# Naive herding in financial markets

*Tamás László Bátyi*

Central European University

Department of Economics

In partial fulfilment of the requirements for the degree of Master of Arts

Supervisor: Professor Ádám Szeidl

Budapest, Hungary

2013

# Abstract

In this paper I propose models of naive herding on financial markets. I show that in a simple model with inferential naivete only, the microstructure of markets prevent even naive agents to engage in herd behavior. Then I suggest a model with correlated private signals and show that if biased agents neglect the correlation structure of the signals, that can result in naive herding even in the simplest possible environment. Moreover, with the existence of both rational and naive agents, informational cascades do occur with positive probability and herding on the wrong states stop endogenously almost surely, so this model has results that are very similar what can be observed in real financial markets. The model has also important implications about how naive beliefs could diverge from rational ones.

## Acknowledgements

I would like to say thanks to Adam Szeidl for the inspiring thoughts and guiding ideas during the whole thesis writing process. Thanks to Peter Kondor for introducing me to the literature of herding in financial markets. I would also like to thank the comments to all my friends I had a discussion with, about the topic of my thesis. And say thanks to Barbi, Sasa and many other friends for the support during my studies.

# Contents

# 1 Introduction

Naive herding in financial markets is a poorly understood, however quite frequent and very important phenomenon. While I will define herding formally later, to intuitively realize how important herding is, it is enough to think about events like the dot-com bubble. Probably almost all of us has a friend or relative who bought stocks just because everyone buys it, however in general we do not really understand how herding works and why it occurs precisely. In this paper I propose a model to analyze naive herding based on the ideas of laboratory experiments about naive herding and how information is transmitted with biases. I show that despite the intuition, inferential naivete only does not lead to informational cascades, the institutional structure of markets works quite well correcting these biases. However introducing correlated signals, with agents neglecting this fact, even a shockingly simple model can quite realistically replicate patterns and behavior of real markets in a stylized way. In this model naive players do engage in herding behavior, even on the wrong states. My results also indicates that even with a small number of rational agents, who do not have behavioral biases, the microsturcture of financial markets ensure that these herds come to and end almost surely in an endogenous way.

This model with correlated signals captures the intuition that the news, advises and professional analyses arriving to an individual are not completely independent. Possibly they contain new information, some new insight or idea, but there is a huge correlation, since they have common sources. Unfortunately transmitted information is not tagged with the source and it is often hard to separate the new insights from a report, hence most people count these common parts multiple times and this leads to biased inference, what can be the cause of naive herding.

In the literature of herding and informational cascades, the most influential model on rational herding is the BHW model of Bikhchandani et al. (1992), what is in some ways the base of almost every herding model since then. In their model agents arrive sequentially and choose between two possible actions after observing what predecessors done and a private signal of their own. The main implication is that there is herding, more importantly herding on the wrong state with positive probability. However this model is far away from a realistic characterization of what is happening on financial markets. The literature of modeling price informativeness and information diffusion in centralized financial markets in a dynamic setting started with the model of Glosten and Milgrom (1985). The setting is quite similar to the BHW model, sequentially arriving agents either buy or sell a stock from Bertrand competing market makers. However their main goal was not to analyze herding behavior, it is an important result that with infinite time horizon market makers learn the true value of the stock.

Later there were several other models of rational herding and learning from prices. The most similar to the previously mentioned ones is from the article of Avery and Zemsky (1998). They developed a Glosten and Milgrom (1985) type model that is comparable with the BHW model. Some of their results are quite surprising and comforting in some ways. They showed that if signals are monotone then there is no herding in the model. The comforting view of this is that the microstructure of financial markets, more precisely the existence of market makers eliminate the BHW-type herding. One can see this result as a proof that financial markets works well and institutions of these markets are quite effective. Other, not necessary so similar models, like Amador and Weill (2012) has similar results, players learn the true state on the long run.

There are several critiques of rational herding models in the literature based on evidence of lab experiments, what suggest that behavioral aspects are indispensable to properly model herding and informational cascades. Kübler and Weizsacker (2004) ran an experiment where agents can decide whether to purchase a costly signal in the BHW setting. Several different specification of the experiment suggested that players are lack the sophisticated, higher order thinking that the equilibrium of these models require. In their experiment signal acquisition is higher than in equilibrium of the model it should be and herding occurs typically later than it should. This result suggest that people does not think over fully how predecessors made their decision, therefore they interpret previous herd decisions as if they were based on private signals.

Two other common property of rational herding models mentioned by Eyster and Rabin (2010) that in these models, herds are either rare or players are not that confident that they are herding on the right state. Therefore in rational herding models there cannot be very confident and frequent herding on the wrong state. And secondly in these models richer action and signal spaces can reduce significantly the probability of herding on the wrong state. These suggest that herding is driven by some behavioral bias or naivete of agents. I will discuss the concept of inferential naivete by Eyster and Rabin (2010) in more detail later in Section 2.2. However many other papers showed ways of capturing naivete and probabilistic biases, like the model of believing in the law of small numbers introduced by Rabin (2002) and further modified and analyzed by Rabin and Vayanos (2010) and the concepts introduced by Rabin and Schrag (1999) in their model of confirmatory bias.

To understand how cascades in financial markets work it is also worth to note that when rational herding occurs then it does not hurt agents in expectation, herding is their optimal decision. However in real life we often see investment decisions not motivated by a rational decision making process or proper accumulation of available information. In my opinion real life herding occurs because people cannot distinguish between new information and already used information. Several laboratory experiments, for example by Eyster and Rabin (2010) shows that people often overweight early signals while inferring from observed actions. Other experiments of social learning by Mobius et al. (2012) also suggests that learning and information transmission is imperfect, and agents cannot always distinguish new information from information they already got on other channels. An other possible view of this multiple counting of information is that agents' signals are somewhat correlated. The news about a stock in the television, the valuation of a bank employee, the yearly report and the advice of a friend has essentially the same source of information, they are highly correlated. However many people thinks of them as independent signals about the stock, hence they count the common part multiple times. This idea is very similar what Eyster and Weizsacker (2012) used in their model of portfolio choice when players neglect the correlation between returns.

The model I first propose and analyze in Section 2 focuses on the concept of inferential naivete. Then in Section 3 I modify this model to analyze the effect of correlation neglect in naive herding. Later in Section 4 I will mention a possible extension of these naivete concepts that can be used to model naive herding in more details. Finally Section 5 concludes my analysis.

# 2 Basic model

To examine and try to explain this phenomena I would use a simple game theoretic model of centralized markets. In the literature the closest to this model is the one used by Avery and Zemsky (1998), with the restriction that the agents' private signal can only be a binary signal.

## 2.1 Formal setup

The formal model follows. There is a binary state of the world $\theta \in \{0, 1\}$, what can be associated with concepts like the true value of the stock. However I will refer to the state as the true value, I would not like to enter into discussions about how can one define the true value of a real stock. This state is not known by any of the players and revealed only after the end of the game. The prior probability of either state is 0.5 and this is common knowledge. Timing is discrete and time horizon is infinite. Or equivalently one can think of this game as a game with finite, but unknown time horizon. The most common assumption for these types of questions is to assume that the game ends after each period with a constant $0 < \gamma < 1$ probability. For technical reasons it is convenient to use the infinite time horizon assumption during the derivations, but occasionally

I refer back to the finite time interpretation while examining the results. There are three types of players. There are market makers whose in each time period quote a bid and an ask price competing on a perfectly competitive market to maximize expected profits, and there are two types of traders. A $\beta$ fraction of them are informed traders maximizing their expected profit and a $1-\beta$ fraction are noise traders, their trading is motivated by some other factors than profit maximization.

A trader arriving in time $t$ can choose from three possible actions. She can either buy $(a_t = a)$ or sell $(a_t = b)$ the stock or make no trade $(a_t = n)$, regardless of her type. Noise traders choose their action randomly with equal $\frac{1}{3}$ probability on each possible action while informed traders first observe a private signal $s_t \in \{0, 1\}$ about the state what is precise with probability $q > 0.5$, observe the quoted prices, and also observe the full history of actions before time period $t$, noted with $h_t = \{a_1, \cdots, a_{t-1}\}$, then make their action to maximize expected payoff. To examine naive herding behavior in the model there can be two types of informed traders, rational and naive ones. Both traders behave optimally given their beliefs about the world, the only difference is that rational agents form their beliefs in a rational way, based on Bayes-rule and naive agents has different belief formation discussed in Section 2.2 and then further examined in Section 4. The fraction of naive traders among informed traders is $\alpha$.

Since there is perfect competition among market makers, their expected profit is zero, so the market makers form their quotes at time $t$ as conditional expectation of true state given all past history and possible actions in $t$, forming their beliefs using Bayes-rule, hence

$$p_t^b = E[\theta | h_t, a_t = b] \quad (1)$$

$$p_t^a = E[\theta | h_t, a_t = a] \quad (2)$$

Note that for simplicity in the paper I will refer to the market maker in singular, but still using the assumption that she operates on a perfectly competitive market, so previously justified decision making rule applies. As further notation let be the market maker's expectation of the state at time $t$, before observing the action of trader $t$ is

$$\Pi_t = E[\theta | h_t] \tag{3}$$

and in some cases I refer to this expectation as the market maker's valuation of the asset or simply the price at time $t$. And finally traders' profit will be

$$u_t(a_t, \theta, p_t^b, p_t^a) = \begin{cases} \theta - p_t^a & \text{if } a_t = a \\ p_t^b - \theta & \text{if } a_t = b \\ 0 & \text{if } a_t = n \end{cases} \tag{4}$$

at the end of the game. Since informed traders are maximizing their expected profit, in equilibrium their strategy is

$$a_t(h_t, s_t, p_t^b, p_t^a) = \begin{cases} a & \text{if } E[\theta | h_t, s_t] > p_t^a \\ b & \text{if } E[\theta | h_t, s_t] < p_t^b \\ n & \text{otherwise} \end{cases} \tag{5}$$

## 2.2 Naive inference

For modeling belief formation of naive traders, in this Section I use the concept of best response trailing naive inference behavior, introduced by Eyster and Rabin (2010). This concept is based on the authors' lab experiments what showed that most players do not think trough previous player's decision making process. Rather they use some simplified inference from previous actions that leads to count early signals multiple times.

Formally, an agent engages in best response trailing naive inference behavior (BRTNI play) when she infers from the history that all predecessors private signal is equal to their actions. Eyster and Rabin (2010) showed that in the model of Bikhchandani et al. (1992) with BRTNI agents, herds on the wrong state are more confident and cannot be easily overturned by strong signals in a rich information environment either. More precisely BRTNI beliefs converge to one of the possible states almost surely.

Application of this concept in a model similar to the BHW model is quite straightforward, however there are some assumptions needed for application in a Glosten and Milgrom (1985) type model. The closest assumptions to the original ones in Eyster and Rabin (2010) would be that a naive agent knows the fraction of noise traders but assumes that all informed trader buys if her signal is $s_t = 1$ and sells if her signal is $s_t = 0$. A straight consequence is that if a naive trader sees a no trade event in the history of trades, then she thinks that this action was played by a noise trader. This assumption has no consequence in the binary signal model, since it is trivial that with binary signals, all informed trader always trades, however it could be important when signal space is richer.

## 2.3 The basic model with naive inference

First, for a precise examination of herding, after mentioning it several times informally before, I define herding behavior formally, then show what this model implies for herding.

**Definition 2.1.** *Trader $t$ engages in herd behavior if her action is independent of her private signal, so if*

$$a_t(h_t) = a_t(h_t, s_t) \tag{6}$$

so when herding occurs then for agents in the herd

$$a_t(h_t, s_t = 0) = a_t(h_t, s_t = 1) \tag{7}$$

Then Proposition 2.2 states a very important feature of the binary state binary signal model, what is a crucial for understanding naive herding.

**Proposition 2.2.** *In this model a rational trader always trades, and always follows their private signal.*

*Proof.* First note, that the trader and the market maker forms the same expectations about the asset, conditional only on the history of trading. Then the ask price is just the weighted average of the market maker's valuation conditional on whether what type of trader will give the ask order, weighting with the probability of that type of trader gives an ask order. The order can came from a noise trader, a naive trader with positive signal, a naive trader with negative signal, a rational trader with positive signal and a rational trader with negative signal.

The market maker's valuation cannot be higher in any of the five cases, than if the ask order came from a rational trader with a positive signal. Secondly note that the rational trader's valuation after observing a signal $s_t = 1$ is the same what the market maker would infer if she would know for sure that this is the case. Therefore the ask price is the convex combination of five conditional valuations of the market maker, from which the highest is equal to the valuation of a rational trader with a positive signal. Hence

$$E[\theta|h_t, s_t = 1] \geq p_t^a \tag{8}$$

so a rational trader with a positive signal always buys.

With exactly the same logic one can prove that a rational trader with a negative signal always sells, and this concludes the proof. ■

Some people might see this result as a very intuitive one, however it has shocking implications for the basic model and for naive herding in this setting, as Proposition 2.3 states.

**Proposition 2.3.** *In the binary state binary signal model all informed trader always trades and always follows their signal. Therefore there is no herding in the model, regardless of the fraction of naive traders.*

*Proof.* For the proof I use induction. The first naive trader that arrives the market sees only rational and noise traders in the history of trading. All rational traders follows their signal, hence the first naive trader's inference from the history is the same as the inference of a rational trader. Since the only difference between rational and naive traders is their inference of signals from the history of trading, then the logic of Proposition 2.2 can be used in exactly the same way. This ensures that the first naive trader also follows their signal.

Then if the first $n$ naive traders also follows their signal the same logic can be used for the $n+1$th naive trader.

Therefore all informed traders always follow their signal, hence there is no herding in this basic model, even with naive traders. ■

It is very important to note that both proofs hold for any $\beta \in [0,1)$ and $\alpha \in [0,1]$, and for any belief of the market maker about these ratios, even when the market maker's belief is different from the true fraction. The only crucial assumption is that the market maker's and the rational players' beliefs has to be the same, however this is not a strong or unrealistic constraint, since both the market maker and rational traders are unbiased, not naive, rational players.

This is a quite surprising and shocking result, that goes against most of the intuition. This shows that in a general set of cases, market institutions can prevent otherwise naive participants to make mistakes they would make without this specific microstructure. And this result also shows that probably naive inference is not the way one should model the natural intuition of double counting information. As I mentioned before correlation neglect is an other possibility to capture almost the same idea with a slightly different formalization.

# 3 Correlation neglect in naive herding

In this section I propose a version of the basic model by using a completely different naivete concept. In this model the over counting of early signals does not come from biased inference, like in Section 2 but from the biased knowledge of the correlation structure of the signals. In this variant of the model the setup is the same as in the basic variant, but private signals are not independent anymore. I call a trader rational if she realize the correlation structure of the signals and reacts accordingly. A trader is naive if she neglects the correlation between signals and treats signals as independent. This feature is to capture that news and reports about a stock are obviously correlated, however people tend to ignore this, partly because of behavioral biases and partly because information is not tagged and they cannot distinguish between news coming from the same or different original sources.

Just like until now the market maker in this model also rational and rational players has some beliefs about the ratios $\alpha$ and $\beta$. The fact, whether these beliefs are right or wrong in most cases does not change the following results, but for the sake of simplicity let's assume that all rational players know the true values of these fractions. Obviously naive traders assume that all traders are rational, since to know that there are traders neglecting correlations they would have to know about these correlations.

## 3.1 Fully correlated signals

The simplest case of this variant of the model is where all signals are perfectly correlated. Moreover, for now let's assume that all traders are informed and naive. Obviously this is a very strong and unrealistic assumption, and this simple version is not capable of analyzing herding since all signals are the same, but it shows clearly the intuition behind the setup and helps to understand the more sophisticated model in Section 3.2.

To prevent the market from collapsing without noise traders let's also assume that if the first trader's posterior is equal to the bid or the ask price then she makes a transaction. For other traders naive beliefs will diverge from the market maker's belief hence trading will occur. Proposition 3.1 summarize what is happening in this simple case.

**Proposition 3.1.** *In this model for $t > 1$ bid and ask quotes are equal and constant, trading occurs in every time period and trader beliefs converge to one of the possible states.*

*Proof.* The market maker is perfectly aware of the correlation structure, hence she knows that from $t = 2$ periods the actions carry no new information, so

$$p_t^b = E[\theta|h_t, a_t = b] = E[\theta|h_2] = E[\theta|h_t, a_t = a] = p_t^a \tag{9}$$

Then for the traders let's assume that the first signal is $s_1 = 1$. Then since all signals are the same, traders' inference from all previous trades coincide with their signal, hence traders become more and more confident that the true state is $\theta = 1$ with time. This implies that all traders buy and their belief converges to $\theta = 1$ regardless of what is the true state. The same logic can be applied for the case where $s_1 = 0$. ■

In this setup, rational traders would realize that only the first signal has information, and all other signals are perfectly correlated with it, hence their beliefs would stay unchanged and equal to the market maker's beliefs after the first trade. However naive traders does not realize the structure of the signals, and since they believe that all signals are independent, they treat the one signal as many similar signals, hence their beliefs would converge to the state what the signals indicate.

Obviously one cannot call this behavior herding, since all traders followed their own signal, but even this simple model shows that naive beliefs can significantly diverge from rational beliefs.

Note that with the results would be similar with noise traders in the system.

## 3.2 Herding with partially correlated signals

In this section, as a more realistic setup, let's assume that signals are not fully correlated. More precisely let's divide the time horizon to periods with length $k$ and assume that signals within a certain period are perfectly correlated and signals across these time periods are independent. This model now is suitable to analyze herding, moreover it has the nice feature that there is always new information on the market, hence by knowing all the signals the true state can be learned. To illustrate this nice feature of the model Proposition 3.2 summarize the analysis when all informed traders are rational.

**Proposition 3.2.** *In the model with partially correlated signals when all informed traders are rational, hence $\alpha = 0$ and there are noise traders so $\beta < 1$ then all informed traders trade, follows their signal and beliefs converge to the true state of the world.*

*Proof.* First note that the market maker change her quotes only in the beginning of each length $k$ time period. Then note that a trader coming at time $t$ neglects all trades that occurred before her arrival but in the same length $k$ period she is in. Hence valuation based on the history is the same for all traders in the same period and also same for the market maker.

Then if the signal in that period is $s_t = 1$ for all $t$ in that period then the ask price in that whole period is the convex combination of the rational trader's valuation, a market maker's valuation on the end of the previous period and the valuation of informed traders with signal $s_t = 0$, with possible zero weight put to the latter. This ensures that the informed trader's valuation after observing the signal $s_t = 1$ is higher than the ask price. The same logic applies to conclude that any informed trader's valuation with $s_t = 0$ is lower than the bid price. This means that in this model all informed traders trade and follows their signal.

Finally, since all informed traders follows their signal almost all signals can be inferred from the history of trades. Since as $t \to \infty$ there is always new independent information on the market, all rational traders and the market maker learn the true state. ■

This is not a surprising result, hence without biased agents this model is essentially equivalent with the basic model without biased agents, hence the implications are the same. However as Proposition 3.3 shows results are extremely different when there are naive traders. For simplicity let's assume that all traders are naive, and to ensure market participation without noise traders let's assume that if a trader's posterior equals either the bid or the ask price then she trades. After the results one can see that it is enough to assume this only for the first trader.

**Proposition 3.3.** *In the model with partially correlated signals when all traders are naive, for large enough $k$ there is herding with probability one, there is herding on the wrong state with strictly positive probability. And naive beliefs converge to either of the possible states almost surely.*

*Proof.* Let's show the proof for the case when the first signal is $s_1 = 1$. In this case the first trader buys by assumption. Then the market maker does not change the quotes for the next $k-1$ trader, but their belief will increase monotonically hence they will all buy. Note that for $t = k+1$ the market maker's valuation after an ask action cannot exceed $E[\theta|s_1 = 1, s_{k+1} = 1]$, hence

$$p^a_{k+1} \leq E[\theta|s_1 = 1, s_{k+1} = 1] \tag{10}$$

moreover, since without correlation, traders should follow their signals, trader $k+1$'s valuation even if $s_{k+1} = 0$ is $E[\theta|s_1 = 1, \cdots, s_k = 1, s_{k+1} = 0]$, and for sufficiently large $k$

$$E[\theta|s_1 = 1, \cdots, s_k = 1, s_{k+1} = 0] > E[\theta|s_1 = 1, s_{k+1} = 1] \geq p^a_{k+1} \tag{11}$$

Therefore for these large enough $k$s all subsequent traders will buy regardless of their signals.

The same logic can be applied to the case when $s_1 = 0$. This means that herding occurs with probability one. Since there is a positive probability that the first signal is wrong, then herding on the wrong state occurs with positive probability. And finally since based on Proposition 2.2, all traders should follow their signals, naive traders interpret the herding actions as subsequent similar signals, hence their belief converge to the possibly wrong state they are herding on. ■

This is an important result of this paper. This shows, that naive herding can occur even in a really simple environment. And this model also coincides with the natural intuition how herding occurs in financial markets, that participants simply cannot filter out from the news they hear what is the new information and what is just repeating already known information. Finally, as Corollary 3.4 and 3.5 show, that this very simple model can generate results that are quite similar to what we see in real financial markets.

**Corollary 3.4.** *In the model with partially correlated signals when $\beta \in (0,1)$ and $\alpha \in (0,1)$ then all rational traders follows their signal, and for large enough $k$ naive traders engage in herd behavior with positive probability.*

*Proof.* The proof regarding to rational players comes from Proposition 3.2 with the same logic as in the proof of Proposition 2.2. The market maker's inference from a trade cannot be higher than a rational player's valuation after observing a positive signal. The second part about naive traders is the same as the proof of Proposition 3.3. ■

**Corollary 3.5.** *In the model with partially correlated signals when $\beta \in (0,1)$ and $\alpha \in (0,1)$, despite the fact that rational and naive beliefs can differ significantly, as $t \to \infty$, the market maker learns the true state almost surely, hence all informational cascades on the wrong state come to an end endogenously with probability one.*

*Proof.* Rational traders always follow their signal and as $t \to \infty$ there is always new information about the true state, hence as long as $E[\theta|h_t] \neq \theta$ the market maker can infer some new information.

And for the end of herds, since the market maker learns the true state with probability one, for $t \to \infty$ all herds could occur only on the true state $\theta$. ■

These two Corollaries show the strength of this model, hence this kind of behavior what can be observed on real financial markets. There are herds on the wrong state, someone might call them bubbles, however there are always traders who do not participate in these informational cascades, and they always end endogenously because of the constantly accumulating information.

## 3.3 Using agents' naivete against them

There is an other important aspect of naive herding, that has nothing to do with the informational cascade itself, rather with the thinking of naive agents. As Proposition 3.3 suggests, naive and rational beliefs can diverge significantly, while market prices corresponds to the rational beliefs. This results that there is a stock on the market what is way too cheap or way too expensive according to the naive agents' beliefs. This means that if institutions permit, their strongly false beliefs can be used against them. First I show a simple game as an illustration then I present the intuition and the connection to current financial institutions.

Let be a player who can offer derivatives to all traders and who is monopolistic on her market. More precisely this monopolist can offer Arrow-Debreu securities for price $p_t^i$ at time $t$ for a security that pays if the true state is $i \in \{0, 1\}$ and the offer is a take it or leave it offer. With prices $p_t^1 = p_t^a$ and $p_t^0 = 1 - p_t^b$, rational players are indifferent between accepting and declining the offer, and both traders' and monopolist's expected profit is zero. However since naive trader's beliefs are diverged towards one of the possible states, with carefully chosen $p_t^1 > p_t^a$ and $p_t^0 > 1 - p_t^b$ rational traders will decline the offer, but there will be naive traders who are willing to buy these products. As a result, these naive traders' expected profit would be negative and the monopolist's expected profit would be positive. This idea is somewhat similar to OTC transactions where participants can trade with various derivatives without the requirement to use the prices from the centralized market.

The model with partially correlated signals therefore not just implies naive herding on the wrong states, but it shows that when OTC transactions are allowed, so institutional structures are more relaxed, then naivete can used against biased agents. And this implication of my model is an important example of how good the microstructure of financial markets are. Small individual investors, who are more likely to be biased and possibly they are more far away from behaving rationally, are allowed to trade on centralized markets, but they have more restricted possibilities to engage in OTC transactions. OTC markets are mostly used and can be used by large institutional participants, where the assumption of rationality is less strong, even if it is clearly not completely true.

# 4 Possible extension of the models

In this section I would like to mention a behavioral bias that can help to model more precisely and understand more carefully and clearly naive herding in financial markets. For this concept I would not like to built formal models, just informally mention the possible application.

## 4.1 Models with confirmatory bias

The model of confirmatory bias by Rabin and Schrag (1999) would imply a natural extension of any model I proposed so far. The start stone could be either the basic model without naive agents or the models with either inferential naivete or correlation neglect. In the model with confirmatory bias, if an agents put not equal probability to the two possible states after observing the history of trading, then she is biased towards her prior hence she misreads any signal contradicting her prior with a positive probability. For example if agent $t$ has $E[\theta|h_t] > 0.5$ then with probability

$q > 0$ she misreads any signal $s_t = 0$ and thinks that her private signal is $s_t = 1$.

This bias is completely independent how the inference from the history of trading was made, or whether that inference was naive or biased in any way mentioned before. Hence confirmatory bias can be a natural an plausible extension of any model I proposed and analyzed. However this model is not formally defined, intuitively, agents with confirmatory bias tend to misread own signals and follow their predecessors without rationally neglecting their own private signal, that can result a behavior similar to herding, however they possibly only follow the signal they think they got.

# 5 Conclusions

Based on my results, I can conclude that herding in financial markets is different from herding in other environments, financial institutions and microstructure of the market play a major role in correcting behavioral biases. The model in Section 2 showed that only naive inference cannot be the cause of naive herding. The model of correlated private signals and traders neglecting this correlation structure in Section 3 is a simple example of how naive agents multiply count essentially the same information, similarly how individuals cannot fully distinguish between news from the same or different sources, and how leads this phenomena to naive herding. In this model there is naive herding, with positive probability on the wrong state. Moreover this model shows that the existence of rational traders prevent these herds to continue forever. This model also shows that naive beliefs can significantly differ from rational ones and without proper institutional background and regulations, their naivete can be used against biased agents.

# References

**Amador, Manuel, and Pierre-Olivier Weill.** 2012. "Learning from private and public observations of others' actions." *Journal of Economic Theory,* 147: 910–940.

**Avery, Christopher, and Peter Zemsky.** 1998. "Multidimensional Uncertainty and Herd Behavior in Financial Markets." *The American Economic Review,* 88(4): 724–748.

**Bikhchandani, Sushil, David Hirshleifer, and Ivo Welch.** 1992. "A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades." *The Journal of Political Economy,* 100(5): 992–1026.

**Eyster, Erik, and Matthew Rabin.** 2010. "Naive Herding in Rich-Information Settings." *American Economic Journal: Microeconomics 2,* November 2010: 221–243.

**Eyster, Erik, and Georg Weizsacker.** 2012. "Correlation neglect in financial decision-making." *Working paper*

**Glosten, Lawrence R., and Paul R. Milgrom.** 1985. "Bid, ask and transaction prices in a specialist market with heterogeneously informed traders." *Journal of Financial Economics,* 14(1): 71–100.

**Kübler, Dorothea, and Georg Weizsacker.** 2004. "Limited depth of reasoning and failure of cascade formation in the laboratory." *Review of Economics Studies,* 71:425–441.

**Mobius, Markus M., Tuan Phan, and Adam Szeidl.** 2012. "Treasure Hunt: Social Learning in the Field." *Working Paper*

**Rabin, Matthew.** 2002. "Inference by Believers in the Law of Small Numbers." *Quaterly Journal of Economics,* 117(3): 775–816.

**Rabin, Matthew, and Joel Schrag.** 1999. "First Impressions Matter: A Model of Confirmatory Bias." *Quaterly Journal of Economics* 114(1): 37–82.

**Rabin, Matthew, and Dimitri Vayanos.** 2010. "The Gambler's and Hot-Hand Fallacies: Theory and Applications." *Review of Economics Studies* 77(2): 730–778.