Institutional Finance

Lecture 09: Limits to Arbitrage, Bubbles & Herding

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LIMITS OF ARBITRAGE - ILLIQUIDITY

- Market liquidity provision =
  = (risky arbitrage) trading to exploit
  temporary mispricing…
- Very similar – just different language
- Why does temporary “mispricing” persist?
  - Illiquidity refers “more” to high frequency mispricing (daily, weekly)
  - Limits to arbitrage literature refers more to long-run mispricings phenomena

EMH AND LIMITS TO ARBITRAGE

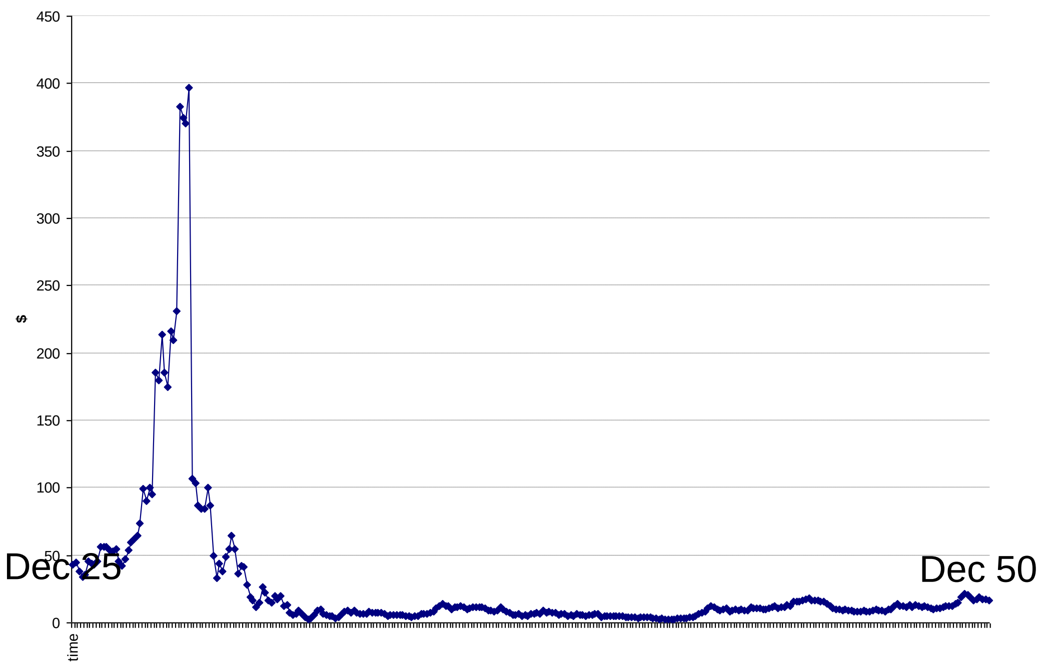
- Keynes (1936) $\Rightarrow$ bubble can emerge
  - "It might have been supposed that *competition between expert professionals*, possessing judgment and knowledge beyond that of the average private investor, would correct the vagaries of the ignorant individual left to himself."
- Friedman (1953), Fama (1965)
  Efficient Market Hypothesis $\Rightarrow$ 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."

BUBBLES – SPECIAL FORM OF MISPRICING: 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

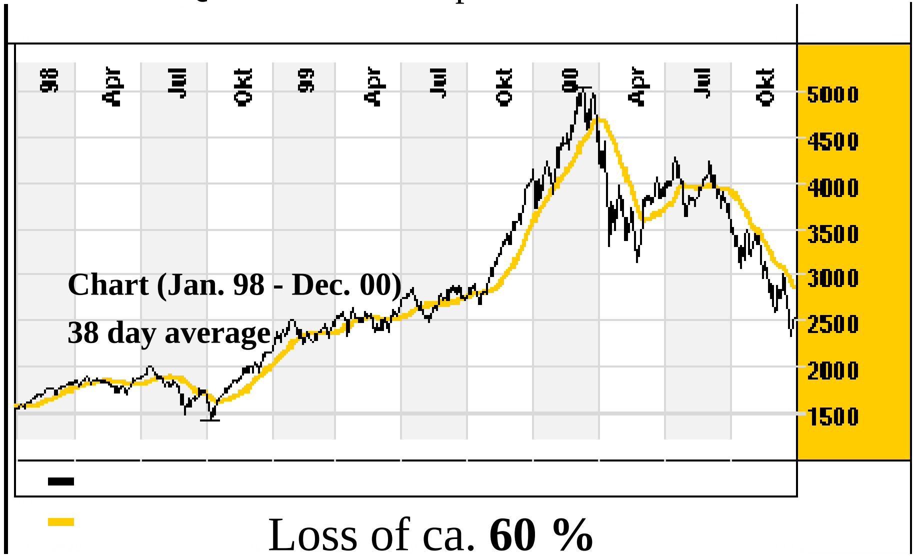
- Company: *Radio Corporation of America (RCA)*
- Technology: *Radio*
- Year: *1920's*



- It peaked at $ 397 in Feb. 1929, down to $ 2.62 in May 1932,

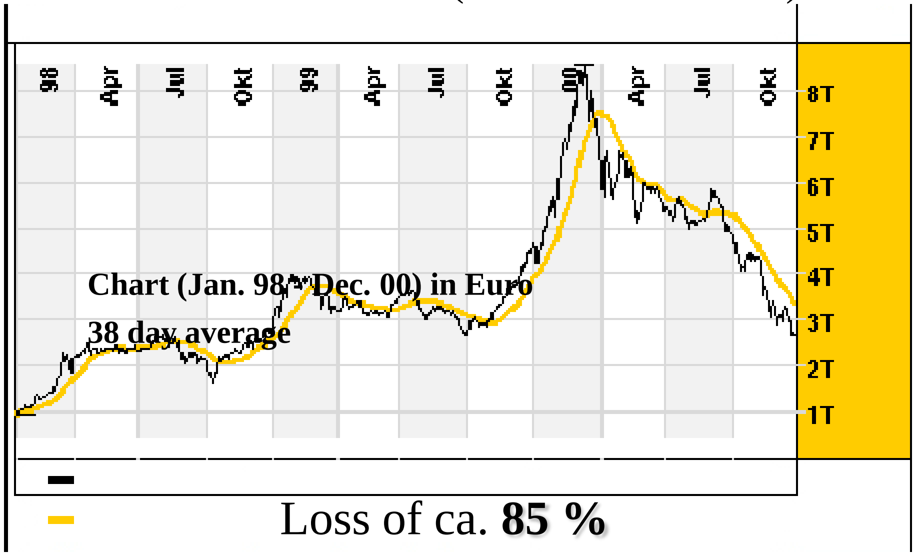
INTERNET BUBBLE? - 1990'S

NASDAQ Combined Composite Index



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

NEMAX All Share Index (German Neuer Markt)



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?**

LIMITS TO ARBITRAGE

- Efficient Market Hypothesis –
  3 levels of justification
  - All traders are rational, since behavioral will not survive in the long-run
  - Behavioral trades cancel each other on average
  - Rational arbitrageurs correct all mispricing induced by behavioral traders

LIMITS TO ARBITRAGE

- Noise Trader Risk
  - DeLong, Shleifer, Summers and Waldmann (1990 JPE)
  - Myopia due liquidity risk
    - Shleifer and Vishny (1997 JF)
- Synchronization Risk
  - Abreu and Brunnermeier (2002 JFE)
- Fundamental Risk
  - Campbell and Kyle (1993 REStud)

NOISE TRADER RISK

- ***Idea:*** Arbitrageurs do not fully correct the mispricing caused by noise traders due
  - Arbs short horizons (later endogenized)
  - Arbs risk aversion (face noise trader risk)
- Noise traders survive in the long-run

NOISE TRADER RISK – DSSW1990A

- OLG model
  - Agents live for 2 periods
  - Make portfolio decision when they are young
- 2 assets
  - Safe asset *s* — pays fixed real dividend *r*; perfect elastic supply; numeraire, i.e. p_s =1
  - Unsafe asset *u* — pays fixed real dividend r; no elastic supply X^{sup}=1; price at t is p_t
  - Fundamental value of *s* = fundamental value of *u*

NOISE TRADER RISK – DSSW1990A

- Agents/Traders
  - Mass $(1-\mu)$ of rational arbs
  - Mass of μ of noise traders, who misperceive next period's price by $\rho_t \sim N(\rho^*, \sigma^2_\rho)$
  - CARA utility function $U(W) = -\exp\{-2\gamma W\}$ with certainty equivalent $E[W] - \gamma Var[W]$
- Individual Demand
  - Arbitrageurs

$$E\left[W\right]-\gamma Var\left[W\right]=c_0+x_t^a\left[r+E_t\left[p_{t+1}\right]-p_t\left(1+r\right)\right]-\gamma\left(x_t^a\right)^2 Var_t\left[p_{t+1}\right]$$

  - Noise traders

$$E\left[W\right]-\gamma Var\left[W\right]=c_0+x_t^n\left[r+E_t\left[p_{t+1}\right]+\rho_t-p_t\left(1+r\right)\right]-\gamma\left(x_t^n\right)^2 Var_t\left[p_{t+1}\right]$$

NOISE TRADER RISK – DSSW1990A

- Individual demand
  - arbitrageurs: $$x_t^a = \frac{r+E_t[p_{t+1}]-(1+r)p_t}{2\gamma Var_t[p_{t+1}]}$$
  - noise traders: $$x_t^n = \frac{r+E_t[p_{t+1}]-(1+r)p_t}{2\gamma Var_t[p_{t+1}]} + \frac{\rho_t}{2\gamma Var_t[p_{t+1}]}$$
- Market Clearing: $(1-\mu)\, x^a_t + \mu\, x^n_t = 1$

$$p_t = \frac{1}{1+r}\left[r + E_t\left[p_{t+1}\right] - 2\gamma Var_t\left[p_{t+1}\right] + \mu\rho_t\right]$$

  - Solve recursively

$$p_{t+1} = \frac{1}{1+r}\left[r + E_{t+1}\left[p_{t+2}\right] - 2\gamma Var_{t+1}\left[p_{t+2}\right] + \mu\rho_{t+1}\right]$$

$$E_t\left[p_{t+1}\right] = \frac{1}{1+r}\left[r + E_t\left[p_{t+2}\right] - 2\gamma Var_t\left[p_{t+2}\right] + \mu\rho^*\right]$$

  - We will se later that $Var_t[p_{t+\tau}]$ is a constant for all τ

NOISE TRADER RISK – DSSW 1990A

- Solve first order difference equation

$$p_t = 1 + \frac{\mu\left(\rho_t - \rho^*\right)}{1+r} + \frac{\mu\rho^*}{r} - \frac{2\gamma}{r} Var_t\left[p_{t+1}\right]$$

- Note that ρ_t is the only random variable.
  Hence, $Var_t\left[p_{t+1}\right] = Var\left[p_{t+1}\right] = \frac{\mu^2\sigma_\rho^2}{(1+r)^2}$

$$p_t = 1 + \frac{\mu\left(\rho_t - \rho^*\right)}{1+r} + \frac{\mu\rho^*}{r} - \frac{(2\gamma)\,\mu^2\sigma_\rho^2}{r\,(1+r)^2}$$

  - 1 = fundamental value
  - Second-term = deviation due to current misperception
  - Third-term = average misperception of noise traders
  - Last-term = arbs’ risk premium

FUND-OUTFLOW RISK - PERFORMANCE BASED ARBITRAGE

- Why are professional arbitrageurs' myopic?
- Modified version of Shleifer & Vishny (1997JF)
  - Two assets
    - Risk-free bond
    - Risky stock with final value *v*
  - Two types of fund managers:
    - Good type knows fundamental value *v*
    - Bad type just gambles with "other people's money"
  - Two trading rounds *t=1* and *2* (in *t=3*, *v* is paid out)
  - Individual investors
    - Entrust their money F_1 to a fund manager without knowing the fund managers' skill level – "separation of brain and money"
    - Can withdraw funds in t=2
  - Noise traders submit random demand

FUND-OUTFLOW RISK - PERFORMANCE BASED ARBITRAGE

- Price setting
  - $P_3 = v$
  - P_2 is determined by aggregate demand of fund manager and liquidity/noise traders
- Focus on case where
  1. $P_1 < v$ asset is undervalued
  2. $P_2 < P_1$ goes even further down in t=2 due to
     - sell order by noise trader
     - sell order by other informed trader
- Performance-based fund flows (see Chevalier & Ellison 1997)

FUND-OUTFLOW RISK - PERFORMANCE BASED ARBITRAGE

- Performance-based fund flows
  - If price drops, prob. increases that manager is bad
  - Clients withdraw their money
  - Shleifer-Vishny 1997 assume $F_2 = F_1 - aD_1 (1 - P_2/P_1)$, where D_1 is the amount the manager invested in the stock.
- "Good" manager's problem who has invested in risky asset
  - Has to liquidate his position at $P_2 < P_1$
    (exactly when mispricing is largest!)
  - Makes losses, even though the asset was initially undervalued.
  - Due to this "outflow risk", a rational fund manager is reluctant to fully exploit arbitrage opportunities
    [Note that fund-outflows exacerbate any risk that margins are binding!]
  - Hence,
    manager focus on short-run price movement
    $\Rightarrow$ Myopia of professional arbitrageurs (justifies DSSW assumption)

SYNCHRONIZATION RISK

- Noise trader risk
  - Risk that **irrational traders** drive price even further from fundamentals
- Synchronization risk
  - One trader alone cannot correct the mispricing (can sustain a trade only for a limited time period)
  - Risk that **other rational traders** do not act against mispricing (in sufficiently close time)
    - Abreu and Brunnermeier (2002, 2003 for **bubble**s)
  - Relatively unimportant news can serve as synchronization device and trigger a large price correction

DO 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

ELEMENTS OF THE TIMING GAME

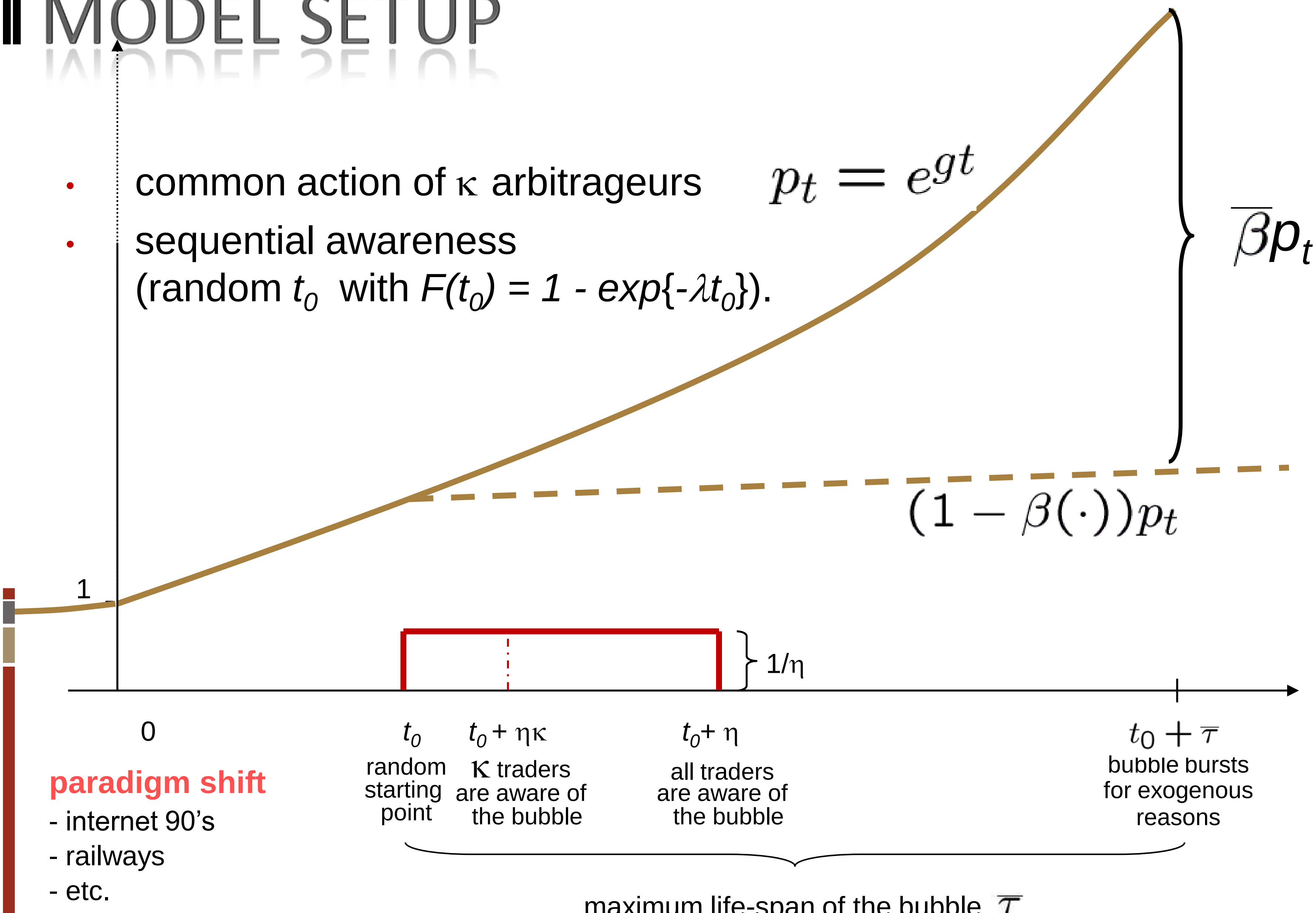
1. *Coordination* at least $\kappa > 0$ arbs have to be 'out of the market'
2. *Competition* only *first* $\kappa < 1$ arbs receive pre-crash price.
3. *Profitable ride* ride bubble (stay in the market) as long as possible.
4. *Sequential Awareness*

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" and persistence of bubble.

MODEL SETUP

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



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

PAYOFF STRUCTURE (CTD.), TRADING (SKIP)

- Small transactions costs ce^{rt}
- 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

$$\Delta\, h(t|t_i) \underbrace{E_t[\text{bubble}|\bullet]}_{\text{benefit of attacking}} \geq (1-\Delta\, h(t|t_i)) \underbrace{\overbrace{(g-r)}^{\text{appreciation rate}} p_t\, \Delta}_{\text{cost of attacking}}$$

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

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

RHS converges to $\rightarrow$ [(*g*-*r*)] as $t \rightarrow \infty$

INTUITION OF SYNCHRONIZATION RISK

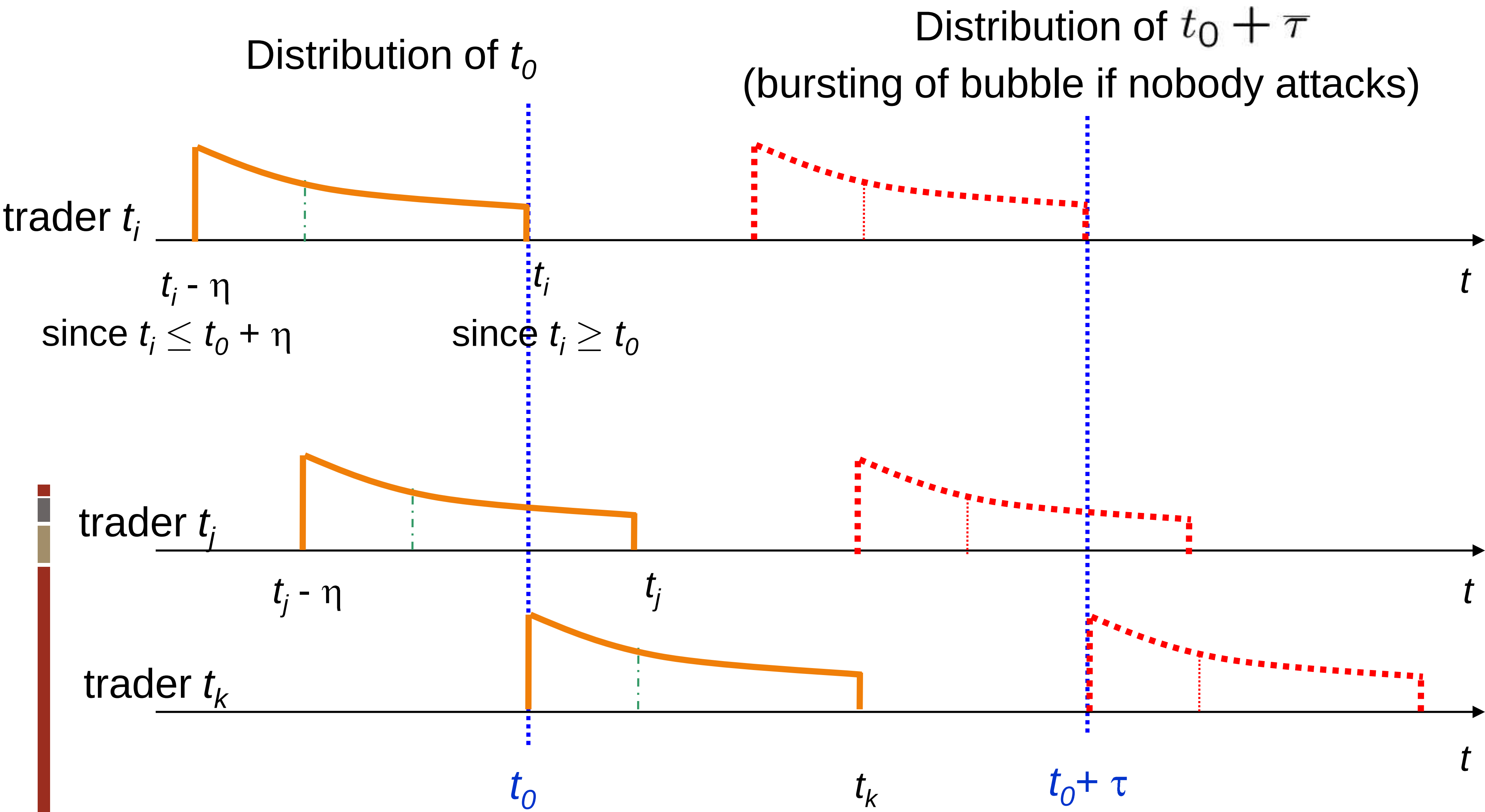
- Hazard rate $h(t|t_i)$ depends on trading behavior of other rational traders
- I received a signal that price is too high at t_i, but others might receive this signal much later (for large η).
- Let me ride the bubble (and enjoy growth rate of g) as long it is unlikely that enough traders are informed about the overpricing.
- All other rational trader think the same way.
  $\longrightarrow$Hence, bubble survives longer.
- This allows me to enjoy the ride even longer.

- Over time, the size of the bubble grows and eventually it will be so large that I am afraid that it will burst on me.
- Everybody sells out τ periods after receiving his signal.
  $\longrightarrow$ Traders leave the market sequentially

PERSISTENCE OF BUBBLES (SKIP)

- **Proposition 2:** Suppose $\frac{\lambda}{1-e^{-\lambda\eta\kappa}} \leq \frac{g-r}{\overline{\beta}}$
  - 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 $t_0 + \overline{\tau}$

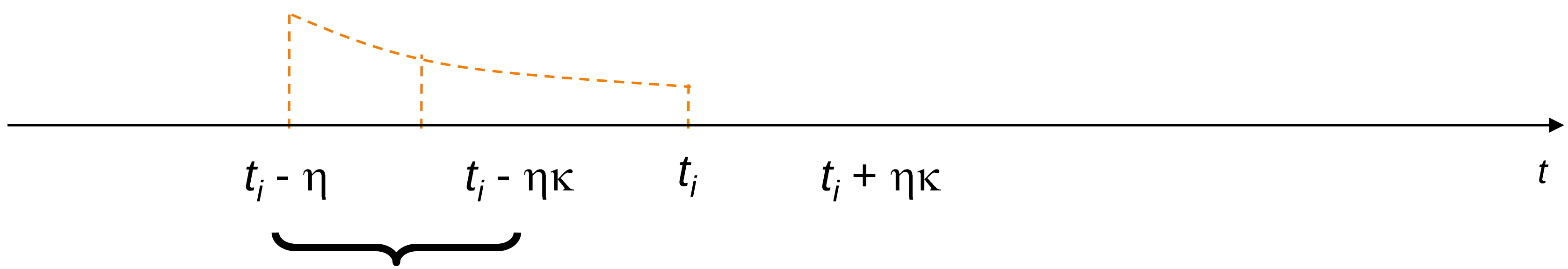
SEQUENTIAL AWARENESS



CONJECTURE 1: IMMEDIATE ATTACK

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

when κ traders are aware of the bubble



If $t_0 < t_i - \eta\kappa$, the bubble would have burst already.

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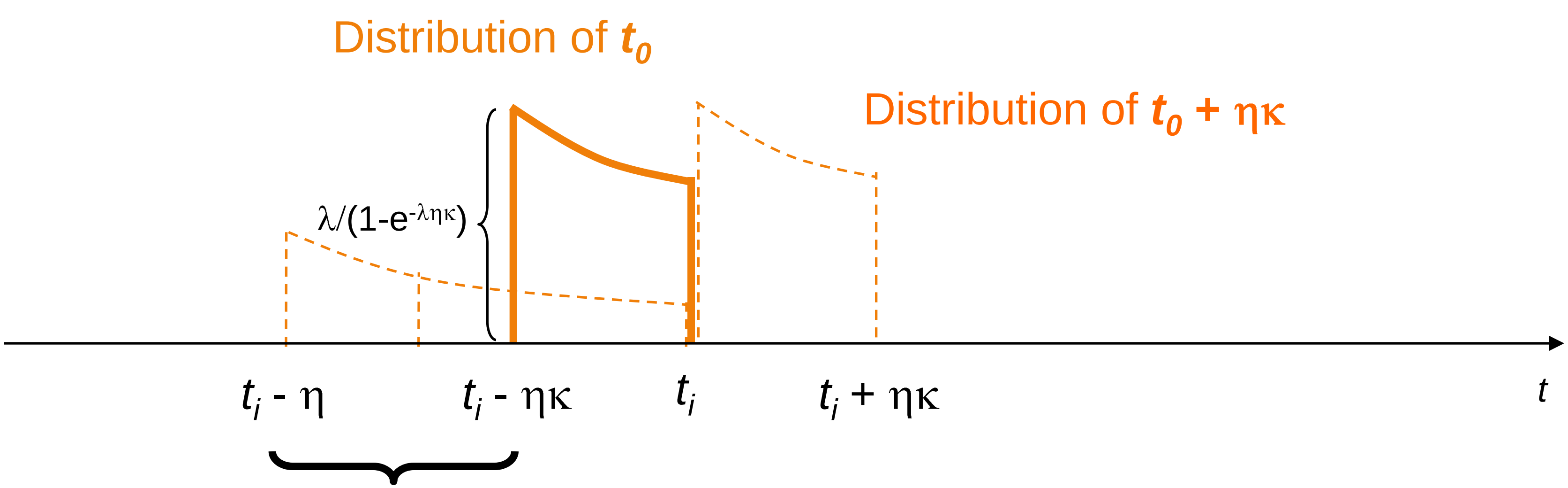

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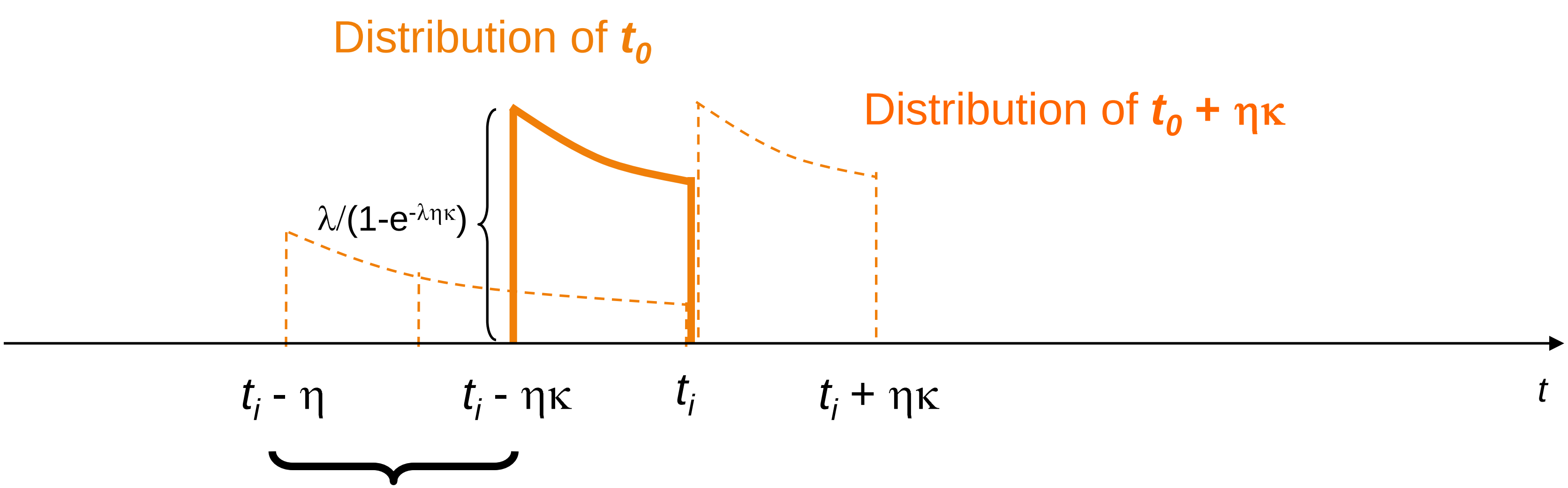

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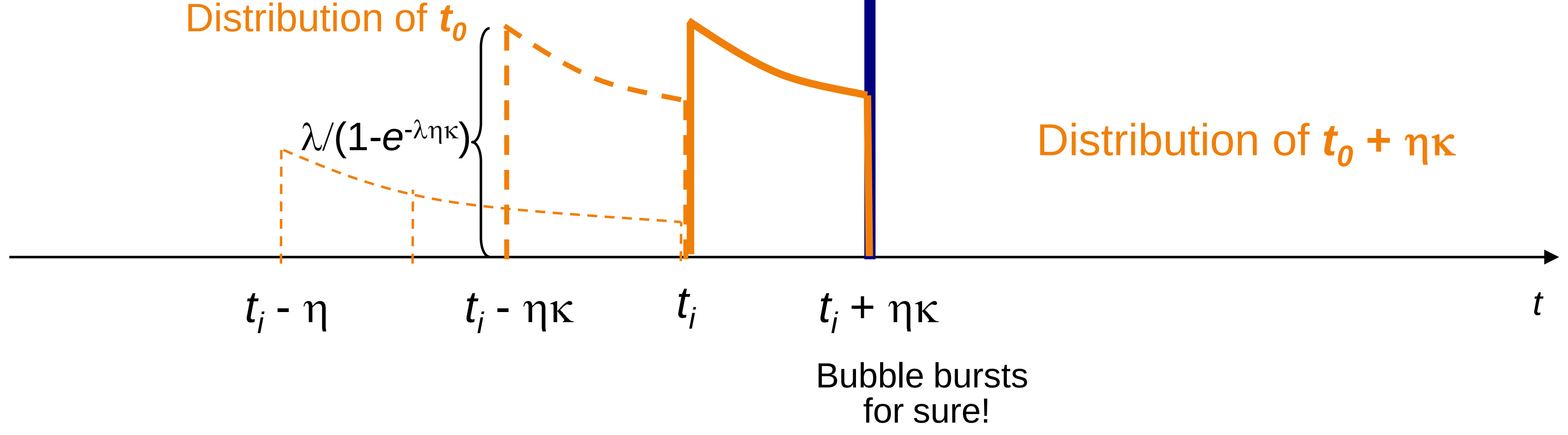
CONJ. 1 (CTD.): IMMEDIATE ATTACK

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

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



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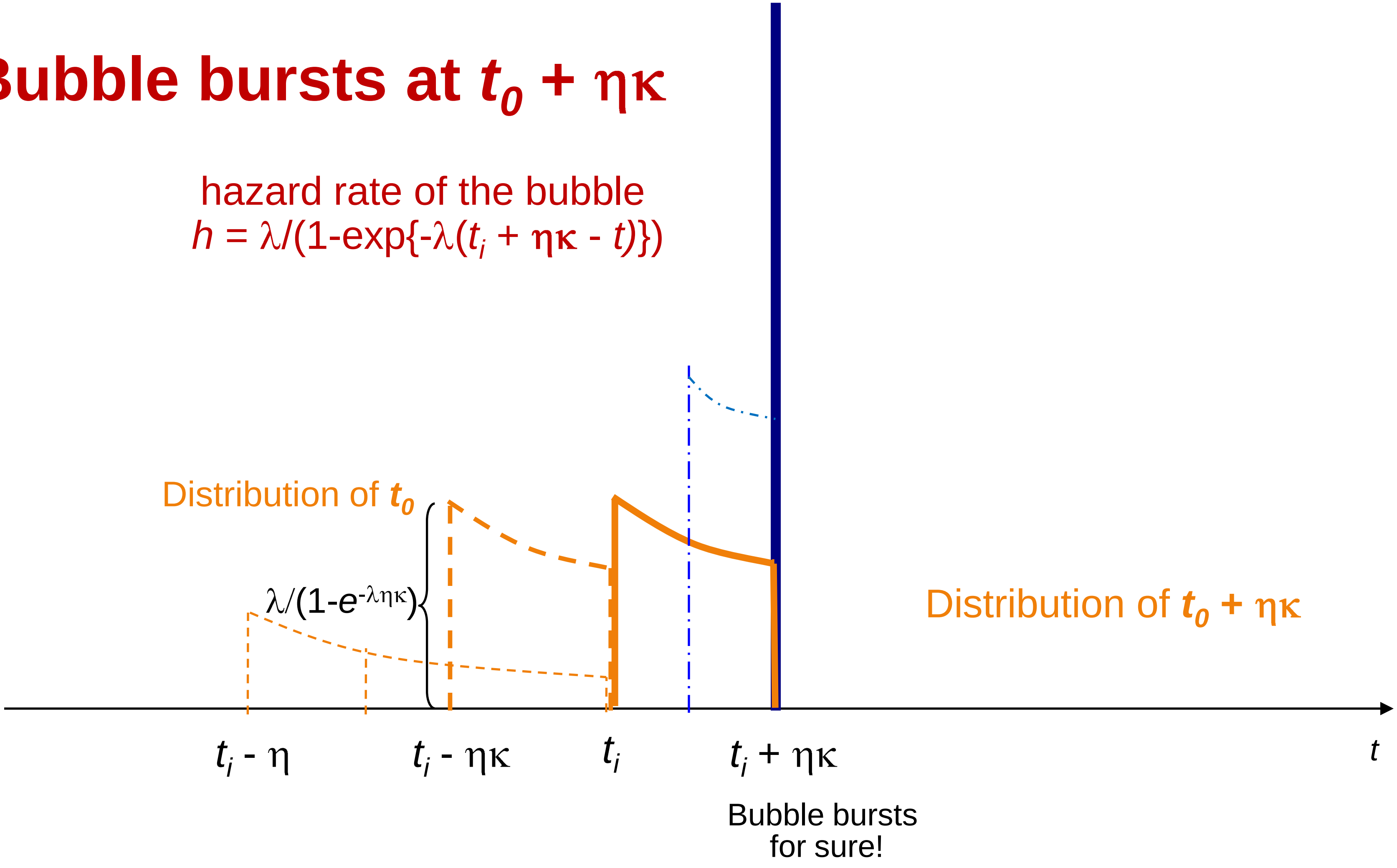

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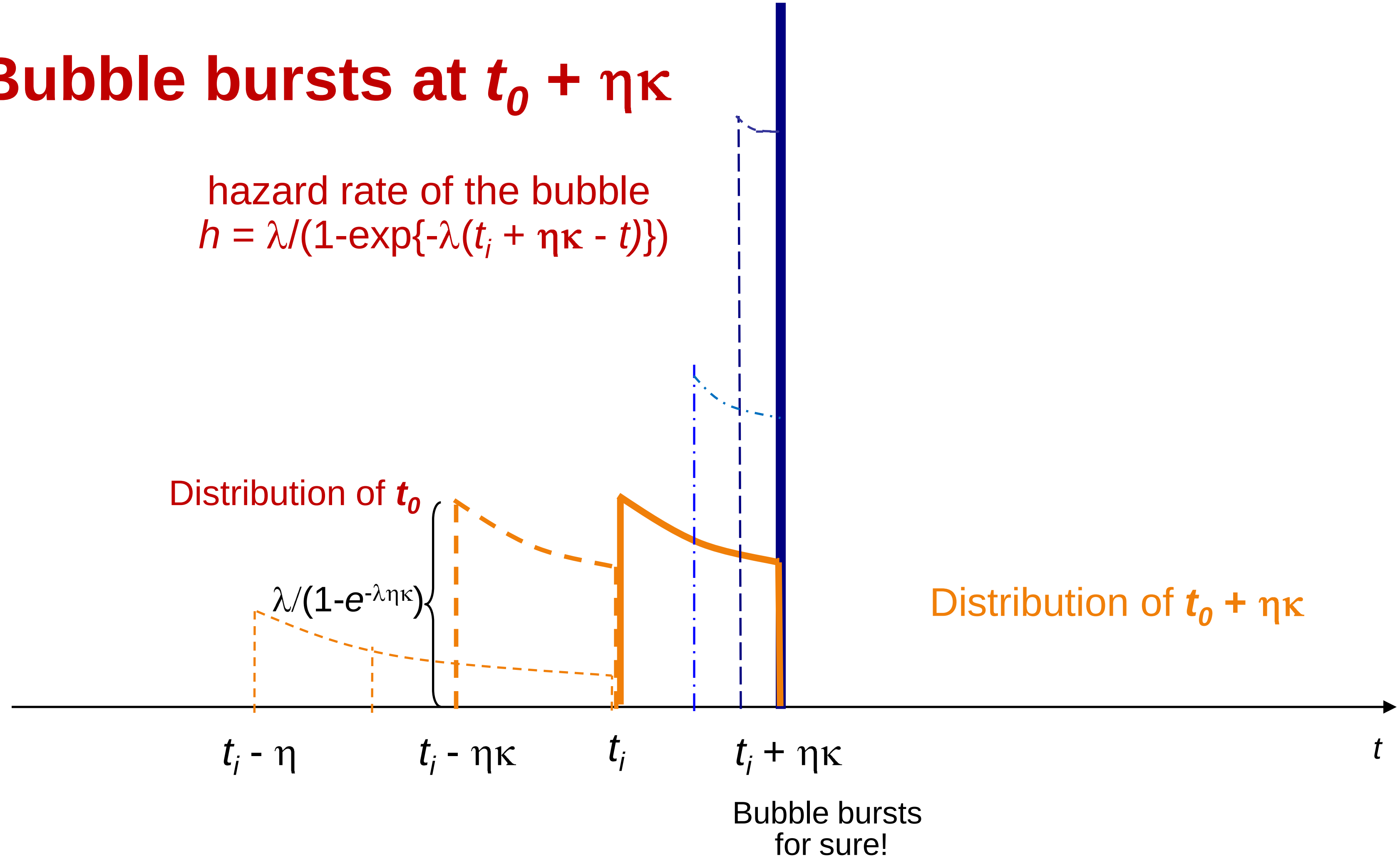
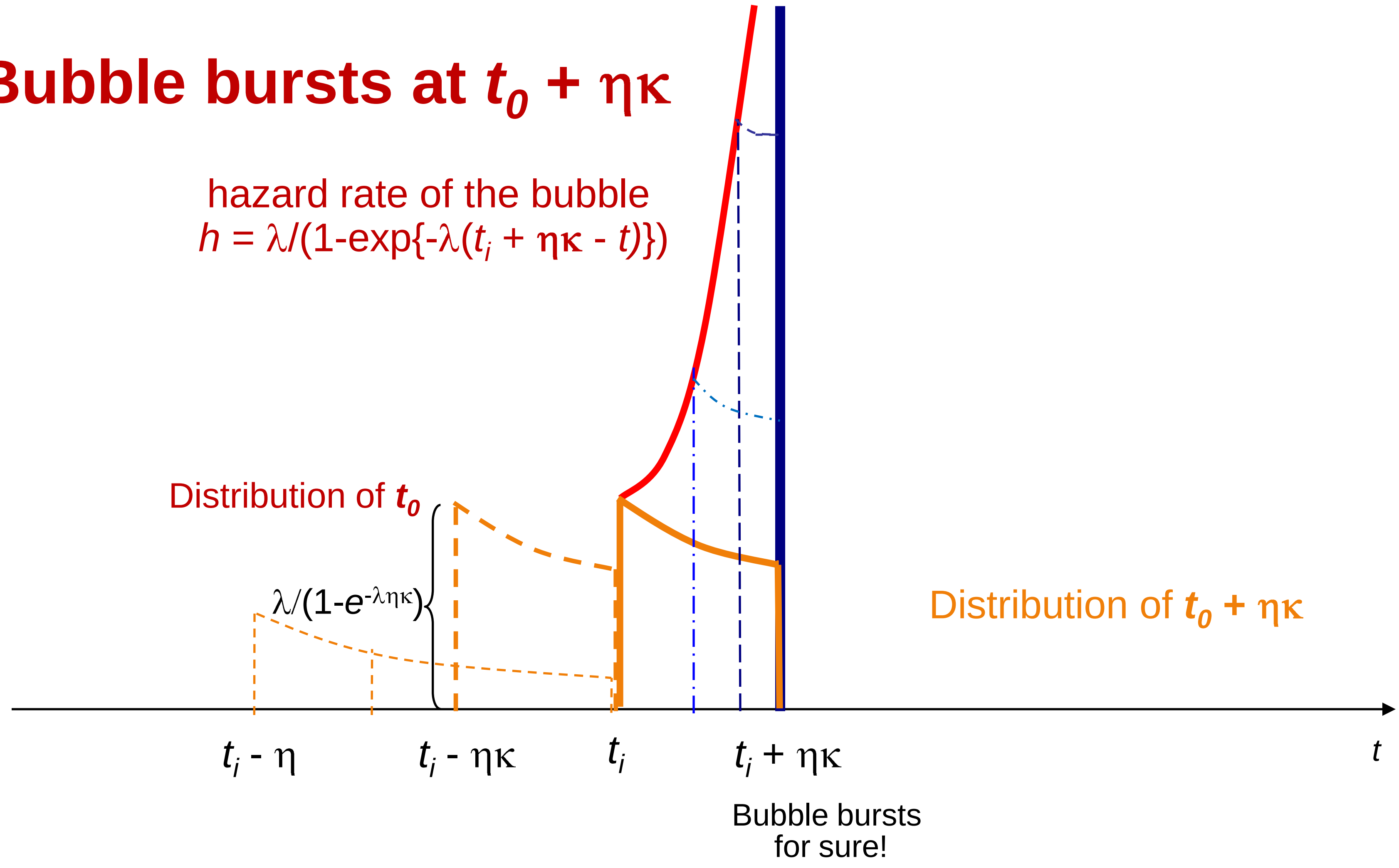


CONJ. 1 (CTD.): IMMEDIATE ATTACK

⇒ **Bubble bursts at t_0 + ηκ**

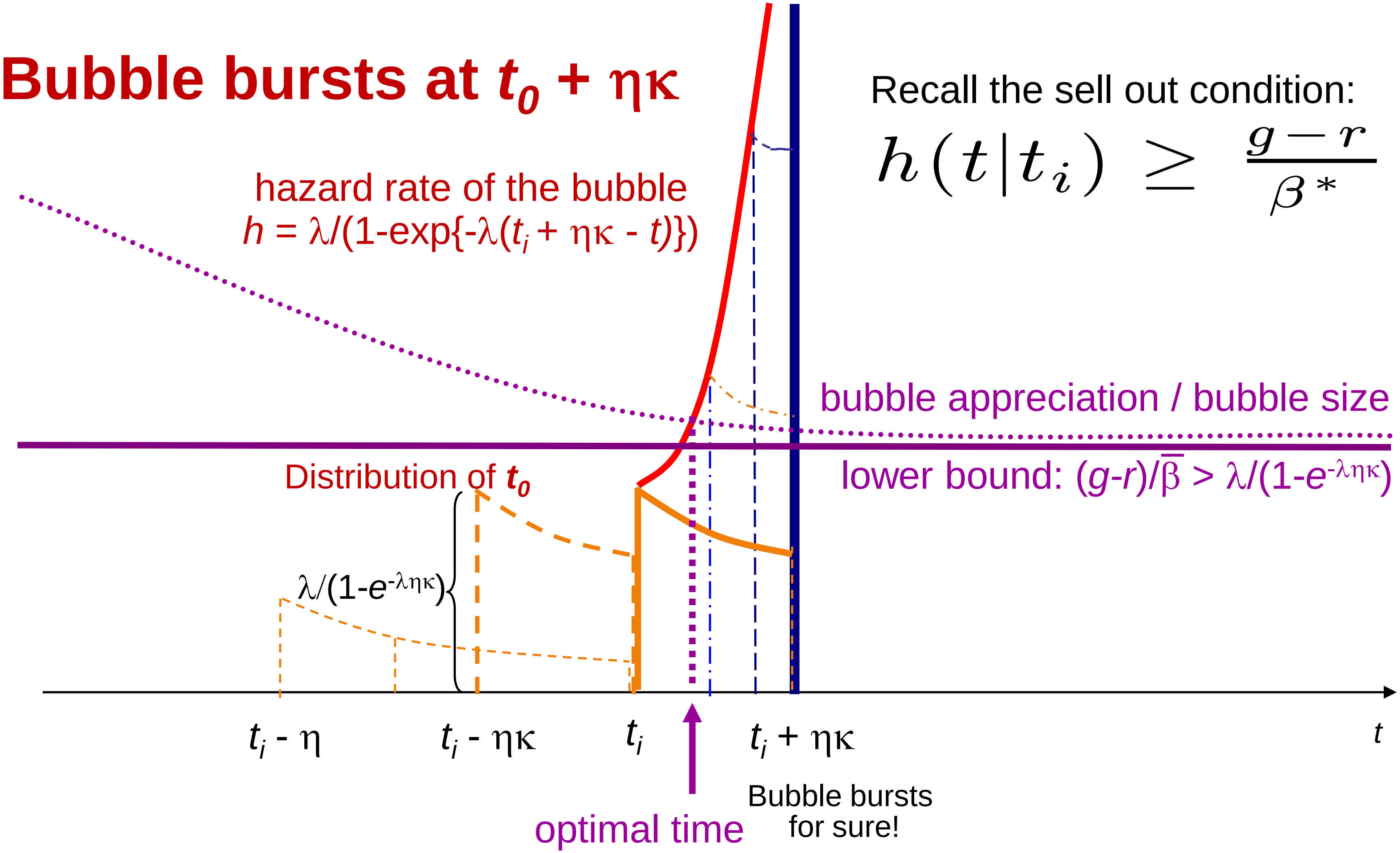


CONJ. 1 (CTD.): IMMEDIATE ATTACK

⇒ Bubble bursts at $t_0 + \eta\kappa$

Recall the sell out condition:

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

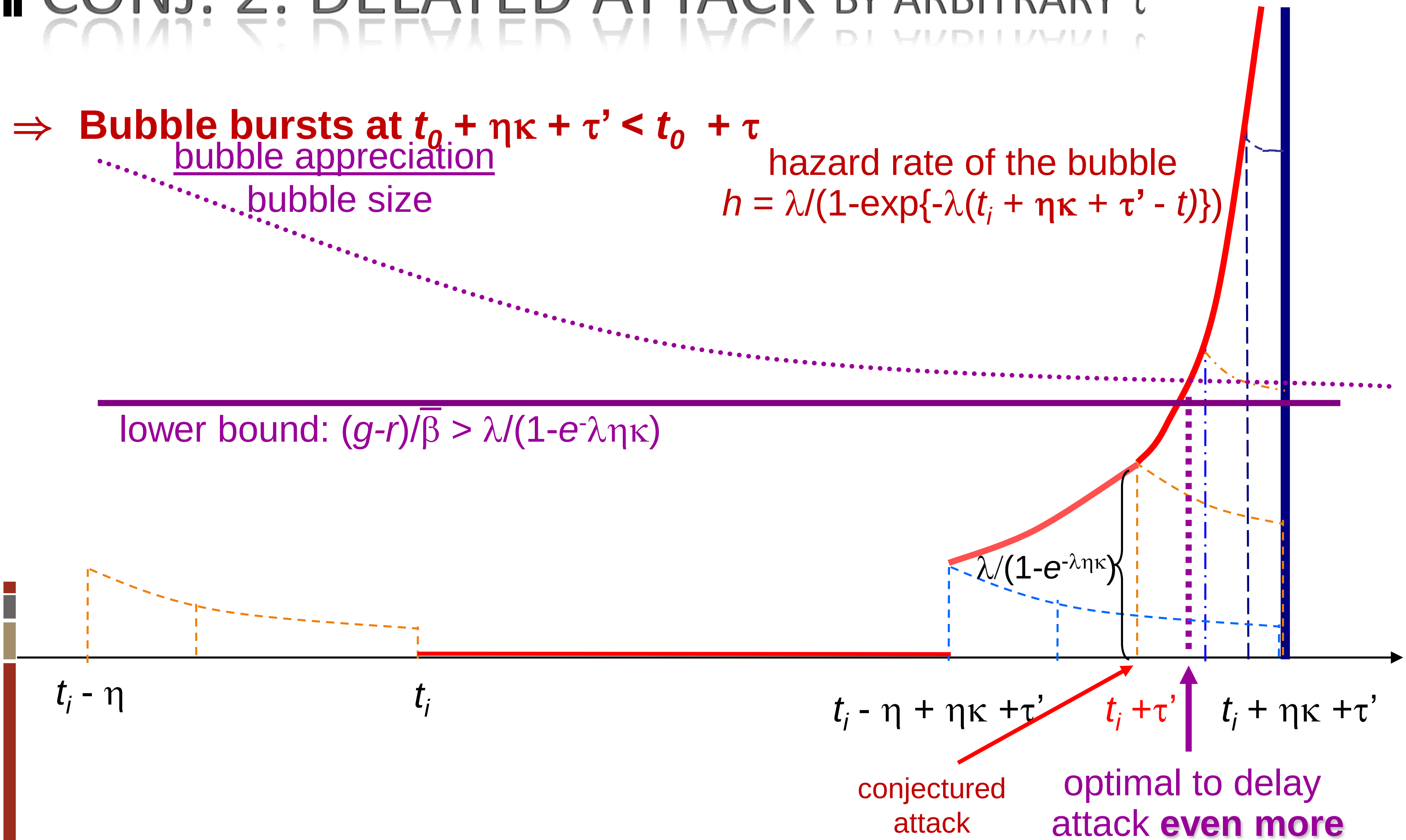


⇒ **"delayed attack is optimal"**

no "immediate attack" equilibrium!

CONJ. 2: DELAYED ATTACK BY ARBITRARY τ'

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



→ **attack is never successful**

→ **bubble bursts for exogenous reasons at $t_0 + \tau$**

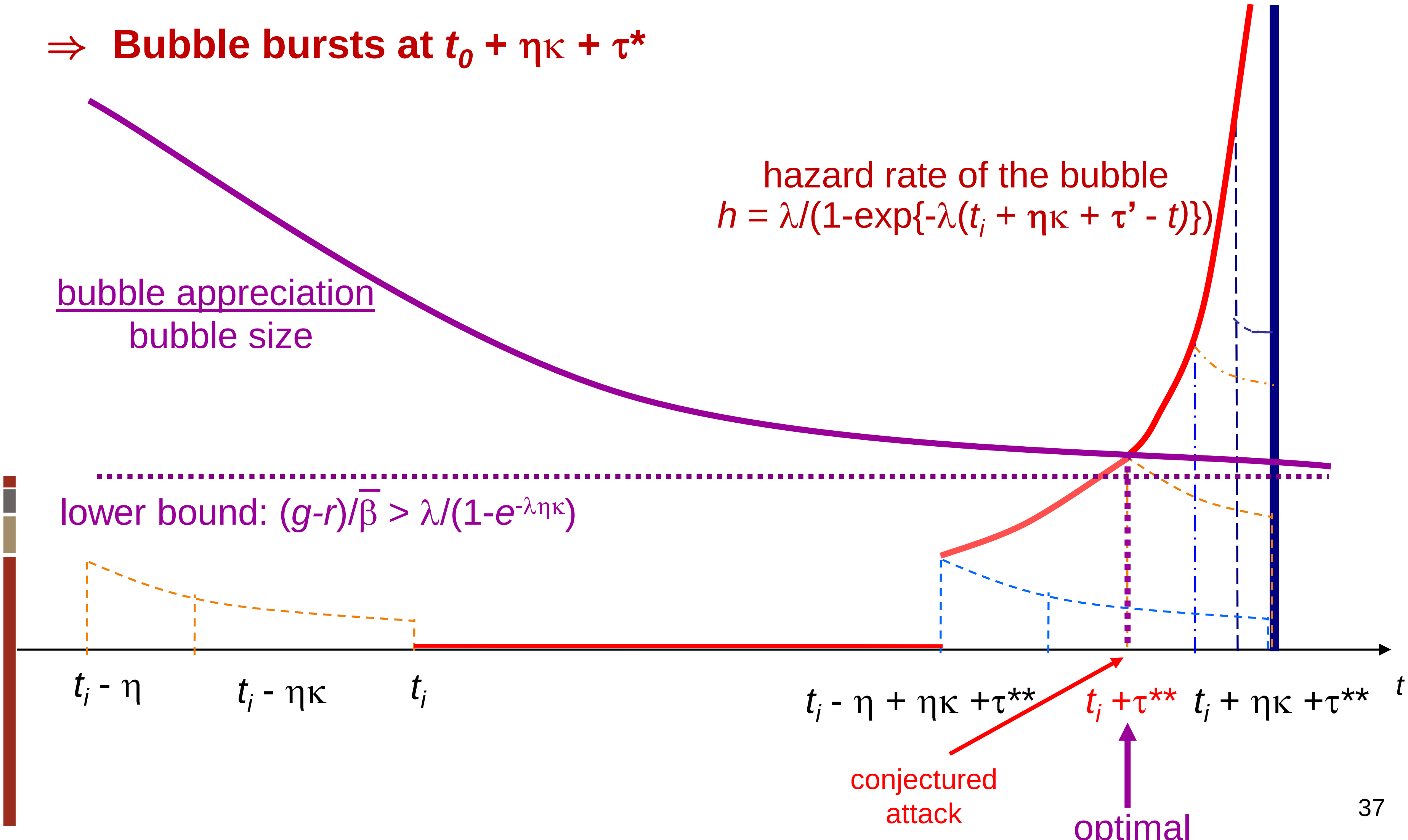
ENDOGENOUS CRASHES

- **Proposition 3:** Suppose $\frac{\lambda}{1-e^{-\lambda\eta\kappa}} > \frac{g-r}{\beta}$
  - **'unique'** trading equilibrium.
  - traders begin attacking after a delay of τ^* periods.
  - bubble ***bursts*** due to endogenous selling pressure at a size of p_t times

$$\beta^* = \frac{1-e^{-\lambda\eta\kappa}}{\lambda}(g-r)$$

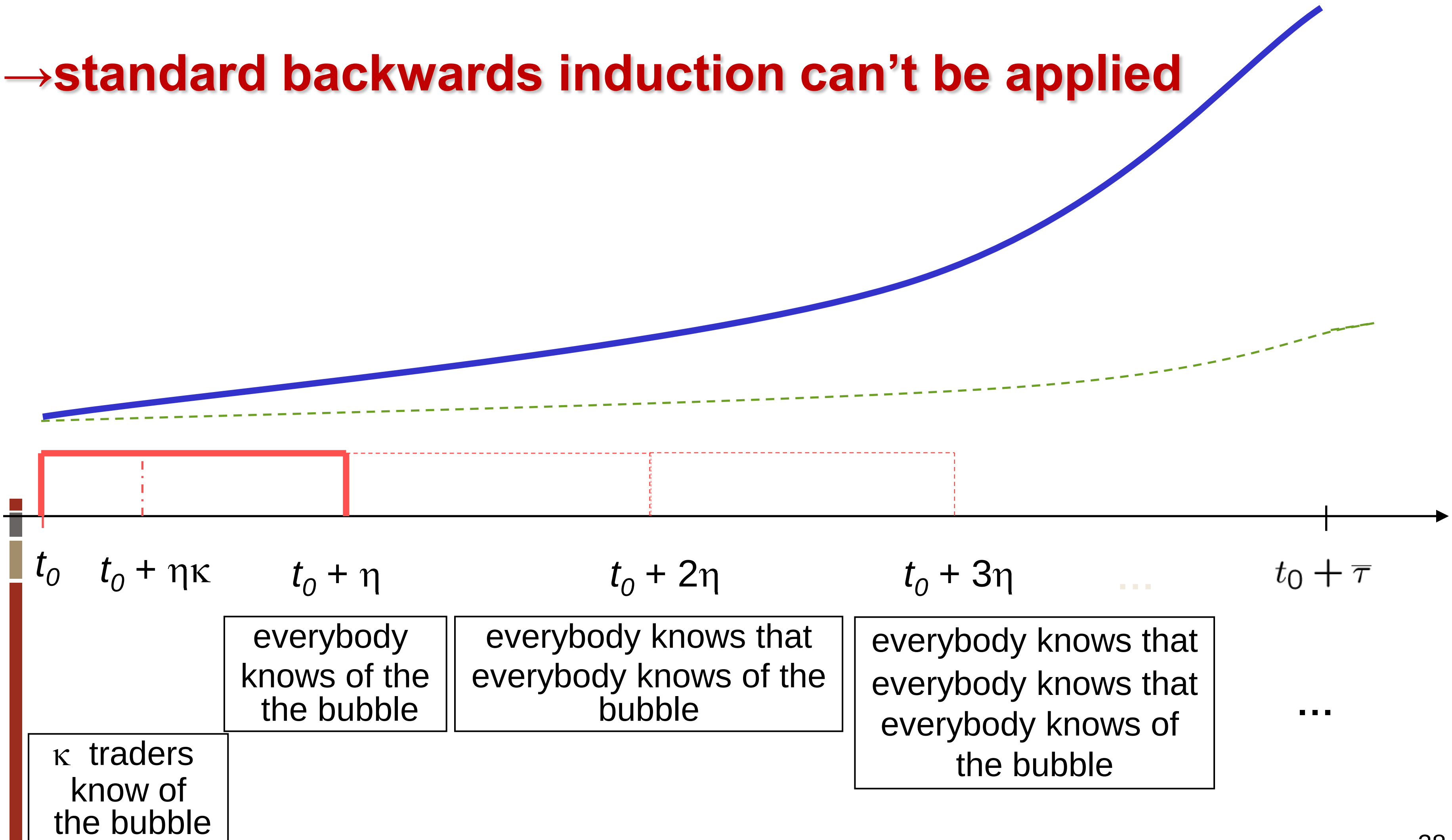
ENDOGENOUS CRASHES

$\Rightarrow$ **Bubble bursts at $t_0 + \eta\kappa + \tau^*$**



LACK OF COMMON KNOWLEDGE

→standard backwards induction can't be applied



(same reasoning applies for κ traders)

ROLE OF SYNCHRONIZING EVENTS

- 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.

"(UN)IMPORTANT" NEWS IN 03/2000

- *Barron's* article published a week *after* the peak.
- BioTech stock: Clinton and Blair's announcement to make human clone project publicly available info (Teodoro D. Cocca)
- Other articles
  - "Mr. Buffet on the Stock Market" in the November 22, 1999 *Fortune*
  - Jeremy Siegel's in the March 14, 2000 *WSJ* article "Big Cap Tech Stocks Are a Sucker Bet"
  - Paul Samuelson in *Newsweek* (September 19, 1966): "The Stock Market Has Predicted Nine Out of the Last Five Recessions"

QUOTES

- Jeremy Siegel **“What Triggered the Tech Wreck?” in the July 2000 *Individual Investor***
  - “Most of history’s big market moves were not motivated by news, economic or otherwise. … What, then, causes most price routs? A seemingly innocuous decline turns into a crash when a sufficient number of short-term investors notice that fewer investors than usual are buying at the dips. That lack of buyers stokes fears that an even larger downward price movement will occur. And the declines become self-reinforcing… That’s precisely what happened to tech stocks in March. The Nasdaq became dominated by trend followers and momentum traders who do not care at all about such fundamentals as earnings, revenue, and intrinsic worth.”

IN SUM

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

    → 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.

WHY DO RATIONALS FAIL TO PREVENT BUBBLES?

1. Unawareness of Bubble

   ⇒ Rational speculators perform as badly as others when market collapses.

2. Limits to Arbitrage
   1. Fundamental risk
   2. Noise trader risk
   3. Synchronization risk
   4. Short-sale constraint

   ⇒ Rational speculators may be *reluctant to go short* overpriced stocks.

3. Predictable Investor Sentiment
   1. AB (2003), DSSW (JF 1990)

   ⇒ Rational speculators may want to *go long* overpriced stock and try to go short prior to collapse.

EMPIRICAL STUDY

- Did hedge funds ride or fight the technology bubble?
  - Brunnermeier and Nagel (2004 JF)

DID HEDGE FUNDS RIDE THE BUBBLE?

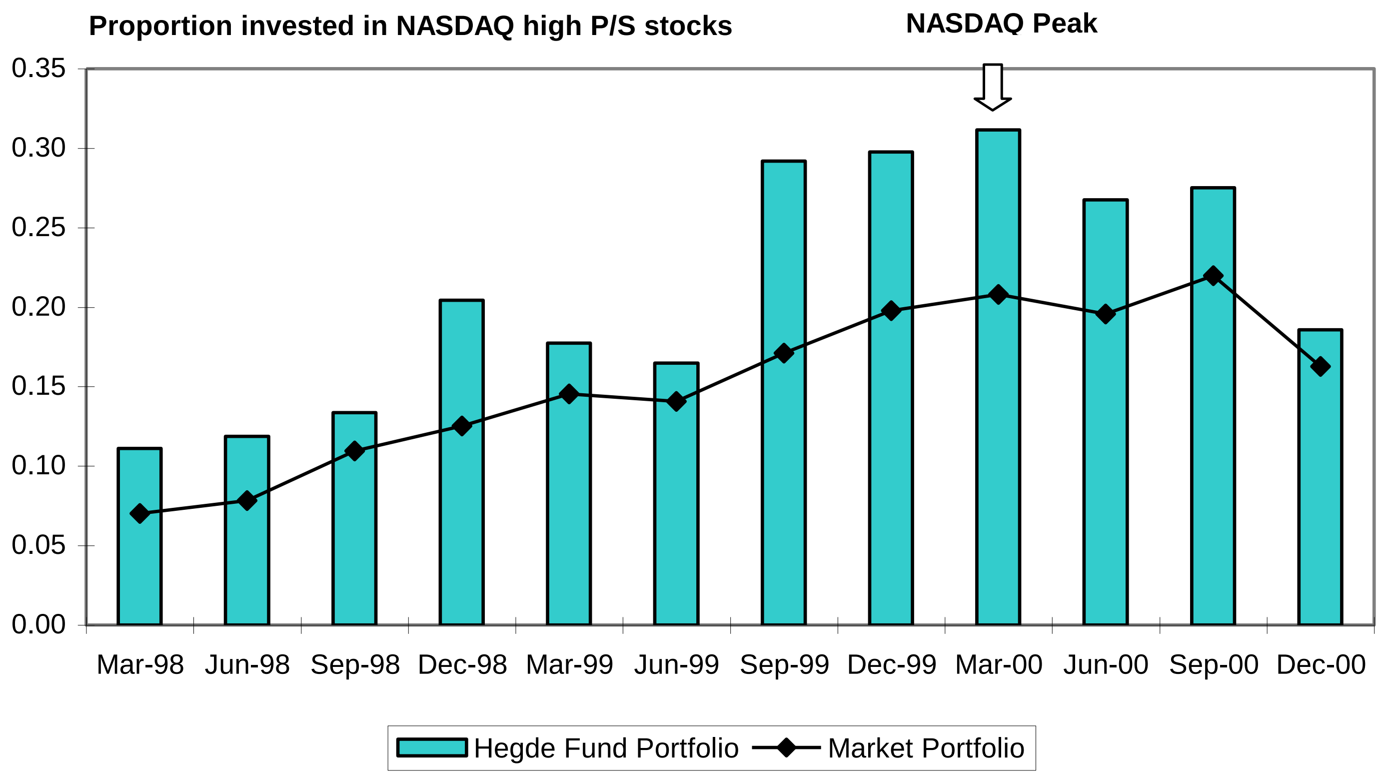


Fig. 2: Weight of NASDAQ technology stocks (high P/S) in aggregate hedge fund portfolio versus weight in market portfolio.

DID SOROS ETC. RIDE THE BUBBLE?

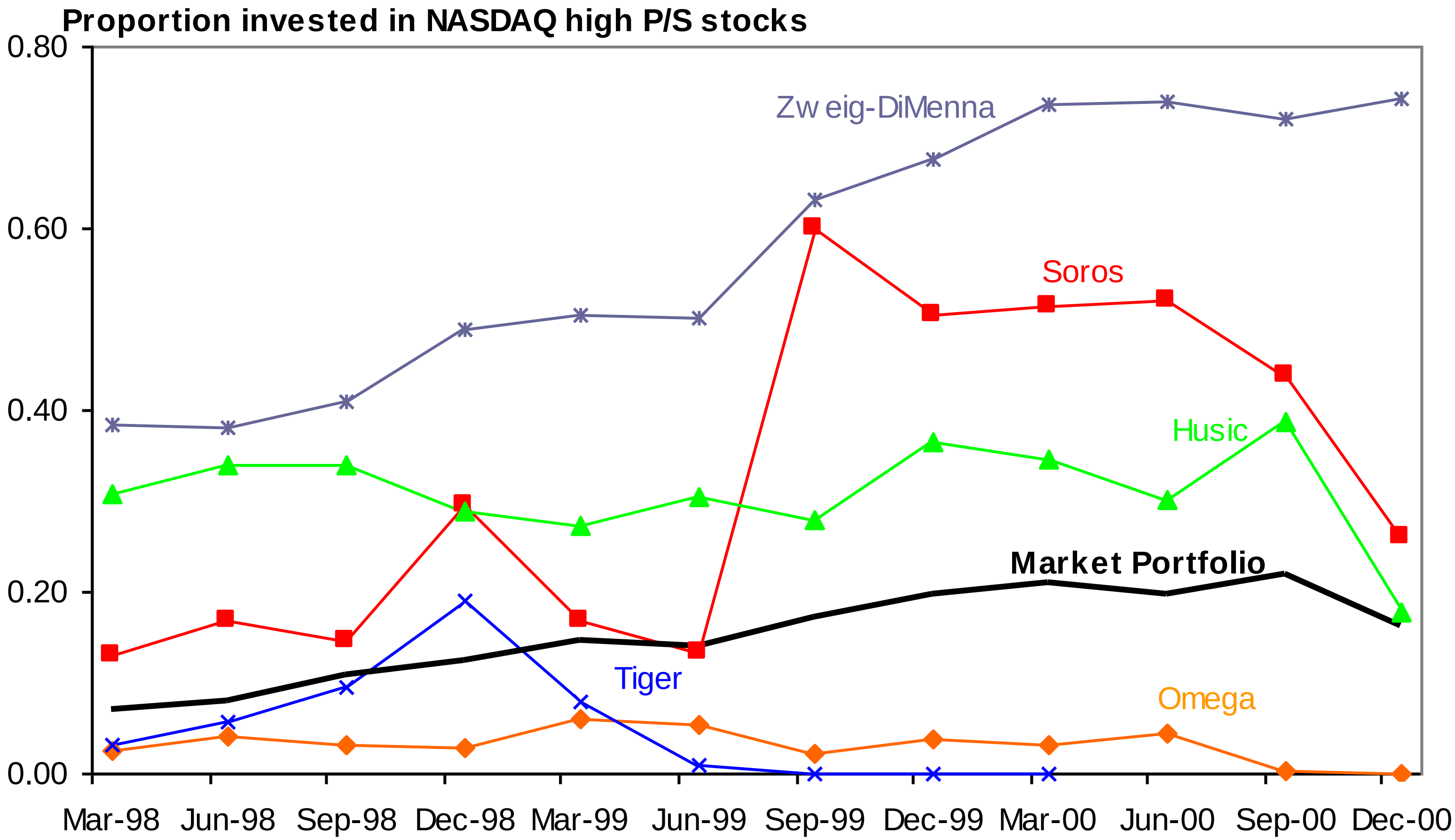
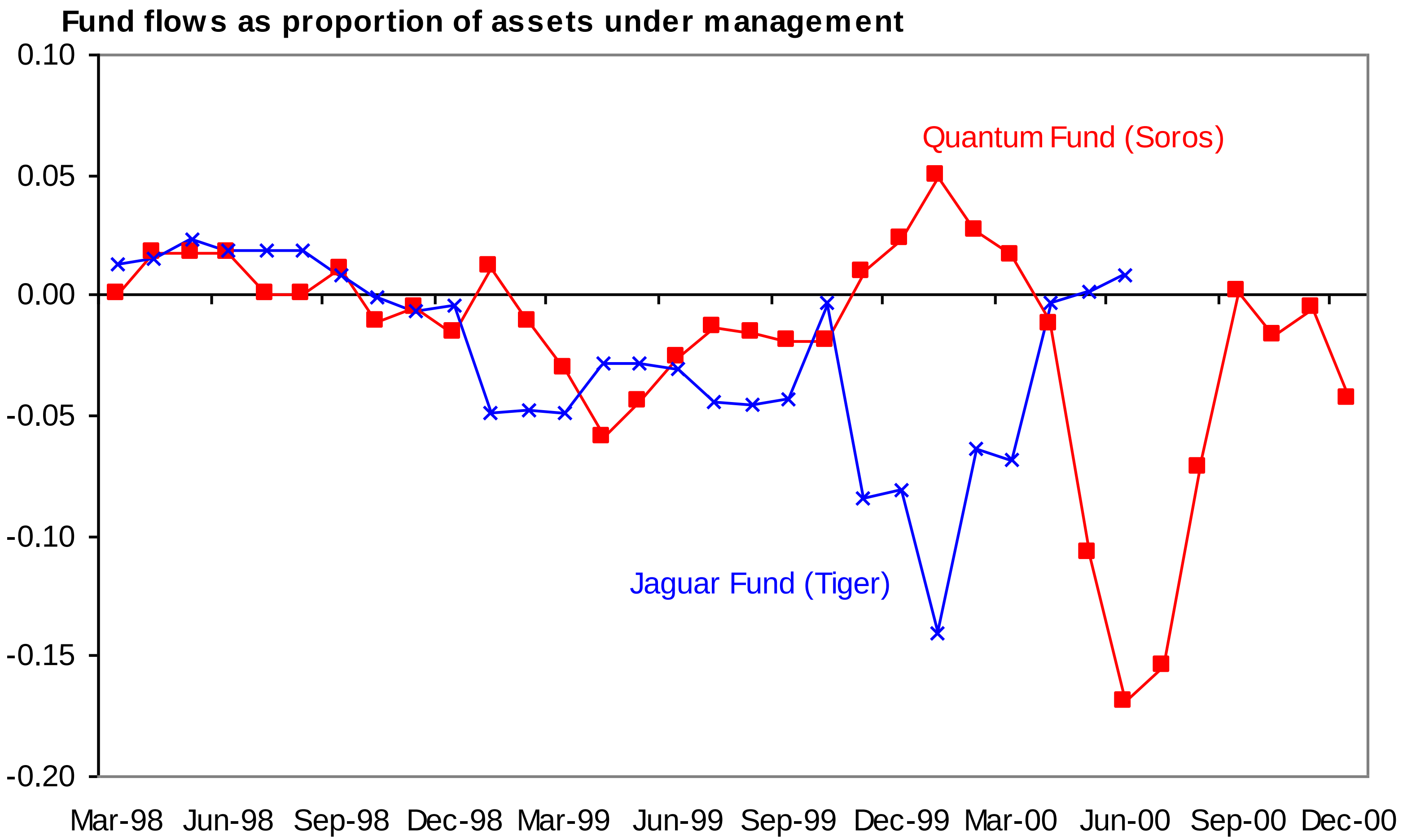


Fig. 4a: Weight of technology stocks in hedge fund portfolios versus weight in market portfolio

FUND IN- AND OUTFLOWS



DID HEDGE FUNDS TIME STOCKS?

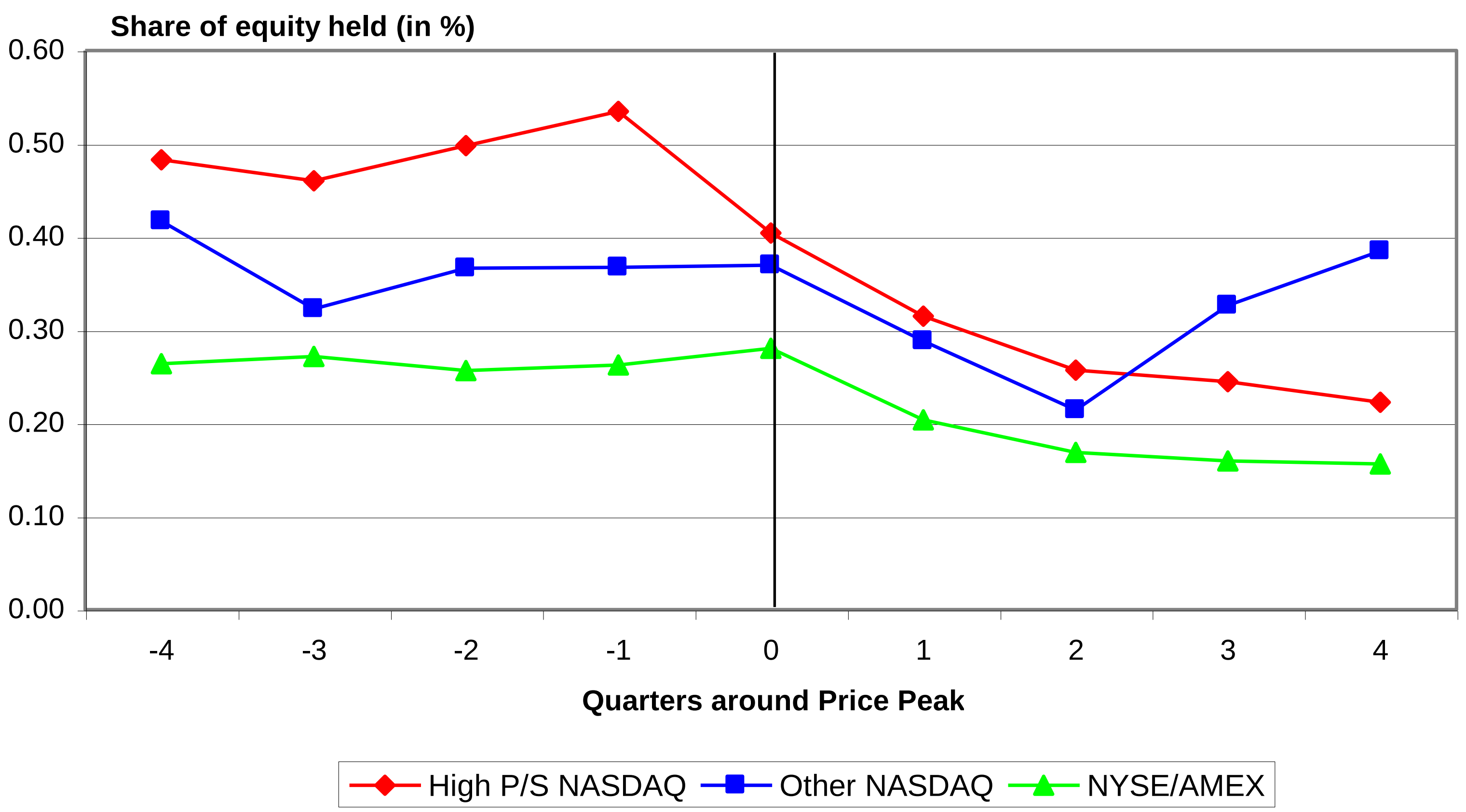


Figure 5. Average share of outstanding equity held by hedge funds around price peaks of individual stocks

DID HEDGE FUNDS' TIMING PAY OFF?

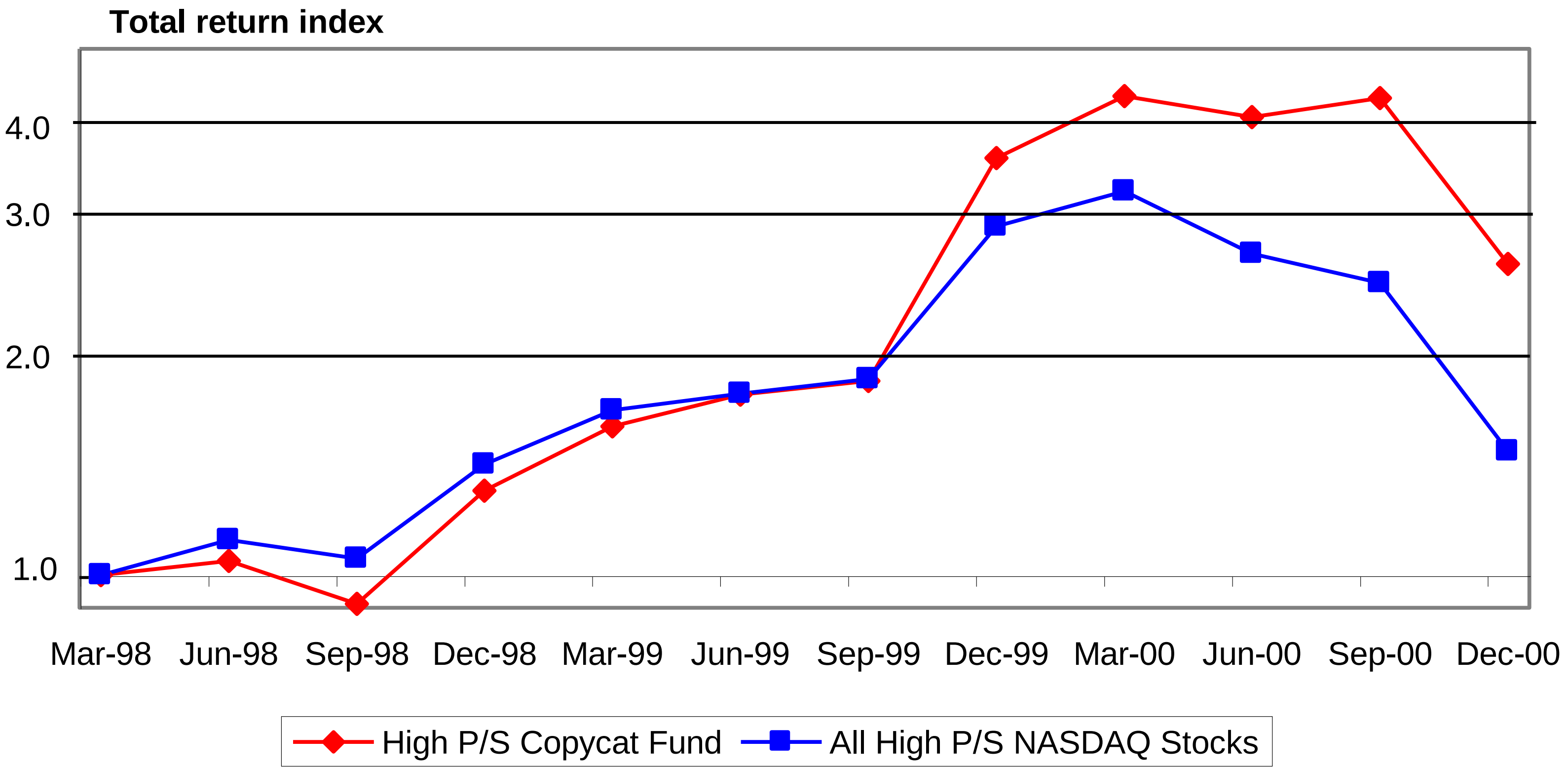


Figure 6: Performance of a copycat fund that replicates hedge fund holdings in the NASDAQ high P/S segment

SUM OF EMPIRICAL ANALYSIS

- 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.

$\Rightarrow$ Supports 'bubble-timing' models

RATIONAL BUBBLES

- All agents are fully rational

$$p_t = \frac{1}{1+r} E_t[p_{t+1} + d_{t+1}]$$

- Solve forward

$$p_t = E_t[\sum_{\tau=1}^{T-1} \frac{d_{t+\tau}}{(1+r)^\tau}] + E_t[\frac{1}{(1+r)^T} p_T]$$

- Securities with
  - finite maturity T, $p_T=0$
  - Infinite maturity $T \to \infty$, -- many solutions
    first part = v_t = fundamental

$$\lim_{T\to\infty} E_t[\frac{1}{(1+r)^T} p_T] = 0$$

RATIONAL BUBBLES (CTD.)

- Many solutions satisfy difference equation
  $p_t = v_t + b_t$
  as long as
  $$b_t = E_t[\frac{1}{1+r} b_{t+1}]$$
- Blanchard-Watson example: bubble persists each period with probably π and bursts otherwise
  - Bubble has to grow at by a factor $(1+r)/\pi$
- Explosive path necessary!
- Bubbles cannot emerge

HERDING 101

- Two equally likely states: “a” & “b”
- Two stocks
  - Payoff of stock A: \$1 if “a” \$0 if “b”
  - Payoff of stock B: \$1 if “b” \$0 if “a”
- Price is fixed to ½
- Each trader receives a signal $S^i \in \{\alpha, \beta\}$
  - $\text{Prob}(\alpha|a) = \text{Prob}(\beta|b) = q > ½$
- You have \$10, which you *either* invest fully in asset A *or* in asset B

EXPERIMENT

- (distribute signals to students!) ....
- Consider the following sequence of signals
  α, α, β, β, β, β, β, β, β, ...
- Rational agents would invest in
  A, A, A, A, A, A, A, A,...
  - First agent follows his signal
  - Second agent infers that first agent got signal α
    - Chooses A if he receives signal α
    - Is indifferent between A and B if he received signal β
      (suppose he follows his own signal β in this case)
  - Third agent infers first agents' signal and thinks that it is more that second agent got α signal
    this dominates his single signal β. Hence, he chooses A as well.
  - Fourth agent cannot infer anything from third agent. He is in the same shoes as third agent. He herds...
  - ...

MARKET MAKER SETS THE PRICE

- Setting like in Glosten-Milgrom (see earlier lecture)
  Read: Avery-Zemsky (1998 AER) or Brunnermeier (2001 Chapter 5)
- *Big difference:* Price adjusts
  - Speed of price adjustment depends on speed of learning of market maker
    - No learning of market maker, price stays constant $\Rightarrow$ herding
    - Market maker learns at same speed as other informed traders
      $\longrightarrow$ positive information externality (learn from predecessors' action) is exactly offset by negative payoff externality (price moves against me)
      $\longrightarrow$ No herding
    - Market maker learns at a slower speed $\Rightarrow$ some herding
      - $\star$ introduce event uncertainty