Bubbles and Crashes

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Hedge Funds and the Technology Bubble

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Story of a typical technology stock

- Company X introduced a revolutionary wireless communication technology.
- It not only provided support for such a technology but also provided the informational content itself.
- It’s IPO price was $1.50 per share. Six years later it was traded at $85.50 and in the seventh year it hit $114.00.
- The P/E ratio got as high as 73.
- The company never paid dividends.
Story of RCA - 1920’s

- **Company:** Radio Corporation of America (RCA)
- **Technology:** Radio
- **Year:**

It peaked at $397 in Feb. 1929, down to $2.62 in May 1932,
Internet bubble?

- 1990’s

**NASDAQ Combined Composite Index**

- Chart (Jan. 98 - Dec. 00)
- 38 day average

Loss of ca. 60 %
from high of $5,132

**NEMAX All Share Index (German Neuer Markt)**

- Chart (Jan. 98 - Dec. 00) in Euro
- 38 day average

Loss of ca. 85 %
from high of Euro 8,583

- Why do bubbles persist?
- Do professional traders ride the bubble or attack the bubble (go short)?
- What happened in March 2000?
Do (rational) professional ride the bubble?

- South Sea Bubble (1710 - 1720)
  - *Isaac Newton*
    - 04/20/1720 sold shares at £7,000 profiting £3,500
    - re-entered the market later - ended up losing £20,000
    - “I can calculate the motions of the heavenly bodies, but not the madness of people”

- Internet Bubble (1992 - 2000)
  - *Druckenmiller* of Soros’ Quantum Fund didn’t think that the party would end so quickly.
    - “We thought it was the eighth inning, and it was the ninth.”
  - *Julian Robertson* of Tiger Fund refused to invest in internet stocks
Pros’ dilemma

- “The moral of this story is that irrational market can kill you …
- Julian said ‘This is irrational and I won’t play’ and they carried him out feet first.
- Druckenmiller said ‘This is irrational and I will play’ and they carried him out feet first.”

Quote of a financial analyst, New York Times

April, 29, 2000
Suppose behavioral trading leads to mispricing.

- Can mispricings or bubbles persist in the presence of rational arbitrageurs?

- What type of information can lead to the bursting of bubbles?
Main Literature

- Keynes (1936) ⇒ bubble can emerge
  - “It might have been supposed that competition between expert professionals, possessing judgment and knowledge beyond that of the average private investor, would correct the vagaries of the ignorant individual left to himself.”

- Friedman (1953), Fama (1965)
  Efficient Market Hypothesis ⇒ no bubbles emerge
  - “If there are many sophisticated traders in the market, they may cause these “bubbles” to burst before they really get under way.”

- Limits to Arbitrage
  - Noise trader risk versus Synchronization risk
    Shleifer & Vishny (1997), DSSW (1990 a & b)

- Bubble Literature
  - Symmetric information - Santos & Woodford (1997)
  - Asymmetric information
Timing Game - Synchronization

- (When) will behavioral traders be overwhelmed by rational arbitrageurs?
- Collective selling pressure of arbitrageurs *more than suffices* to burst the bubble.
- Rational arbitrageurs understand that an eventual collapse is inevitable. But when?
- Delicate, difficult, dangerous *TIMING GAME*!
Elements of the Timing Game

- **Coordination**: at least $\kappa > 0$ arbs have to be ‘out of the market’
- **Competition**: only first $\kappa < 1$ arbs receive pre-crash price.
- **Profitable ride**: ride bubble as long as possible.
- **Sequential Awareness**: A **Synchronization Problem** arises!
  - Absent of sequential awareness, competitive element dominates $\Rightarrow$ and bubble burst immediately.
  - With sequential awareness, incentive to TIME THE MARKET leads to $\Rightarrow$ “delayed arbitrage” $\Rightarrow$ persistence of bubble.
introduction

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Model setup

- common action of $\kappa$ arbitrageurs
- sequential awareness
  (random $t_0$ with $F(t_0) = 1 - \exp\{-\lambda t_0\}$).

$p_t = e^{gt}$

$\frac{1}{\eta}$

paradigm shift
- internet 90’s
- railways
- etc.

$\beta p_t$

$1 - \beta(\cdot) p_t$

$t_0$
random starting point

$t_0 + \eta \kappa$
$\kappa$ traders are aware of the bubble

$t_0 + \eta$
all traders are aware of the bubble

$t_0 + \tau$
bubble bursts for exogenous reasons

maximum life-span of the bubble $\tau$
Payoff structure

- **Cash Payoffs (difference)**
  - Sell ‘one share’ at $t-\Delta$ instead of at $t$.

\[
p_{t-\Delta} e^{r\Delta} - p_t
\]

where \( p_t = \begin{cases} 
  e^{gt} & \text{prior to the crash} \\
  (1 - \beta(t - t_0)) e^{gt} & \text{after the crash}
\end{cases} \)

- **Execution price at the time of bursting.**

\[
p_t^{\text{burst}} = \begin{cases} 
  e^{gt} & \text{for first random orders up to } \kappa \\
  (1 - \beta(t - t_0)) e^{gt} & \text{all other orders}
\end{cases}
\]
Payoff structure (ctd.), Trading

- Small transactions costs $c e^r$
- Risk-neutrality but max/min stock position
  - max long position
  - max short position
  - due to capital constraints, margin requirements etc.

Definition 1: **trading equilibrium**
- Perfect Bayesian Nash Equilibrium
- Belief restriction: trader who attacks at time $t$ believes that all traders who became aware of the bubble prior to her also attack at $t$. 
Sell out condition for $\Delta \to 0$ periods

- sell out at $t$ if

$$\Delta h(t|t_i)E_t[\text{bubble}|\bullet] \geq (1-\Delta h(t|t_i))(g - r)p_t \Delta$$

- appreciation rate
- benefit of attacking
- cost of attacking

$$h(t | t_i) \geq \frac{g - r}{\beta^*}$$

bursting date $T^*(t_0) = \min\{T(t_0 + \eta \kappa), t_0 + \tau\}$

RHS converges to $\to [(g-r)]$ as $t \to \infty$
Persistence of Bubbles

Proposition 2: Suppose \( \frac{\lambda}{1-e^{-\lambda \eta \kappa}} \leq \frac{g-r}{\beta} \).

- existence of a unique trading equilibrium
- traders begin attacking after a delay of \( \tau^1 < \overline{\tau} \) periods.
- bubble does not burst due to endogenous selling prior to \( t_0 + \tau \).
Sequential awareness

Distribution of $t_0$

(trusting of bubble if nobody attacks)

$t_i - \eta$

since $t_i \leq t_0 + \eta$

$t_i$

since $t_i \geq t_0$

$t_j - \eta$

$t_j$

$t_0$

$t_k$

$t_0 + \tau$

$t_k$

$t_0$
Conjecture 1: Immediate attack

\[ \Rightarrow \text{Bubble bursts at } t_0 + \eta \kappa \]

when \( \kappa \) traders are aware of the bubble

\[ \lambda/(1-e^{-\lambda \eta \kappa}) \]

If \( t_0 < t_i - \eta \kappa \), the bubble would have burst already.
Conj. 1 (ctd.): Immediate attack

⇒ Bubble bursts at $t_0 + \eta \kappa$

hazard rate of the bubble

$$h = \lambda/(1 - \exp\{-\lambda(t_i + \eta \kappa - t)\})$$

Distribution of $t_0$

$\lambda/(1 - e^{-\lambda \eta \kappa})$

Distribution of $t_0 + \eta \kappa$

$t_i - \eta$

$t_i - \eta \kappa$

$t_i$

$t_i + \eta \kappa$

Bubble bursts for sure!
Conj. 1 (ctd.): Immediate attack

⇒ Bubble bursts at $t_0 + \eta \kappa$

hazard rate of the bubble $h = \frac{\lambda}{1 - \exp\{-\lambda (t_i + \eta \kappa - t)\}}$

Recall the sell out condition:

\[
 h(t | t_i) \geq \frac{g - r}{\beta^*}
\]

Recall the sell out condition:

lower bound: $(g-r)/\beta > \frac{\lambda}{1 - e^{-\lambda \eta \kappa}}$

bubble appreciation / bubble size

Distribution of $t_0$

$t_i - \eta$
$t_i - \eta \kappa$
$t_i$
$t_i + \eta \kappa$

optimal time to attack $t_i + \tau_i$ ⇒ “delayed attack is optimal”

no “immediate attack” equilibrium!
Conj. 2: Delayed attack by arbitrary $\tau'$

⇒ Bubble bursts at $t_0 + \eta \kappa + \tau' < t_0 + \tau$

bubble appreciation
bubble size

hazard rate of the bubble
$h = \lambda/(1-\exp\{-\lambda(t_i + \eta \kappa + \tau' - t)\})$

lower bound: $(g-r)/\beta > \lambda/(1-e^{-\lambda \eta \kappa})$

⇒ attack is never successful
⇒ bubble bursts for exogenous reasons at $t_0 + \tau$

⇒ optimal to delay attack even more
Endogenous crashes

Proposition 3: Suppose

\[
\frac{\lambda}{1-e^{-\lambda \eta \kappa}} > \frac{g-r}{\beta}.
\]

- ‘unique’ trading equilibrium.
- Traders begin attacking after a delay of \( \tau^* \) periods.
- Bubble bursts due to endogenous selling pressure at a size of \( p_t \) times

\[
\beta^* = \frac{1-e^{-\lambda \eta \kappa}}{\lambda} (g - r)
\]
Endogenous crashes

\[ t_i - \eta \quad t_i - \eta\kappa \quad t_i \quad t_i - \eta + \eta\kappa + \tau^* \quad t_i + \tau^* \quad t_i + \eta\kappa + \tau^* \]

⇒ Bubble bursts at \( t_0 + \eta\kappa + \tau^* \)

hazard rate of the bubble
\[ h = \frac{\lambda}{1 - \exp\{-\lambda(t_i + \eta\kappa + \tau' - t)\}} \]

bubble appreciation
bubble size

lower bound: \( \frac{(g-r)}{\beta} > \frac{\lambda}{1 - e^{-\lambda\eta\kappa}} \)

conjectured
attack

optimal
Lack of common knowledge

⇒ standard backwards induction can’t be applied

\[ t_0 \quad t_0 + \eta \kappa \quad t_0 + \eta \quad t_0 + 2\eta \quad t_0 + 3\eta \quad \ldots \quad t_0 + \tau \]

Everybody knows of the bubble

Everybody knows that everybody knows of the bubble

Everybody knows that everybody knows that everybody knows of the bubble

(\text{same reasoning applies for } \kappa \text{ traders})
introduction
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preliminary analysis
persistence of bubbles
synchronizing events
price cascades and rebounds
conclusion
Role of synchronizing events (information)

- News may have an impact disproportionate to any intrinsic informational (fundamental) content.
  - News can serve as a synchronization device.
- Fads & fashion in information
  - Which news should traders coordinate on?
- When “synchronized attack” fails, the bubble is temporarily strengthened.
Setting with synchronizing events

- Focus on news with no informational content (sunspots)
- Synchronizing events occur with Poisson arrival rate $\eta$.
  - Note that the pre-emption argument does not apply since event occurs with zero probability.
- Arbitrageurs who are aware of the bubble become increasingly worried about it over time.
  - Only traders who became aware of the bubble more than $\tau_e$ periods ago observe (look out for) this synchronizing event.
Synchronizing events - Market rebounds

**Proposition 5:** In ‘responsive equilibrium’

Sell out

- a) always at the time of a public event $t_e$,
- b) after $t_i + \tau^{**}$ (where $\tau^{**} < \tau^*$),

except after a failed attack at $t_p$, **re-enter** the market for $t \in (t_e, t_e - \tau_e + \tau^{**})$.

**Intuition for re-entering the market:**

- for $t_e < t_0 + \eta \kappa + \tau_e$ attack fails, agents learn $t_0 > t_e - \tau_e - \eta \kappa$
- without public event, they would have learnt this only at $t_e + \tau_e - \tau^{**}$.
- the existence of bubble at $t$ reveals that $t_0 > t - \tau^{**} - \eta \kappa$
- that is, no additional information is revealed till $t_e - \tau_e + \tau^{**}$
- density that bubble bursts for endogenous reasons is zero.
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Price cascades and rebounds

- Price drop as a synchronizing event.
  - through psychological resistance line
  - by more than, say 5%

- Exogenous price drop
  - after a price drop
    - if bubble is ripe
      ⇒ bubble bursts and price drops further.
    - if bubble is not ripe yet
      ⇒ price bounces back and the bubble is strengthened for some time.
Proposition 6:

Sell out

a) after a price drop if $\tau_i \leq \tau_p(H_p)$

b) after $t_i + \tau^{***}$ (where $\tau^{***} < \tau^*$),

re-enter the market after a rebound at $t_p$ for $t \in (t_p, t_p - \tau_p + \tau^{***})$.

- attack is costly, since price might jump back
  $\Rightarrow$ only arbitrageurs who became aware of the bubble more than $\tau_p$ periods ago attack bubble.

- after a rebound, an endogenous crash can be temporarily ruled out and hence, arbitrageurs re-enter the market.

- Even sell out after another price drop is less likely.
Conclusion of Bubbles and Crashes

- **Bubbles**
  - Dispersion of opinion among arbitrageurs causes a synchronization problem which makes coordinated price corrections difficult.
  - Arbitrageurs time the market and ride the bubble.
  - \( \Rightarrow \) Bubbles persist

- **Crashes**
  - can be triggered by unanticipated news without any fundamental content, since
  - it might serve as a synchronization device.

- **Rebound**
  - can occur after a failed attack, which temporarily strengthens the bubble.
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http://www.princeton.edu/~markus
reasons for persistence

- data
- empirical results
- conclusion
Why Did Rational Speculation Fail to Prevent the Bubble?

1. Unawareness of Bubble
   ⇒ Rational speculators perform as badly as others when market collapses.

2. Limits to Arbitrage
   - Fundamental risk
   - Noise trader risk
   - Synchronization risk
   - Short-sale constraint
     ⇒ Rational speculators may be reluctant to go short overpriced stocks.

3. Predictable Investor Sentiment
   - AB (2003), DSSW (JF 1990)
     ⇒ Rational speculators may want to go long overpriced stock and try to go short prior to collapse.
reasons for persistence

data

empirical results

conclusion
Data

- Hedge fund stock holdings
  - Quarterly 13 F filings to SEC
  - mandatory for all institutional investors
    - with holdings in U.S. stocks of more than $100 million
    - domestic and foreign
    - at manager level
  - Caveats: No short positions

- 53 managers with CDA/Spectrum data
  - excludes 18 managers b/c mutual business dominates
  - incl. Soros, Tiger, Tudor, D.E. Shaw etc.

- Hedge fund performance data
  - HFR hedge fund style indexes
reasons for persistence

data

empirical results

did hedge funds ride bubble?
did hedge funds’ timing pay off?

conclusion
Did hedge funds ride the bubble?

Fig. 2: Weight of NASDAQ technology stocks (high P/S) in aggregate hedge fund portfolio versus weight in market portfolio.
Did Soros etc. ride the bubble?

Fig. 4a: Weight of technology stocks in hedge fund portfolios versus weight in market portfolio
Fund in- and outflows

Figure 4b: Funds flows, three-month moving average

Fund flows as proportion of assets under management

Quantum Fund (Soros)

Jaguar Fund (Tiger)
Did hedge funds time stocks?

Figure 5. Average share of outstanding equity held by hedge funds around price peaks of individual stocks
Did hedge funds’ timing pay off?

**Figure 6: Performance of a copycat fund that replicates hedge fund holdings in the NASDAQ high P/S segment**
Conclusion

- Hedge funds were riding the bubble
  - Short sales constraints and “arbitrage” risk are not sufficient to explain this behavior.

- Timing bets of hedge funds were well placed. Outperformance!
  - Rules out unawareness of bubble.
  - Suggests predictable investor sentiment. Riding the bubble for a while may have been a rational strategy.

⇒ Supports ‘bubble-timing’ models