Financial Markets Microstructure

Lecture 20

Asset Price Bubbles

Egor Starkov

Københavns Unversitet
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Previously on FMM

- Information and trading volumes:
  - Private signals create disagreement $\rightarrow$ generate trade, which reveals and aggregates private info
  - Public signals should theoretically mitigate disagreement and lead to less trade
  - But IRL trading volumes increase around public announcements
  - **Kondor**: Possible explanation through second-order beliefs

Today

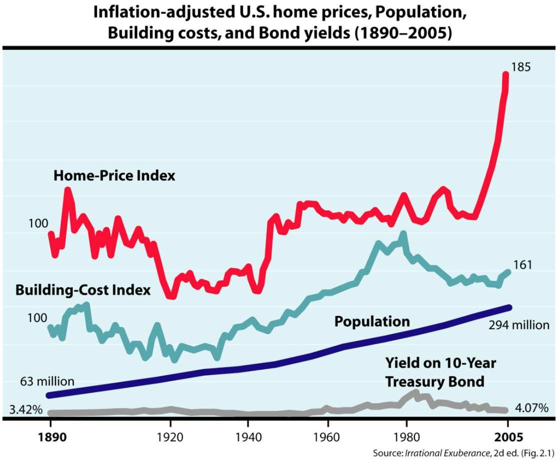
Two stories for why bubbles may occur

- Rational herding
  - Herding: following the actions of others, even when this goes against one's own private information
  - We will look at different explanations for why this may be rational
- Lack of common knowledge/coordination (Abreu and Brunnermeier [2003])
  - There is a difference between everybody knowing that an asset is overpriced, and everybody knowing that everybody knows...
  - Again, speculation depends on these *higher-order beliefs*

Bubbles

- **Wikipedia**: "Trade in high volumes at prices that are considerably at variance with intrinsic values"
- **Investopedia**: "A surge in equity prices, often more than warranted by the fundamentals and usually in a particular sector, followed by a drastic drop in prices as a massive sell-off occurs"
- **Chicago Fed**: "...a bubble exists when the market price of an asset exceeds its price determined by fundamental factors by a significant amount for a prolonged period"

Examples of bubbles



- US **housing** market had a bubble in mid-2000s
- Its burst was a significant contributor to the Great Recession

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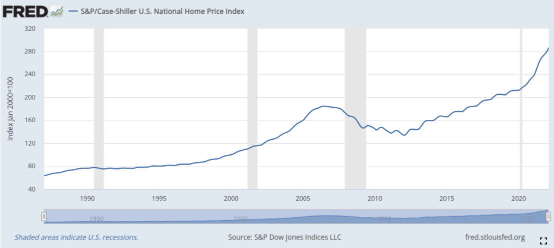

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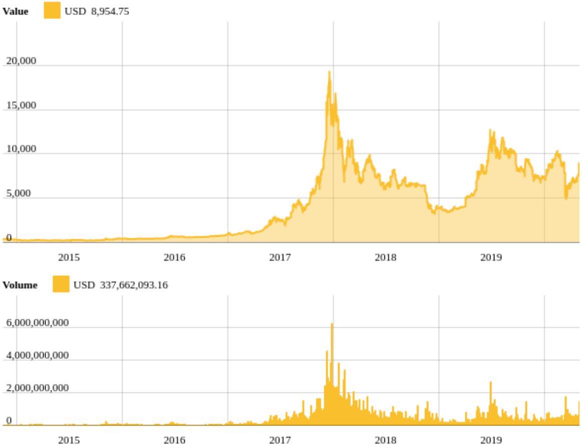

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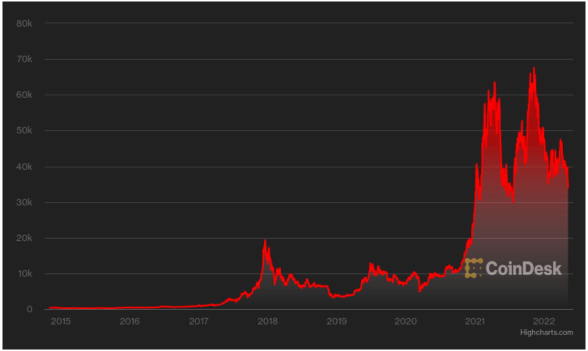
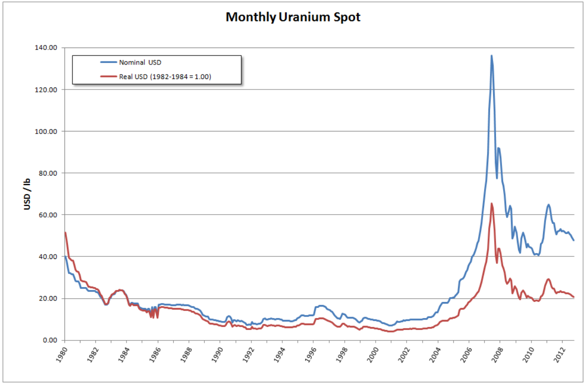


- **Bitcoin** grew and burst pretty badly at the end of 2017.
- ...and is just pretty volatile overall
- (to be fair, like with any fiat currency, not clear what bitcoin's fundamental value is, so can say that any positive price is a bubble)

Examples of bubbles

- we remember the **Gamestop** frenzy of January 2021...

Examples of bubbles



- In the early noughties, the price of **uranium** was upward trending
- In late 2006 the Cigar Lake Mine in Canada containing the largest known undeveloped reserves was flooded
- This seemingly set off an uncontrolled increase in price followed by a crash: classic bubble behavior

This lecture:

1. Herd Behavior in Financial Markets

2. Abreu and Brunnermeier: Bubbles and Crashes

Herding: Introduction

- **Herding**: ignoring private information in favor of "wisdom of the crowd"
  1. Herding may be the efficient response to new information or similarity between agents...
  2. ...but it may also be the inefficient result of a certain decision making process. Here: focus on the latter
- In **financial markets**: momentum trading, positive-feedback trading
- In 1992, a wave (a herd?) of articles showing that herding could be result of rational informational cascade
- Today we look at this and other 'rational' explanations
- Note: I will follow the presentation in Bikhchandani and Sharma [2000].
  See Bikhchandani et al. [2021] for a comprehensive review of the literature.

Preview

- Agents arrive at the market sequentially and need to make a decision
- Every agent has a private signal and observes decisions of previous agents (but not their signals!)
- Ideally: pool private information to find best decision
- But here: sequential decision making
  - First-comers: make decisions based on information
  - But as time goes by, people may start disregarding their own information and just choose the most popular action
  - Herding ensues, but it is *fully rational*: public information swamps private information
- Informational cascade: a few pieces of information may determine everyone's choice

Model

- **State** (fundamental) $v \in \{L, H\}$;
- In each period $t \in \{1, 2, ...\}$ an individual arrives and needs to make a **decision** $d_t \in \{0, 1\}$ (invest or not);
- **Payoffs** $u(d_t, v)$:
  - $u(0, v) = 0$,
  - $u(1, L) = L - m < 0$,
  - $u(1, H) = H - m > 0$,
  - (say for now that price (midquote) m is fixed and there is no spread: $a = b = m$)

Model: Beliefs

- Represent all beliefs p about v as probabilities of $v = H$ conditional on relevant info.
- "Market belief" q_t
  - q_0 is the public prior belief – e.g., $1/2$;
  - q_t incorporates info contained in decisions at $t = 1, 2, ..., t-1$
- Period-t agent observes q_t and a private signal η_t and forms private belief r_t.
  - Suppose $\eta_t \in \{h, l\}$ with $\mathbb{P}(\eta_t = h|v = H) = \mathbb{P}(\eta_t = l|v = L) = \rho$.
- All beliefs calculated using Bayes' rule

Decisions

- Agent behaves optimally $\Rightarrow$ chooses $d_t = 1$ iff $r_t \geq \bar{r} \equiv \frac{m-L}{H-L}$.
- Use Bayes' rule to compute $r_t(\eta_t, q_t)$:

$$r_t(h, q_t) = \frac{q_t \rho}{q_t \rho + (1 - q_t)(1 - \rho)}$$
$$r_t(l, q_t) = \frac{q_t(1 - \rho)}{q_t(1 - \rho) + (1 - q_t)\rho}$$

Note $r_t(h, q_t) > q_t > r_t(l, q_t)$.

Herds and cascades

- If $r_t(h, q_t) > \bar{r} > r_t(l, q_t)$ then the agent follows their signal
  $\rightarrow$ their action is informative
  $\rightarrow$ public belief is updated: $q_{t+1}(q_t, d_t = 1) = r_t(h, q_t)$; $q_{t+1}(q_t, d_t = 0) = r_t(l, q_t)$.
- If $r_t(h, q_t) > r_t(l, q_t) > \bar{r}$ then the agent chooses $d_t = 1$ regardless of private signal
  $\rightarrow$ action uninformative $\rightarrow$ $q_{t+1} = q_t$
  $\rightarrow$ next agent will also ignore private signal!
  - Everyone ignores private signals and chooses the same action (we have a herd)
  - Market belief q_t is frozen in place; private information is not aggregated!
  - This herd may be incorrect (unless $q_t = 0$ or $q_t = 1$)
  - (Same happens if $\bar{r} > r_t(h, q_t) > r_t(l, q_t)$ with $d_t = 0$)

What triggers the herd?

- A few incorrect signals can be enough enough to set off a herd
- A small piece of information ‘cascades’ through the system
- Each agent is rational, but together they may seem stupid: their information taken together is very precise, but there is no information aggregation
- A specific example with numbers of how a herd may arise: here

Herds and cascades: comments

- Incorrect herds only occur if distribution of η_i is bounded – otherwise strong enough signals could overpower the public info
- In a slightly richer model, the opposite outcome is also possible – state of permanent uncertainty in which everyone acts solely on their private signal, ignoring public information
- Terminology:
  - Herd $=$ action convergence ($d_{t+1} = d_t$ from some point onwards)
  - Cascade $=$ public belief convergence ($q_{t+1} = q_t$ from some point onwards)
  - Distinction is not super important for our purposes

What if we introduce a price?

- As before: unknown asset value v, and each trader receives a private signal η_i
- With probability π the trader is a noise trader, who buys/sells/abstains with equal probability, w.p. $1 - \pi$ rational as above
- A risk-neutral market maker quotes competitive bid-ask prices
- What will happen?

What if we introduce a price?

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- A risk-neutral market maker quotes competitive bid-ask prices
- What will happen?
  - This is standard Glosten-Milgrom, so no herds!
  - Prices adjust in such a way that following private signals is optimal, and prices themselves then incorporate all private signals!

More layered model

- However, the GM result is in part due to model simplicity
- Avery and Zemsky [1998] expand on this analysis
  - Suppose $v \in \{0, \frac{1}{2}, 1\}$
  - If $v = \frac{1}{2}$, this is perfectly revealed by the private signal: $\eta_t = \frac{1}{2}$
  - If $v \in \{0, 1\}$, trader t receives informative signal with precision $\rho_t \equiv \mathbb{P}(\eta_t = v)$
  - Furthermore, a proportion $\mu \in \{\mu^H, \mu^L\}$ of traders have perfect information: $\rho_t = 1$ after a good signal
  - The remaining traders have noisy info: $\rho_t \in (\frac{1}{2}, 1)$ after a good signal

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- Three levels of uncertainty (for MM):
  - Event uncertainty: $v = 1/2$ (no event) or $v \in \{0, 1\}$ (event)
  - Value uncertainty: if event, $v = 1$ or $v = 0$
  - Composition uncertainty: many informed traders (μ^H: well-informed economy) or few (μ^L: poorly-informed economy)

Herding can occur with pricing and multi-layered uncertainty

- In GM, price mechanism worked as a screening device: made sure that high types bought and low types sold
- But now, it is possible to 'misprice' such that herding occurs, at least temporarily
  - Can be because $\mu = \mu_H$ so all traders know v, but MM does not (non-speculative bubble)
  - Can be because $\mu = \mu_L$ but traders do not know that and perceive past order flow as more informative than it is (speculative bubble)
- This allows bubbles to occur

See numerical example here

Other types of herding: Reputational herding

A brief example.

- **Two managers**: Invest or not in project of unknown value (gets imperfect signal $\eta \in \{1, 0\}$)
- **Type**: Each manager either smart or dumb (doesn't know). If both managers smart, observe same η; if one or both dumb, observe independent signals η
- **Payoffs**: Managers maximizes their reputation (want to appear smart)
- **Herding**: Manager 1 moves first, then manager 2
  - If manager 1 invests, manager 2 can deduce that $\eta_1 = 1$. Suppose $\eta_2 = 0$. Then one of the two (or both) must be dumb.
  - If manager 2 does not invest, he reveals this. If player 1's investment then succeeds, people will assume that manager 2 is the dumb manager
  - Investing might be better: even if the investment fails, people might think that both managers are smart, but got an 'unlucky' signal

Herding: Conclusion

- **Herding**: may occur when private information cannot be easily aggregated
- **Price mechanism**: alleviates problem by providing private incentives to trade and thus reveal information, which is then incorporated into prices
- **Multi-layered uncertainty**: can make the herds occur even with flexible prices
- **Aside**: *Momentum trading* often assumed to be a 'behavioral feature': but it may be perfectly rational
- **Empirical estimation of herding**: some conclusions can be tested in the data but to a very limited extent; see Bikhchandani and Sharma [2000] and Bikhchandani et al. [2021] for details.

This lecture:

1. Herd Behavior in Financial Markets
2. Abreu and Brunnermeier: Bubbles and Crashes

Abreu and Brunnermeier [2003]: Introduction

- Efficient market hypothesis: bubbles are impossible
  - In finite model, use backward induction argument: no mispricing in last period, which should be foreseen in second-last period, etc. $\rightarrow$ unravelling
- This requires that all traders agree on when the bubble will collapse (at least on the distribution of times)
- Here: a model in which coordination is needed to cause a crash
- Coordination, in turn, depends on beliefs about others
  - Back to higher order beliefs

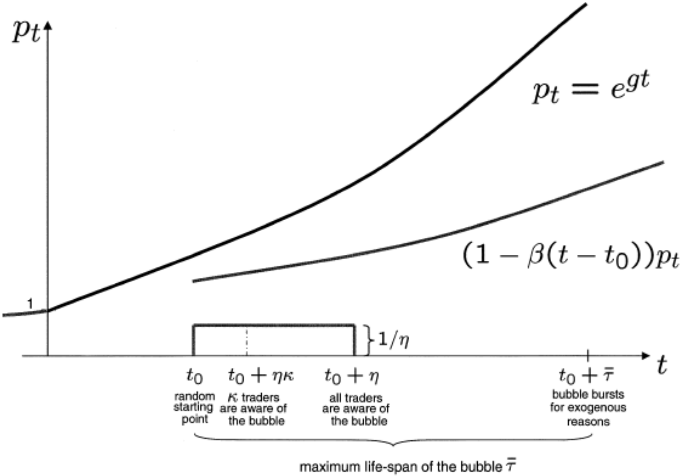
Model

- **Single asset traded**: value at t is v_t
- **Progress**: At $t = 0$, technological progress makes v_t grow at rate g
- **Slowdown**: at some random time t_0, there is a slowdown and v_t growth slows to $r < g$
- **Price**: Price grows at rate g until either
  - At least a fraction κ of rational traders sell the asset (κ is the *absorption capacity* of the economy), or
  - The market is exogenously corrected at time $t_0 + \overline{\tau}$
- **Gradual learning**: Each period, a fraction $1/\eta$ of rational traders become aware of the mispricing
  - But they don't know t_0, and hence don't know how many others know of the mispricing

Traders

- **Behavioral traders** think progress will last forever
  - When enough rational traders sell, absorption capacity of behavioral traders is reached and price must drop
  - At this point, everybody becomes aware of the mispricing
  - If this doesn't happen, then market exogenously collapses when mispricing is too big
- **Rational traders** know progress is temporary, but not when it stops
  - Implication: when you learned that progress has stopped, you are not sure what other people believe
  - Suppose you learn at t'. At $t' + \eta$ you know that everybody knows
  - But somebody else might learn that progress stopped at $t'' > t'$; he will not know that everybody knows until $t'' + \eta > t' + \eta$

Graphically



(Note: graph is from the paper and it has a mistake)

Why bubbles then?

- In this model there is never *common knowledge*: you are never sure what the others know. This prevents usual backward induction
- At least κ traders must sell to burst bubble: coordination important
- But it is hard to coordinate without common knowledge
- Therefore, mispricing can go on for a long time

Even if traders realize the market will crash, they don't know exactly when, incentivizing them to ride the bubble

Definition of a bubble

- In this setting, let's use a very strict definition of a bubble
- In particular, notice that after $t_0 + \eta\kappa$, the mispricing is known by enough traders to correct it

Definition

A bubble is persistent mispricing *beyond* $t_0 + \eta\kappa$

- Thus, in this definition it is not enough that the asset is priced over its value for there to be a bubble
- The mispricing must be well-known to traders

Some observations

The following is shown in the paper:

- Traders either take the maximum long (buy) or short (sell) position
- When a rational trader 'goes short', all traders who learned of the mispricing before him will already have gone short
- Once a rational trader goes short, he never re-enters the market: he waits for the bubble to burst

Bubbles and crashes

Generally, in the model, there are two possible types of equilibria

- Exogenous crash
  - When the growth rate g under the bubble is high, dispersion η and absorption capacity κ are high, informed traders sell out very slowly
  - In effect, they take a chance on 'riding the bubble'
  - As a result, selling will never be sufficient to burst the bubble, which will burst at the exogenous date $t_0 + \overline{\tau}$
- Endogenous crash
  - When traders have incentives to sell quick, this leads to unraveling: enough traders will sell to make the bubble burst
  - However, 'bubble incentives' remain: the sooner the price crashes, the smaller the cost of riding the bubble
  - Therefore, the bubble will be smaller but still exist

The role of ‘sunspots’

- **Sunspot equilibria**: refers to equilibria where *economically irrelevant information* has an influence
- In our case: suppose an uninformative event is observed with a certain probability
- If informed traders decide to coordinate their actions around this event (eg. use the strategy ‘sell when event occurs’), it can become pivotal
- Example from article: in 1980s trade data had big market impact in the US; in 1990s Alan Greenspan’s statements were more influential
  - If sufficiently many people react to an event you must too - even if the event carries little/no information by itself

Abreu and Brunnermeier: Conclusion

- Standard arguments against bubbles rely a lot on common knowledge between agents
- When we dispense with common knowledge, belief dispersion among agents can cause mispricings to persist even after everyone has observed the mispricing
- Thus, bubbles may not be fixed by the market
- As a side-effect, seemingly insignificant events can serve to coordinate actions and cause crashes

References I

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Herding example: Setup

- This example follows that in Bikhchandani and Sharma [2000]
- Suppose $q_0 = 1/2$
- **Payoffs**: Let $L - m = -1$; $H - m = 1$
  - Then $\bar{r} = 1/2$
  - Suppose that agents flip a 50/50 coin whenever indifferent
- Suppose the following signal sequence realized: $\{h, l, l, l, \ldots\}$
- Denote by $\mathbb{I}_i$ agent i's information set

Herding example: Analysis

First agent

- Information set $\mathbb{I}_1 = \{\eta_1 = h\}$
- Then

$$r_1(h, 1/2) = \mathbb{P}(v = H|\mathbb{I}_1) = \frac{\frac{1}{2}\rho}{\frac{1}{2}\rho + \frac{1}{2}(1-\rho)} = \rho$$

- Since $\rho > 1/2$: invest.
- **Thus**, given $\eta_1 = h$, first agent invests: $d_1 = 1$

Herding example: Analysis (2)

Second agent

- Second agent can perfectly deduce first agent's signal: $\eta_1 = h$ if $d_1 = 1$, $\eta_1 = l$ otherwise.
  - In other words, $q_2 = r_1 = \rho$, no information is lost.
  - Second agent receives $\eta_2 = l$, his information set is $\mathbb{I}_2 = \{\eta_1 = 1, \eta_2 = -1\}$
- Signals are *symmetric*, so

$$r_2(l, \rho) = \mathbb{P}(v = H | \mathbb{I}_2) = \frac{\frac{1}{2}\rho(1-\rho)}{\frac{1}{2}\rho(1-\rho) + \frac{1}{2}(1-\rho)\rho} = 1/2$$

- Thus, second agent is indifferent, flips a coin to decide. If $d_2 = 0$ then we are back to $q_3 = 1/2$.
- But suppose the coin-toss decides invest: $d_2 = 1$

Herding example: Analysis (3)

Third agent

- Third agent can also perfectly deduce the first agent's signal
- Information set is $\mathbb{I}_3 = \{\eta_1 = h, d_2 = 1, \eta_3 = l\}$. Furthermore,

$$\mathbb{P}(d_2 = 1 | v = H) = \rho + (1-\rho)(1/2) = (1+\rho)/2$$
$$\mathbb{P}(d_2 = 1 | v = L) = \rho(1/2) + (1-\rho) = 1 - \rho/2$$
$$\Rightarrow q_3(q_2 = \rho, d_2 = 1) = \frac{\rho \frac{1+\rho}{2}}{\rho \frac{1+\rho}{2} + (1-\rho)\left(1 - \frac{\rho}{2}\right)}$$
$$\Rightarrow r_3(l, q_3) = \frac{\rho \frac{1+\rho}{2}(1-\rho)}{\rho \frac{1+\rho}{2}(1-\rho) + (1-\rho)\left(1 - \frac{\rho}{2}\right)\rho} = \frac{1+\rho}{3} > \frac{1}{2}$$

- Hence, $d_3 = 1$

Herding example: Analysis (4)

Fourth agent

- Information set $\mathbb{I}_4 = \{\eta_1 = h, d_2 = d_3 = 1, \eta_4 = l\}$
- Agent four knows that agent three would have invested regardless of his signal
- So he doesn't learn anything from d_3. So $q_4 = q_3$ and $r_4(l, q_4) = r_3(l, q_3)$
- Hence $d_4 = 1$
- Same for all subsequent agents: $d_i = 1$ for all i, regardless of η_i!
- We have a herd! – and a very inefficient one at that! (Look at signals) back

Herding with prices example

Take an extreme case of Avery and Zemsky's model: suppose the following parameter values

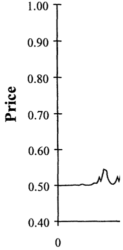
- $\mathbb{P}(v = 1/2) = 0.9999$: very small prior probability of an 'event'; $\mathbb{P}(v = 1) = \mathbb{P}(v = 0) = 0.00005$
- $\frac{\mathbb{P}(\mu=\mu^H)}{\mathbb{P}(\mu=\mu^L)} = 99$: high prior probability of a well-informed economy
- If economy is poorly informed: all traders have $p_i = 0.51$, i.e. very poor signal about value

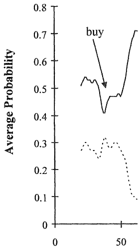
Suppose we're in an unlikely state of the world

1. Value is low ($v = 0$) implying that there is an event
2. The economy is poorly informed ($\mu = \mu^L$)

How will market learn state of the world? Let's look at a simulation

Herding with prices example (2)

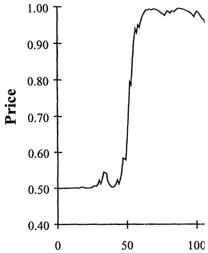


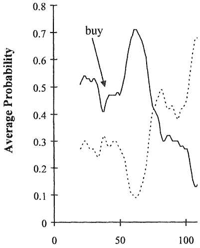


Three of first five traders buy

- Since economy poorly informed: herd buying starts
- MM thinks it's likely that economy is well informed: price goes up

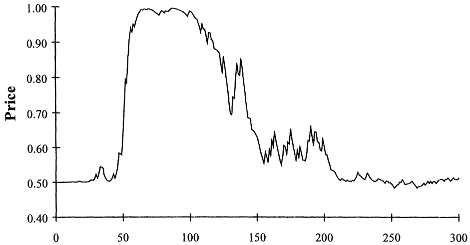
Herding with prices example (3)

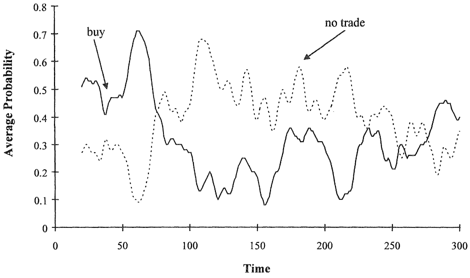




As the price goes up, the herd is broken: trading volume diminishes as rational traders drop out

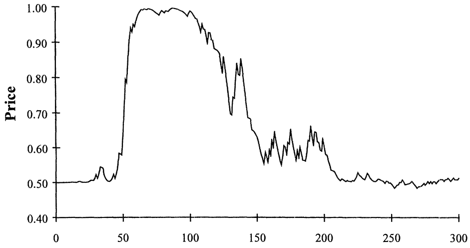
Herding with prices example (4)

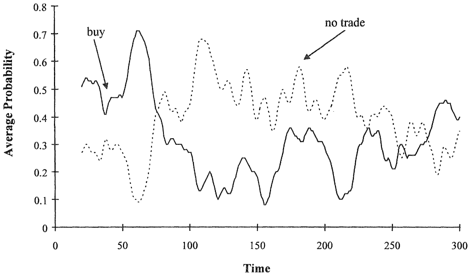




As herd becomes apparent, MM realizes that only a few informative trades have been made $\rightarrow$ price toward $1/2$

Herding with prices example (5)





Rational traders only re-enter in period 220: trade based on information (buy if high/sell if low)

In the example, the price is persistently above the level that would ensue if traders pooled their information

Back