investment markets. Investment based on genuine long-term expectation is so difficult (...) as to be scarcely practicable. He who attempts it must surely (...) run greater risks than he who tries to guess better than the crowd how the crowd will behave.' (Keynes, 1936, p.157)

examine the effect of short-term traders on the behaviour of long-term traders and the dynamics and informativeness of asset prices. In my model, short-term traders use their private information not to infer the true value of the asset, but the actions of next traders and the future price of the asset, just as in the beauty contest of (Cespa and Vives, 2014).

The second strand is the theory of herding on financial markets. The basic idea and modeling setup was introduced by Banarjee (1992) and Bikhchandani et al. (1992) (hereinafter referred to as BHW) who studied the process of social learning from aggregating private information. In these models, sequentially arriving agents receive a noisy private signal and choose between two possible actions. They try to infer previous agents private information from observing past actions. In Banarjee's example people arrive sequentially and choose between two restaurants. A guest with negative information on restaurant A may be swayed to enter it anyway, if he sees that A was chosen by two more previous guests than B (the information in two positive action may outweigh the private negative information). All subsequent guests will enter A, albeit they know that the market has not incorporated more private information due to herding. The implication of these models is that herding behavior is frequent, even on the wrong state, initial actions have disproportionately greater weight in the process of social learning, and herding happens with low consensus and hence high fragility. I buld on the sequential approach and Bayesian belief-updating process of these models.

The literature on herding and social learning in dynamic financial markets with asymmetric information was estabilished by Glosten and Milgrom (1985), where informed traders buy or sell a stock to Bertrand competing, uninformed market makers in a BHW-style model. The paper finds that the market learns the true value of the asset on a long-enough time horizon. Avery and Zemsky (1998) showed that when the restaurant-model is applied to financial markets, price adjustments prevent herd behavior. An important result of the paper is that herding behavior is only present when there is multidimensional uncertainty on the market, i.e. when the market is uncertain on both the existence and the effect of a shock that hit the true value of the asset. Pricing bubbles might appear only with a third dimension of uncertainty, when the market makers do not know the quality of traders information.

However, many studies critique the results of financial herding literature on behavioral grounds. Eyster and Rabin (2010) emphasized that the full rationality assumption of these models leads to extreme or unrealistic results. The level of sophistication of people is not plausible and the predicted behavior seems unlikely, as showed by many lab experiments (see for example Kübler and Weizsäcker (2004) or Eyster and Rabin (2010)). The main critique is that the rational herding literature implies that herds on the wrong state are never confident and therefore fragile. Richer information and signal spaces eliminate herds almost completely. Thus, they suggest that the models should be extended with some form of behavioral bias to capture reality better. Based on these result, I will propose a model in which long-term investors' judgements on the composition of the market participants are biased.

In my model, to capture that even long-term investors may be misled by short-term speculation I build on the behavioral bias called the curse of knowledge as introduced to economics by Camerer et al. (1989). This concept is based on lab experiments showing that despite the conventional economic intuition regarding asymmetric information, more information might eventually hurt. Better-informed agents are not able to ignore their own private information and reproduce the judgment of less-informed agents, as the betterinformed project their own information on the less-informed. For example, a seller of a lemon might set lower price to compensate for defects that are unobservable for the buyer. Furthermore, in a recent study Madarasz et al. (2014) showed that not only better-informed agents exaggerate the extent to which less-informed agents should act as if they were better informed, but lesser-informed agents anticipate such misperceptions as revealed by their experiments. Thus, the buyer is aware that the seller overestimates her knowledge and bargains accordingly. In my model, long-term investors overestimate the horizon of the market, projecting long-term, fundamental thinking on all fund managers on the market, while short-term investors are aware of this and trade accordingly.

The motivation behind my model is that fund managers often face short-term incentives (Chevalier and Ellison, 1998), and this can influence asset prices.Dasgupta and Prat (2008) examine the behavior of rational fund managers who have career concerns in their uility function. They show that the equilibrium properties of a market where traders care about their reputation for investing ability are very different from standard markets. The extent to which prices are able to aggregate private information is limited, as conformism arises when prices become more precise and fund managers engage in herd behavior. However, fund managers are constantly measured to benchmarks, and cannot rely on reputation in keeping their investors for long ⁴. Thus, including short-term returns directly into the profit function of certain part of traders allows for a more upfront, first-order analysis. My goal is to examine how asset prices behave in such an environment if part of the traders directly optimize on a short horizon.

I propose a basic BHW-style model with short-term traders with a behavioral bias inspired by the 'curse of knowledge' in Section 2. In Section 3, I present some insights from the basic model and analyze the effect of the 'curse of knowledge' on long-term traders and the dynamics of prices. Finally, Section 4 concludes my analysis.

⁴An illustrative example is the case of two legendary hedge fund managers, Stanley Druckenmiller of Quantum Fund and Julian Robertson of Tiger Managment, both of whom suffered substantial losses and capital outflows during the dotcom bubble (see New York Times, 2000)

The model

To analyze the behaviour of prices and investors in a market with short-term and longterm traders, I will use a simple sequential trading model of dynamic, centralized financial markets. In the literature, my model is closest to (Avery and Zemsky, 1998), with only a binary signal space and two types of fund managers.

2.1 Basic model with short-term traders

A single asset is traded on the market with an equiprobable liquidation value of $\theta = 0$ or 1, referred to as the true value of the asset. This could be associated to the fundamental value of a stock, or the principal payment of a bond. Timing is discrete and the time horizon is infinite. Prices are set by Bertrand-competing, risk neutral, profit maximizing market makers who interact with a sequence of individuals chosen from a continuum of traders following the standards of the literature (Glosten and Milgrom, 1985). For convenience, I will refer to the market maker in singular, although the assumption of competing market makers is valid throughout the analysis. Quoted prices are equal to the expected value of θ based on all publicly available information, i.e. the history of observed trades at the beginning of period t, denoted by H_t . The expected value of the market maker at the beginning of time period t is

$$p_t = \mathbb{E}_t[\theta = 1|H_t] \tag{2.1}$$

. I will refer to this expectation as prior. The market maker is restricted to zero profit by perfect competition, but she sets a bid-ask spread after observing the trader's chosen action to allow for adverse selection. Hence, the trader arriving in period t faces a bid p_t^b when she wants to sell the asset and an ask p_t^a when she wants to buy the asset:

$$p_t^b = \mathbb{E}_t[\theta = 1 | H_t, h_t = sell] \tag{2.2}$$

$$p_t^a = \mathbb{E}_t[\theta = 1 | H_t, h_t = buy]$$
(2.3)

There are two types of traders, fund managers and noise traders. At each period $t \in \{1, 2...\}$ either a fund manager or a noise trader arrives to the market maker with probabilities $1 - \mu$ and $\mu \in (0, 1)$ respectively. Each trader is risk neutral, and chooses an action h_t to buy $(h_t = buy)$ one unit or to sell $(h_t = sell)$ one unit of the asset, or refrain from trading. Noise traders trade for liquidiy reasons. For simplicity, assume that noise traders choose their action randomly with equal $\frac{1}{3}$ probability on each possible action. Thus, each action has probability $\gamma \equiv \frac{1-\mu}{3}$ independently from trading history. Fund managers receive a private, noisy signal $s_t \in \{0, 1\}$ on the true value of the asset that is precise with probability 0.5 < q < 1. Fund managers form expectaions rationally, based on the Bayes-rule. Thus, the valuation of a trader receiving a negative signal is

$$\theta_0^t = \mathbb{E}[\theta|s_t = 0, H_t] = \frac{(1-q)p_t}{(1-q)p_t + q(1-p_t)}$$
(2.4)

,

while the infromed trader receiving a positive signal updates his prior as

$$\theta_1^t = \mathbb{E}[\theta|s_t = 1, H_t] = \frac{qp_t}{qp_t + (1-q)(1-p_t)}$$
(2.5)

There are two types of fund manager in the model: $\mu \in (L, S)$, where L denotes longtime investor (a fund manager optimizing on the true value of the asset) and S denotes short-term investor (a fund manager optimizing on the price of the asset in period t + n). A fund manager is short-term investor with probability $\alpha \in (0, 1)$, thus α is the measure of the 'myopia' of the market. There is $(1 - \alpha)\mu = \mu_L$ probability that a long-term investor arrives in period t, and $\alpha \mu = \mu_S$ probability that a short term investor. The payoff of a long-term investor depends on the true value of the asset:

$$\pi_t^L(h_t, p_t^a, p_t^b, \theta) = \begin{cases} \theta - p_t^a & \text{if } h_t = buy\\ p_t^b - \theta & \text{if } h_t = sell \end{cases}$$
(2.6)

The payoff of a short-term investor μ_S depends on the market price of the asset at time period t + n:

$$\pi_t^S(h_t, p_t^a, p_t^b, p_t(t+n)^a, p_t(t+n)^b) = \begin{cases} p_{t+n}^h - p_t^a & \text{if } h_t = buy, h_{t+n} = h\\ p_t^b - p_{t+n}^h & \text{if } h_t = sell, h_{t+n} = h \end{cases}$$
(2.7)

where p_{t+n}^h is the price set by the market maker in period t + n if the market order is h. For example, if the action chosen by trader t + n is buying the asset, the profit of the short-term investor will be $\pi_t^S = p_{t+n}^a - p_t^a$, but if trader t + n rather decides to sell the asset, the profit will be $\pi_t^S = p_{t+n}^b - p_t^a$. Short-term traders can be conceived as fund managers who need to impress their investors and are under the pressure of short-term benchmarks.

The strategic players of the above model are fund managers. The vector $\underline{\lambda}_{H_t}$ denotes the strategy of a long-term investor in period t given history H_t , with $\lambda_{H_t}^h(s_t)$ denoting the probability that she takes action h having received signal s_t . The vector $\underline{\sigma}_{H_t}$ denotes the strategy of a short-term investor in period t given history H_t , with $\sigma_{H_t}^h(s_t)$ denoting the probability that she takes action h having received signal s_t . To shorten notation, and when this is unlikely to create confusion, I will use λ_t , σ_t instead of λ_{H_t} , σ_{H_t} .

The structure of the game described above is common knowledge. A Bayesian Nash equilibrium of the game consists of sequences $\underline{\lambda}_{H_t}$ and $\underline{\sigma}_{H_t}$ maximizing expected profits for fund managers with prices set by the Bertrand-competing market maker as in 2.1.

Definition 1. The sequences $\underline{\lambda}_{H_t}$ and $\underline{\sigma}_{H_t}$ are Bayesian Nash equilibrium of the game if and only if they satisfy

- $\lambda_{H_t}^{buy}(s_t) \ge 0 \implies \mathbb{E}[\theta_t | s_t, \sigma_t] \ge p_t^a$; with p_t^a given by 2.3.
- $\lambda_{H_t}^{sell}(s_t) > 0 \implies \mathbb{E}[\theta_t | s_t, \sigma_t] \le p_t^b$; with p_t^b given by 2.2.
- $\mathbb{E}[\theta_t|s_t, \sigma_t] > p_t^a \implies \lambda_{H_t}^{buy}(s_t) = 1$; with p_t^a given by 2.3.
- $\mathbb{E}[\theta_t|s_t, \sigma_t] < p_t^b \implies \lambda_{H_t}^{sell}(s_t) = 1$; with p_t^b given by 2.2.
- $\sigma_t^{buy}(s_t) > 0 \implies \mathbb{E}[p_{t+n}|s_t, \lambda_t] p_t^a \ge 0$ with p_t^a given by 2.3.
- $\sigma_t^{sell}(s_t) > 0 \implies p_t^b \mathbb{E}[p_{t+n}|s_t, \lambda_t] p_t^a \ge 0$ with p_t^b given by 2.2.
- $\mathbb{E}[p_{t+n}^h|s_t, \lambda_t] > p_t^a \implies \sigma_t^{buy}(s_t) = 1$; with p_t^a given by 2.3.
- $\mathbb{E}[p_{t+n}^h|s_t, \lambda_t] < p_t^b \implies \sigma_t^{sell}(s_t) = 1$; with p_t^b given by 2.2.

where $\mathbb{E}[\theta_t|s_t, \sigma_t]$ and $\mathbb{E}[\theta_t|s_t, \lambda_t]$ are Bayesian updated beliefs on the true value of the asset.

Part one (part two) claims that long-term investors only buy the asset (sell the asset) if they expect to earn positive profits by doing so. Part three (part four) claims that longterm investors always buy the asset (sell the asset) the action grants strictly postive profits in expectation. Part five (part six) claims that short-term investors only buy the asset (sell the asset) if they expect that the price of the asset will be higher (lower) in period t + nthan in period t. Part seven (eight) claims that short-term investors always buy the asset (sell the asset) if by doing so they expect to make strictly positive profits.

2.2 The curse of knowledge

For modeling the behavioral bias of long-term traders, I will use the concept of Camerer et al. (1989) as extended by Madarasz et al. (2014). The 'curse of knowledge' in this setup implies that long-term traders are unable to abstract from their own preferences, even when it would be their interest to do so. That is, they assume that every fund manager on the market optimizes the true value of the asset. Short-term traders are aware of the biased judgment of long-term traders, and update beliefs accordingly. I assume that the market maker is fully rational. Formally, the prior of long-term traders and the market maker will diverge, as they update the unconditional mean by aggregating private information differently.

Results

First, for a precise analysis, I would like to introduce a formal definition of informational cascades and herding, after referring to these phenomena several time informally. Differentiating between the two phenomena is important, as imitative behavior not neccessary implies an informational cascade

Definition 2. An informational cascade occurs in the market in period t when

$$P[h_t|s_t, H_t] = P[h_t|H_t] \qquad \forall h_t, s_t \tag{3.1}$$

During an informational cascade, traders trade regardless their signal. Thus, no new information reaches the market, as the distribution of publicly observable actions is independent of the true value of the asset. As for herding, in this paper I will use an approach analogous to Avery and Zemsky (1998), who define herd behavior of a trader as imitating previous actions instead of following private information 1 .

¹However, there are various definitions of herding in the literature. (Vives, 1997) defines herding as socially inefficient reliance on public information that hampers efficient social learning.

Definition 3. A long-term trader with private information s_t engages in herd behavior at time t when $\lambda_{H_t}^{buy}(0) = \lambda_{H_t}^{buy}(1)$ or $\lambda_{H_t}^{sell}(1) = \lambda_{H_t}^{sell}(0)$.

Herd behavior occurs when a long-term trader's action is independent of her signal. In a herding period, if she receives negative (positive) private information on the true value of the asset, yet her strictly prefferred action is to buy (sell) the asset, after observing market history H_t . During herds, it is optimal for a trader to disregard her private information. In a model with only long-term investors and only one dimension of uncertainty (on the true value of the asset), the microstructure of financial market would prevent herd behavior, as shown by (Avery and Zemsky, 1998). In rational herding models, herding is an extreme event which occurs rarely, with low confidence in the value of the asset hence high fragility.

3.1 Basic model with short-term traders

In my basic model with short-term traders, each actor is perfectly rational. Fund managers receive a signal s_t on the true value with the same precision q. Long-term traders and the market maker are aware that there is a probability μ_S that a short-term trader arrives who optimizes on the price of the asset in period t + n instead of the true value of the asset. Throughout the following analysis, I will concentrate on the case when n = 1.

Proposition 1 states an important feature of the basic model. Because noise traders are willing to absorb any amount of losses, and due to the assumption of full rationality longterm traders will always trade. The informational advantage vis-á-vis the market maker ensures that following private signals is always a dominant strategy.

Proposition 1. In the basic model with short-term traders, a rational long-term trader will always trade and follow her signal.

Proof. Consider the example of a long-term trader arriving with a positive signal $(s_t = 1)$. There is an informational advantage in her favor, as she updates the prior of the market based on a signal with precision q:

$$\theta_t^1 = \frac{qp_t}{qp_t + (1-q)(1-p_t)}$$
(3.2)

The market maker has to take into consideration the possibility that a noise trader or a short-term trader (see below) arrived:

$$p_t^a = \frac{(\gamma + \mu_L q + \mu_S q_S)p_t}{(\gamma + \mu_L q + \mu_S q_S)p_t + (\gamma + \mu_L (1 - q) + \mu_S (1 - q_S))(1 - p_t)}$$
(3.3)

where $q_S = q$ if the short-term trader follows her signal and $q_S = 0$ if she does not.

Note that the market maker and the long-term trader interpret the history of market orders in the same way. Both possess the same information on the composition of past traders and the information content of market orders. That is, they will update the same prior p_t . However, the long-term trader arriving at time t receives a private signal on the true value of the asset. The market maker does not know what type of trader arrives, therefore the bid and the ask prices are the weighted averages of the valuations of the possible types of traders arriving in the given period. Hence, the valuation of the long-term trader with a positive signal will always be higher than the ask price, resulting in positive expected profits from trading according to the signal. Following the very same logic, proving that a long-term trader arriving with a negative signal will engage in selling is straightforward.

This result is in line with the findings of Avery and Zemsky (1998) who showed that the driving forces behind informed trading are the information asymmetries between traders and the market maker. The history of market orders can only trigger herding if it is interpreted differently by informed traders and the market maker.

In the presence of short-term traders, it is neccessary to introduce a concept that is different from herding. Consider a case when a short-term speculator with a negative signal buys the asset in order to generate a herd and profit from the increased price in a later period.

Definition 4. A short-term trader engages in manipulative trading if she trades contrary to her private information in order to influence the next trader to perform the action most favorable to the short-term trader.

An important distinction between manipulative trading and herd behavior is that in case of the former, the speculator trades against his signal intentionally, in order to influence the perceived history of the next trader. Note that the expected profit of the short-term speculator arriving in time period t is not directly dependent on the true value of the asset. She utilizes her private signal to infer the action of the trader in period t + 1. Proposition 2 describes the behavior of short-term traders in the basic model.

Proposition 2. A short-term trader follows her signal when the market prior is in the interval $I \in (1 - \underline{p_t}, \underline{p_t})$, hereinafter referred to as the 'interval of sincerity'. Outside of interval I, short-term traders will always sell (buy) if the prior is converging to 1 (0).

Proof. See Appendix.

Assume that there is a 'bullish' history, i.e. the trader arriving in period t observes more buy than sell orders. As prices become more accurate, subsequent buy orders move the price less and less. As the price setting process is symmetric, i.e. a buy order outweighs a sell order, if a 'surprising' order arrives, prices react stronger. Intuitively, the market maker thinks that a a surprising order contains more information, and updates prices accordingly. Due to this skewed distribution of returns, if prices are sufficiently precise, short-term traders will speculate contrary to trading history. Even though the probability of a contrarian action in the next period is smaller, the expected value of a contrarian trade becomes greater due to the higher profit from it. Nevertheless, this does not imply that short-term traders are able to manipulate the market into trading against private information.

Proposition 3. Manipulative trading is not possible in the basic model.

Proof. It follows from Proposition 1 and 2. Although short-term traders deviate from their signal, they cannot manipulate long-term traders, who will always follow their signal. \Box

Therefore, from this simple model one can conclude that the presence of short-term traders only does not cause herding. The microstructure of financial markets prevent manipulative trading. Yet, short-term traders may deviate from their private signal as market prices become precise enough, and trading profits from sincere trading become small. Due to short-term traders, the market will learn the true value of the asset at a slower pace than in the benchmark model of Glosten and Milgrom (1985), as short-term traders are trading contrarian when prices become accurate enough.

3.2 A model with behavioral bias

In the following, I will examine a slightly modified model, using the behavioral bias called the 'curse of knowledge' (Camerer et al., 1989). In this section, I assume that long-term traders underestimate the 'myopia' of the market: even in the presence of short-term traders, they act as if there were more long-term, fundamental traders on the market, and less short-term speculators. Short-term speculators are perfectly aware of the biased judgement of long-term traders, and trade accordingly (as in Madarasz et al. (2014)). Take the simplest case, where long-term traders completely ignore the different incentives of short-term traders, and act as if every trader would be a long-term investor optimizing on the true value of the asset. Clearly, this is a strong assumption, but this simple model helps to understand the dynamics of markets with short-term traders.

Proposition 4 shows how the behavior of long-term traders changes in the presence of this judgemental bias. A key feature of the model is that the market maker is fully rational, he is aware that short-term traders are present on the market. Thus, long-term traders might become overly optimistic or pessimistic as prices converge to 1 or 0, and engage in herding.

Proposition 4. In the model where long-term traders do not know about the myopia of the market, there is herding with positive probability, which is misdirected with positive probability.

Proof. See Appendix.

In this setup, long-term traders misjudge the information content of market orders, as they ignore the presence of short-term traders. However, short-term traders traders know about this behavioral bias, and update priors accordingly. The market maker is perfectly rational. As the prior becomes more accurate and leaves the interval of sincerity, shortterm traders stop trading sincerely, but long-term traders are not aware of this. They assign greater information content to market orders than the market maker, thus beliefs on the true value of the asset will start to diverge. Eventually, for a large enough bullish (bearish) history, even the prior of long-term traders with negative (positive) signal will be larger than the ask (bid) set by the market maker, and herding occurs. Due to noise traders, every trade history occurs with positive probability. Therefore, herding on the wrong state also happens with positive, albeit low probability.

An interesting result of the model is that when long-term traders start herding, shortterm traders will behave as contrarians, counterbalancing the herding mass. Intuitively, the case is analogous to a situation when prices have been rising for a long time, and short-term traders start to speculate on the collapse of the price.

Proposition 5. Short-term traders outside the interval of sincerity will push prices towards the unconditional mean.

Proof. Take the case of herd buying. Knowing that a long-term trader arriving next period would buy regardless of her signal, short-term trader t can make greater profit from buying than from selling. Notwithstanding, the market maker also knows where long-term traders start herding, and she also knows the incentives of short-term traders. Note that by construction of the model, herding occurs only outside of the interval of sincerity, where priors of long-term traders and the market maker start to diverge. Thus, when the prior of long-term traders reach a threshold p'_t where herding of long-term traders start, buy orders stop containing any more for the market maker. Hence, she will stop increasing prices.

Nonetheless, this alters the short-term traders' best response. If prices cannot increase, the highest profit they can expect from buying the asset is zero. Therefore, they will sell, regardless of the signal. If a short-term trader arrives during a period of herding, she will trade contrary to the herding mass, and may end herding by moving price towards the unconditional mean. Thus, herding stop endogenously almost surely. The above argumentation is valid for herd selling as well. \Box

The reason of the contrarian behavior of short-term traders is the skewed distribution of returns. In this sense, short-term traders are beneficial to the market, as their market orders push the prices against the herding mass, which will result that herds will end endogenously almost surely. However, this setup implies that prices cannot converge to the true value of the asset. In Glosten and Milgrom (1985) the market maker always learn the true value of the asset on an infinite time horizon. In this setup, the case is different.

Proposition 6. Informational cascades occur with positive probability in the market equilibrium when long-term traders do not know about short-term traders. *Proof.* Following from Proposition 5, if the prior of long-term traders exceeds a treshold p'_t and they engage in herding, the market maker will stop updating prices. As short-term traders will not follow their private signal either, no information reaches the market. However, mainly due to short-term traders, information cascades almost surely end endogenously.

In this model, prices will never leave the interval $(1 - p'_t, p'_t)$, convergence to 0 or 1 does not happen. The market maker will never learn the true value of the asset. This shows an inefficiency caused by short-term traders and the judgemental bias of long-term traders, as in the benchmark model of (Glosten and Milgrom, 1985), the market eventually learns the true value of the asset.

Conclusion

The key message of this paper is that we should expect the presence of short-term traders to affect the dynamics of financial markets. Particularly, I showed that the presence of shortterm traders only cannot induce herding, and manipulative trading strategies cannot be profitable. The institutions of financial markets prevent such biases. However, if long-term traders underestimate the myopia of the market, they might become overly optimistic or pessimistic as prices become accurate enough, thus herding occurs with positive probability, even on the wrong state. Short-term traders are 'leaning against the wind' during herding periods, for example they sell when every long-term trader are buying, speculating on the collapse of the price. This is due to the skewed distribution of returns.

As (Della Croce et al., 2011) emphasizes, regulators are increasedly concerned about short-temism amongst institutional investors. According to my results, the main problem is that long-term traders underestimate the myopia of the market. However, the topic needs thorough empirical analysis. An ideal dataset would contain a large number of fund managers' holding period of traded assets, and their estimation of the market's holding period. Is there a projection of one's own holding period to other investors? Also, the behaviour of fund managers should be examined: do short-term traders indeed trade in a contrarian way after a bullish or bearish history? If empirical evidence would confirm the results of my model, regulators should focus on increasing the transparency on the investment horizon of fund managers, to reduce the judgmental biases.

I have built a simple, stylized model with short-term traders and a behavioral bias called the 'curse of knowledge'. I believe that my model should be developed in future research to handle richer and more realistic setups. Considering the growing importance of institutional investors and the shortening investment horizons of them, the effects of short-term trading might be an important tppic of researchers and regulators.

Appendix

Proof of Proposition 2

Proof. As shown in Proposition 1, if trader t + 1 is a long-term trader, she will follow her signal regardless of the action of short-term trader t. Assume that short-term traders always follow their signal as well. Take the case when $s_t = 1$. The short-term speculators expected profit depends on the expected action of the next trader. Introduce the notations

$$A \equiv P(h_{t+1} = buy|h_t = buy, s_t = 1) = \gamma + (\mu_L + \mu_S)[q^2 + (1-q)^2]$$
(A.1)

$$B \equiv P(h_{t+1} = sell | h_t = buy, s_t = 1) = \gamma + (\mu_L + \mu_S)[2q(1-q)].$$
(A.2)

where A is the probability that the next trader's action will be the same (i.e. receives the same signal or noise trader) as the short-term trader in period t, and B is the probability that her action will be different. Note that A > B, for any $q \in (0.5, 1)$. Based on Proposition 1 and our initial assumption, the next informed trader's signal implies the next trader's action. Then, the expected profit of the short-term trader following a positive

signal and buying is as follows:

$$\mathbb{E}[\pi_{t+1}^S | s_t = 1, h_t = buy] = A(p_{t+1}^a - p_t^a) + B(p_{t+1}^b - p_t^a)$$
(A.3)

where $p_{t+1}^a - p_t^a$ is positive payoff, in case the next action is also buy and prices increase, and $p_{t+1})^b - p_t^a$ is negative payoff in case the next action is sell.

In contrast, if she would deviate from her signal, the expected profit would be

$$\mathbb{E}[\pi_{t+1}^S | s_t = 1, h_t = sell] = B(p_t^b - p_{t+1}^b) + A(p_t^b - p_{t+1}^a)$$
(A.4)

where $p_t^b - p_{t+1}^b$ is positive payoff when the next action is also sell, and $p_t^b - p_{t+1}^a$ is negative payoff in case the next action is buy. The initial assumption on the sincere trading of the short-term investor is true if

$$\mathbb{E}[\pi_{t+1}^{S}|s_{t} = 1, h_{t} = buy] > \mathbb{E}[\pi_{t+1}^{S}|s_{t} = 1, h_{t} = sell]$$
(A.5)

in every possible equilibria. Note that this expression is equivalent to

$$\frac{A}{B}[(p_{t+1}^{aa} - p_t^a) + (p_t - p_t^b)] > (p_t^b - p_{t+1}^{bb} + (p_t^a - p_t)$$
(A.6)

where p_{t+1}^{aa} (resp. p_t^{bb}) is the price of the asset if $h_t = h_{t+1} = buy$ (resp. sell). Also, note that the price set by the market maker in period t in case $h_t \neq h_{t+1}$ is exactly the prior p_t of period t, due to Bayesian updating process of the market maker.

When prices converge to 1 after a string of buys, each subsequent buy action will move the price less and less, as the information content of the same action is decreasing. As $p_t \to 1, (p_t^a - p_t)$ and $(p_{t+1}^{aa} - p_t^a) \to 0$. At the same time, if a 'surprising' sell order arrives after a bullish history to the market maker, it will have a larger effect on the price. The proportion of the effect of buy and sell orders, $|\frac{p_t^b - p_t}{p_t^a - p_t}|$, and $|\frac{p_{t+1}^{bb} - p_t^b}{p_{t+1}^a - p_t^a}|$ are increasing in p_t . From this, it follows that the above inequality cannot be true after trespassing a prior \underline{p}_t that is large enough, as the increasement in the former proportions will outweigh that coefficient $\frac{A}{B} > 1$. As the prior gets larger, the proportional difference between price changes downward and upward gets larger as well. From this, it follows that the above inequality cannot be true after exceeding a prior \underline{p}_t that is large enough. Thus, for every A and B, it is possible to find a \underline{p}_t where if $p_t > \underline{p}_t$, then

$$\frac{A}{B}(p_{t+1}^{aa} - p_t^a + p_t - p_t^b) < (p_t^b - p_{t+1}^{bb}) + (p_t - p_t^a)$$
(A.7)

We arrived to a controversy. Short-term investors do not trade sincerely after a long enough bullish history if they receive a positive signal. If they receive a negative signal, however, they will also sell, as

$$\mathbb{E}[\pi_{t+1}^{S}|s_{t} = 0, h_{t} = sell] > \mathbb{E}[\pi_{t+1}^{S}|s_{t} = 0, h_{t} = buy]$$
(A.8)

or, equivalently

$$\frac{A}{B}(p_t^b - p_{t+1}^{bb} + p_t^b - p_t) > (p_{t+1}^{aa} - p_t^a) + p_t - p_t^b)$$
(A.9)

is always true assuming a bullish history, following a logic similar to the positive signal case. In every possible equilibrium, after a threshold prior \underline{p}_t short-term traders will sell regardless their signal. Thus, from the viewpoint of the market maker and the long-term investor, after the prior surpassed \underline{p}_t (which is public information), the action of a short-term trader does not contain any information regarding her signal. That is, short-term investors are treated just like noise traders when the prior is not in the interval of sincerity, as their action contains no information on their signal. Following the same logic, the proof is straightforward on the negative side as well. As the Bayesian updating process of the

market maker is symmetric by construction, the interval of sincerity is symmetric as well, that is $I \in (1 - \underline{p_t}, \underline{p_t})$.

Proof of Proposition 4

Proof. Take the case of herd buying. There is herd buying if $\theta_0^t > p_t^a$. Because of noise trading, any finite history occurs with positive probability. Suppose that there is a bullish history, i.e. t = 2n + k, and the long-term informed trader arriving at period t observes n sell orders and n + k buy orders. The market maker knows that in each period there is μ_s probability that a short-term trader arrives, but the long-term trader does not.

Until the prior is in the 'interval of sincerity', the valuation of the market maker and the long-term trader is the same, as short-term traders follow their signal, and their actions convey valuable information to the market. After having exited the 'interval of sincerity', the market maker knows that short-term traders will sell regardless their private information, thus a buy order conveys less information, as the probability that a sincere trader arrived has decreased. The priors of the market maker and the long-term trader outside of the 'interval of sincerity' will diverge:

$$p_t^{MM} = \frac{[\gamma + (\mu_L + \mu_S)q]^x(\gamma + \mu_L q)^{b-s-x}}{[\gamma + (\mu_L + \mu_S)q]^x(\gamma + \mu_L q)^{b-s-x} + [\gamma + (\mu_L + \mu_S)(1-q)]^x[\gamma + \mu_L (1-q)]^{b-s-x}} < p_t^{LTT} = \frac{\gamma + (\mu_L + \mu_S)q]^{b-s}}{[\gamma + (\mu_L + \mu_S)q]^{b-s} + [\gamma + (\mu_L + \mu_S)(1-q)]^{b-s}}$$
(A.10)

where b - s is the difference between buy and sell orders in history H_t , and x is the number of buy orders inside the interval of sincerity. Therefore, the prior of the market maker is no greater in a bullish history than that of the long-term trader. There is herd

buying if

$$\theta_t^0 = \frac{(1-q)p_t^{LT}}{(1-q)p_t^{LT} + q(1-p_t^{LT})}$$

$$> p_t^a = \frac{(\gamma + q\mu_L)p_t^{MM}}{(\gamma + q\mu_L)p_t^{MM} + [\gamma + (1-q)\mu_L](1-p_t^{MM})}$$
(A.11)

which is equivalent to

$$\frac{(1-q)^2 \mu_L + (1-q)\gamma}{(\gamma+q)q\mu_L} \frac{1-p_t^{MM}}{p_t^{MM}} > \frac{1-p_t^{LT}}{p_t^{LT}}$$
(A.12)

Note that $\frac{(1-q)^2 \mu_L + (1-q)\gamma}{(\gamma+q)q\mu_L} < 1$ for any $0 < \mu < 1$ and $q \in (0.5, 1)$. As b-s increases, p_t^{LT} converges faster to 1 than p_t^{MM} , thus $\frac{1-p_t^{LT}}{p_t^{LT}}$ converges faster to 0 than $\frac{1-p_t^{MM}}{p_t^M M}$. Therefore, the above inequality will always be true for a bullish enough history. For given precision q and proportion of short-term traders α there is always a value k such that $\theta_0^t > p_t^a$. The central point of this argumentation is that the prior of the long-term trader increases faster than the market maker, as she overestimates the investment horizon of the market.

A similar reasoning estabilishes that herd selling also occurs with positive probability. Therefore, due to noise traders, herding on the wrong direction occurs with positive probability. $\hfill\square$

To illustrate the above reasoning, I present some of my numerical simulations with two different market setups. The x axis shows the number of subsequent buys, while the y axis shows the difference between the valuation of a long-term trader with a judgemental bias receiving a negative signal, and the ask price set by the rational market maker $(\theta_0 - p_t^a)$. If the difference becomes positive, herd buying starts.

In the first market, half of the market participants are informed traders, and half of informed traders. I present setups with three different information precision setups. In the second market, 80% of market participants are informed traders, but only 25% of them are long-term traders. Again, three different setups are presented based on different information precision. Herding occurs in all cases.



Figure A.1: $\theta_0 - p_t^a$, with parameters $\mu = 0.5$, $\alpha = 0.5$ and precision of signal q from left to right is 0.55, 0.75 and 0.95



Figure A.2: $\theta_0 - p_t^a$, with parameters $\mu = 0.8$, $\alpha = 0.75$ and precision of signal q from left to right is 0.55, 0.75 and 0.95

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