Bubbles and Crashes

- Dilip Abreu
  Princeton University
- Markus K. Brunnermeier
  Princeton University

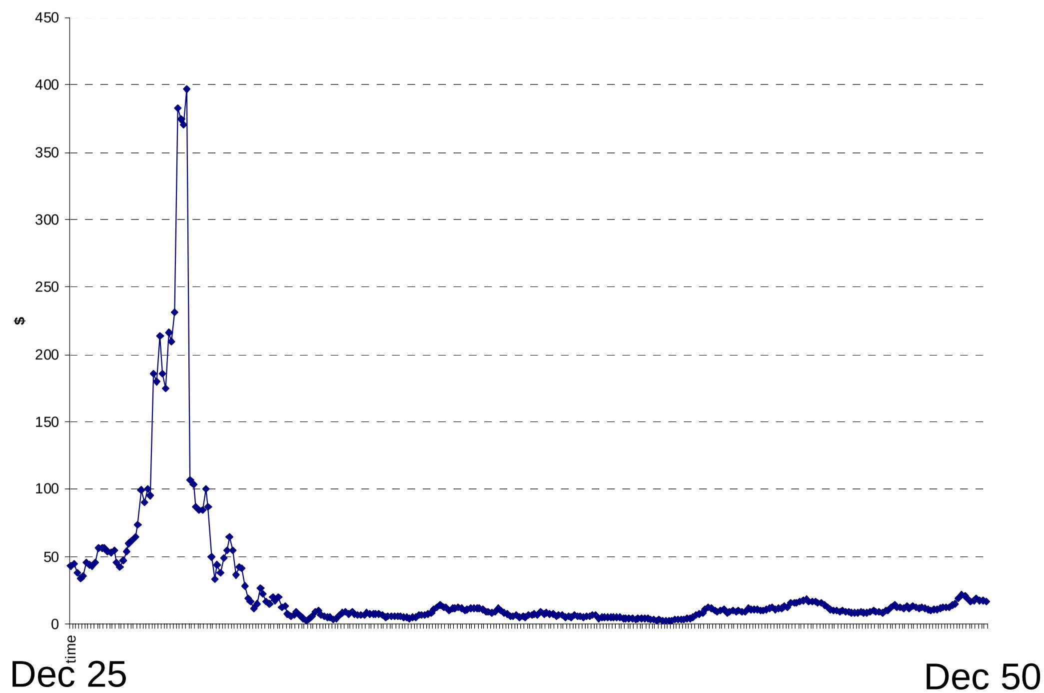
http://www.princeton.edu/~markus

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

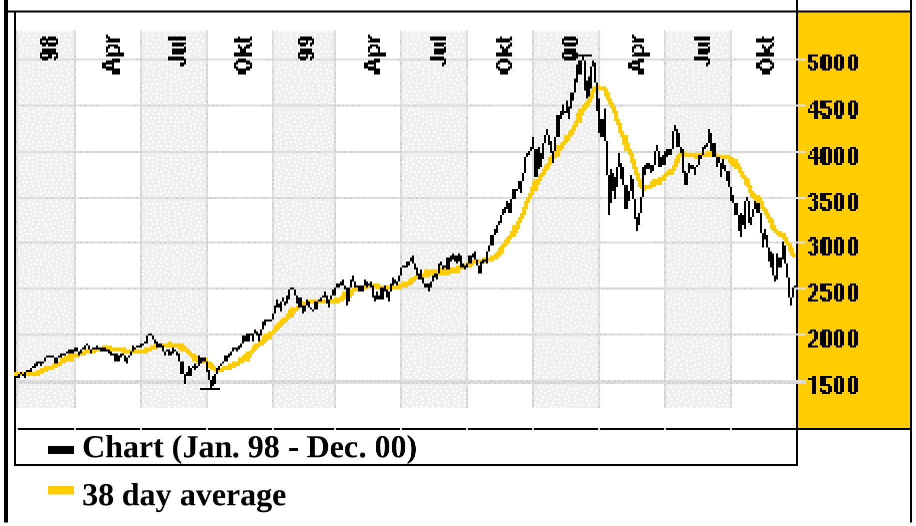
- Company: *Radio Corporation of America (RCA)*
- Technolgoy: *Radio*
- Year: *1920's*



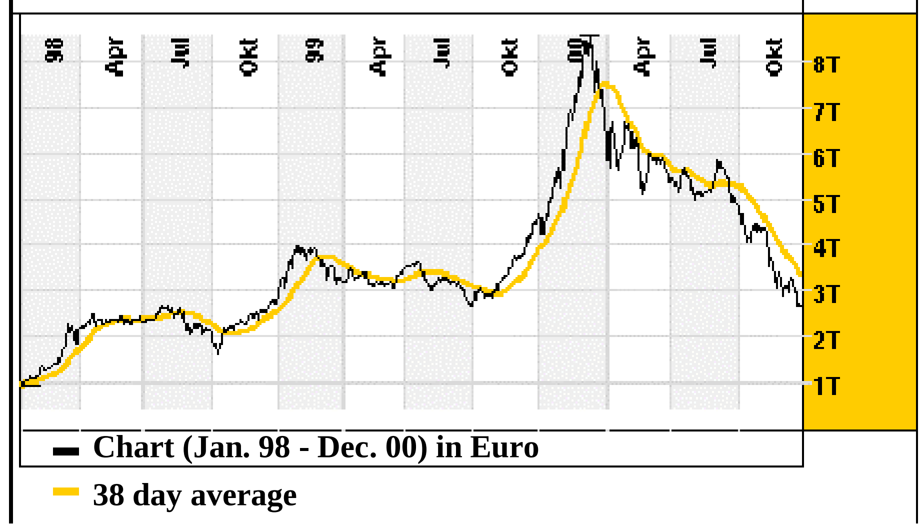
➤ It peaked at $ 397 in Feb. 1929, down to $ 2.62 in May 1932,

Internet bubble? - 1990's

NASDAQ Combined Composite Index



NEMAX All Share Index (German Neuer Markt)



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

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

- **Are bubbles *recurrent*?**
- **What happened in March 2000?**
- **Further evidence of bubble**
  - crash was not accompanied by fundamental news.
  - excess volatility

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

Classical Question

  - 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
  - arbitrageurs are myopic/short-lived and risk averse (DeLong et al. [DSSW], 1990a)
  - fund managers (arbitrageurs) face liquidation risk due to principal-agent problem (Shleifer & Vishny, 1997)
  - arbitrageurs exploit delayed reaction of feedback traders (DeLong et al. [DSSW], 1990b)

Market timing & Synchronization

- Market timing
  - ❶ ride the bubble as long as possible (conflicting interest)
    - sell right before others

–≫CONFLICT≪–

- Synchronization problem
  - ❷ bubble only bursts if more than κ arbitrageurs attack (common action)
  - ❸ arbitrageurs become sequentially aware of the mispricing

Lack of synchronization

⇓

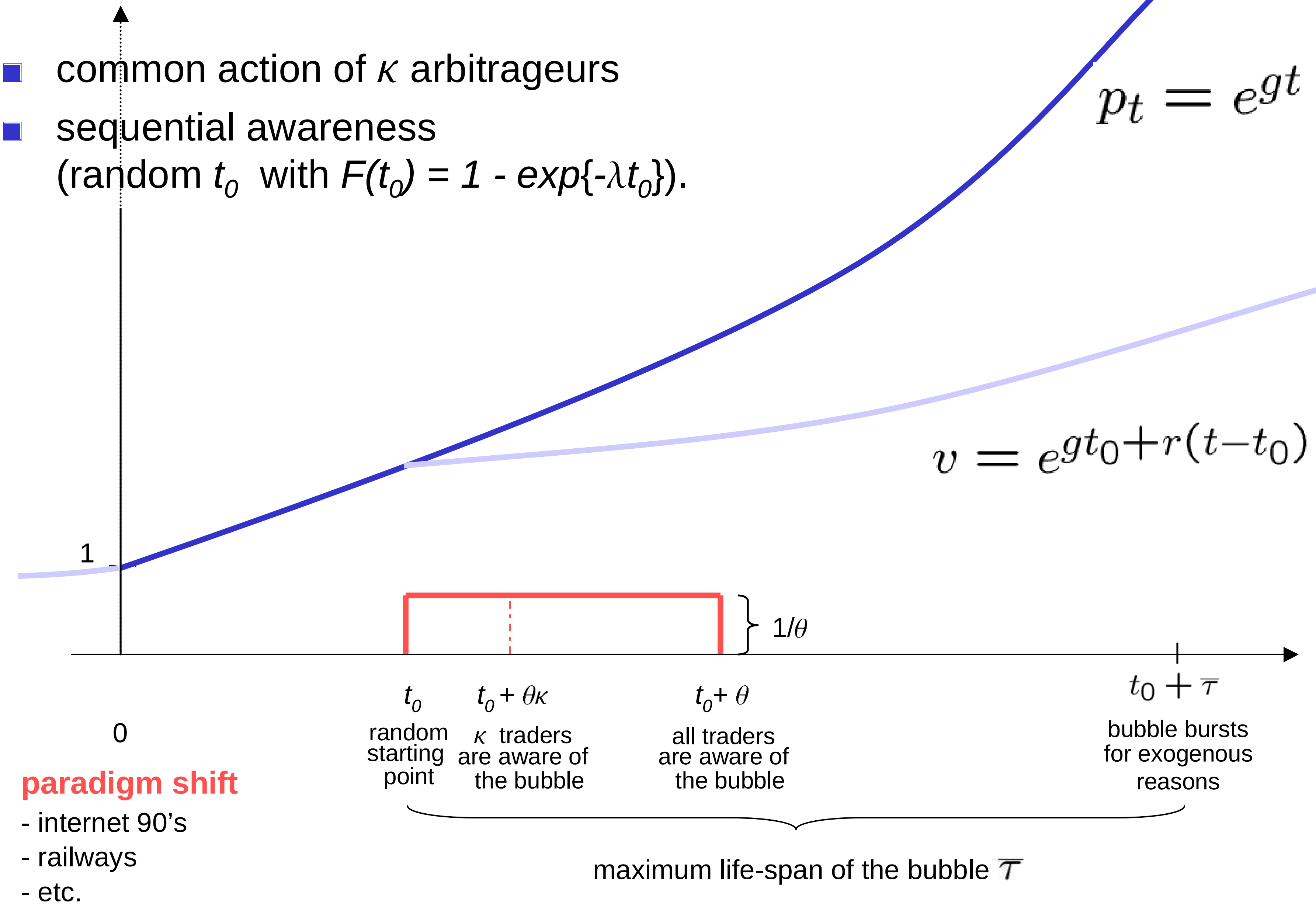
“delayed arbitrage”

⇓

Bubble persists

Model setup

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



Payoff structure

- Cash Payoffs (difference)
  - Sell 'one share' at $t\text{-}\Delta$ instead of at t.

$$p_{t-\Delta}\, e^{r\Delta} - p_t$$

where
$$p_t = \begin{cases} e^{gt} & \text{prior to the crash} \\ e^{gt_0 + r(t-t_0)} & \text{after the crash} \end{cases}$$

  - Execution price at the time of bursting.

$$p_t^{\text{burst}} = \begin{cases} e^{gt} & \text{for first random orders up to } \kappa \\ e^{gt_0 + r(t-t_0)} & \text{all other orders} \end{cases}$$

Payoff structure (ctd.), Trading

- Reputational penalty cp_t
  for attacking if bubble does not burst
  - relative performance evaluation
  - draw downs
- Risk-neutrality but max/min stock position
  - max long position $\sigma = 0$
  - max short position $\sigma = 1$
  - 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*.

- introduction
- model setup
- **persistence of bubbles**
  - arbitrageurs never burst bubble
    - graphical illustration
    - proof for symmetric strategies
  - lack of common knowledge
- endogenous **crashes**
- public events
- conclusion

Persistence of Bubbles

- **Proposition 1:** Suppose $\theta\kappa \geq -\ln(1 - \frac{\lambda}{g-r+c})(\frac{1}{\lambda})$
  - existence of a unique trading equilibrium
  - traders begin attacking after a delay of $\tau^* < \overline{\tau}$ periods.
  - bubble ***never*** bursts due to endogenous selling pressure. It only bursts at $t_0 + \overline{\tau}$.

Attack condition for $\Delta \to 0$ periods

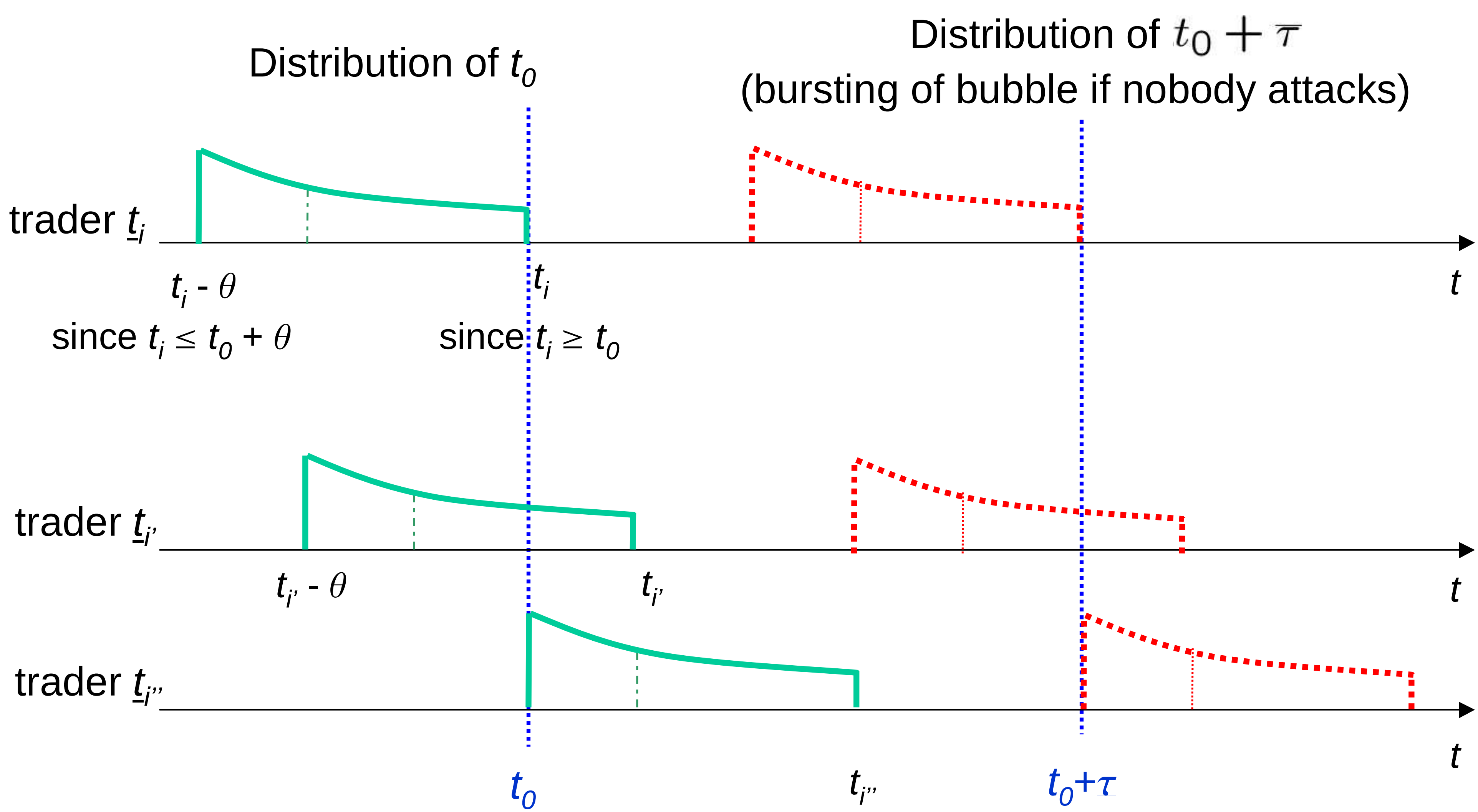
- attack at *t*
  - if prob that bubble will burst in next instant > 0
  - if prob that bubble will burst in next instant = 0

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

$$h(t|t_i) \geq \frac{(g-r)+c}{1-E[e^{-(g-r)(t-t_0)}|\cdot]}$$

RHS converges to ↘ [$(g\text{-}r) + c$] as $t \to \infty$

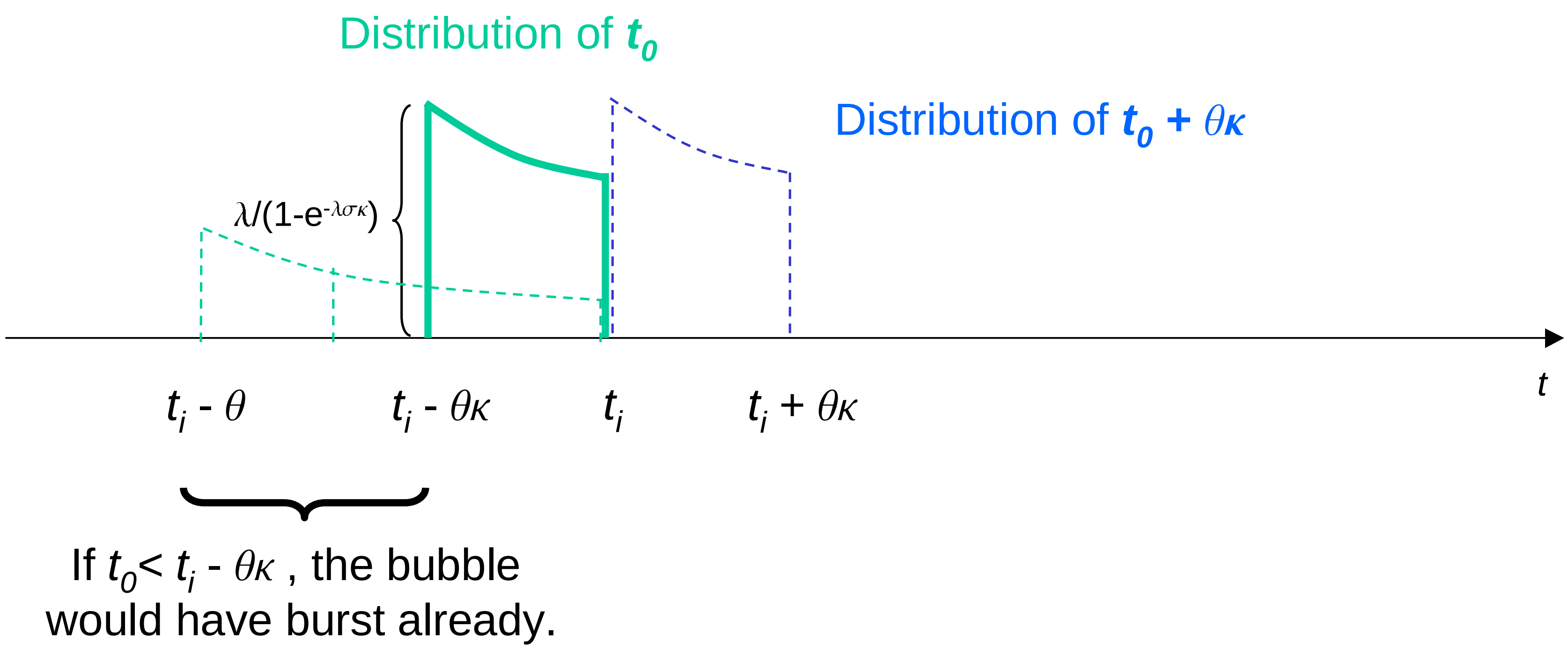
Sequential awareness



Conjecture 1: Immediate attack

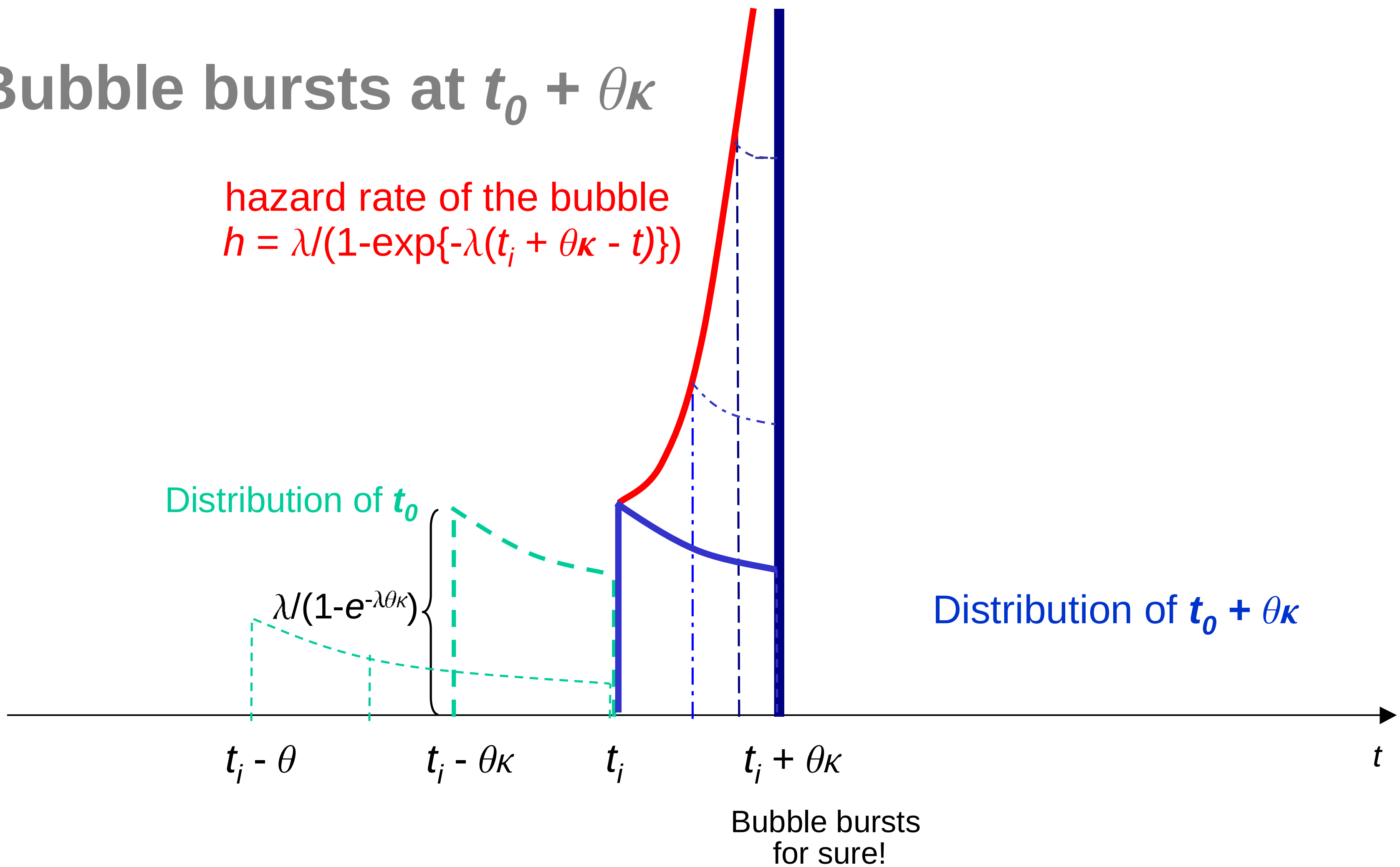
⇒ **Bubble bursts at $t_0 + \theta\kappa$**

when κ traders are aware of the bubble



Conj. 1 (ctd.): Immediate attack

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

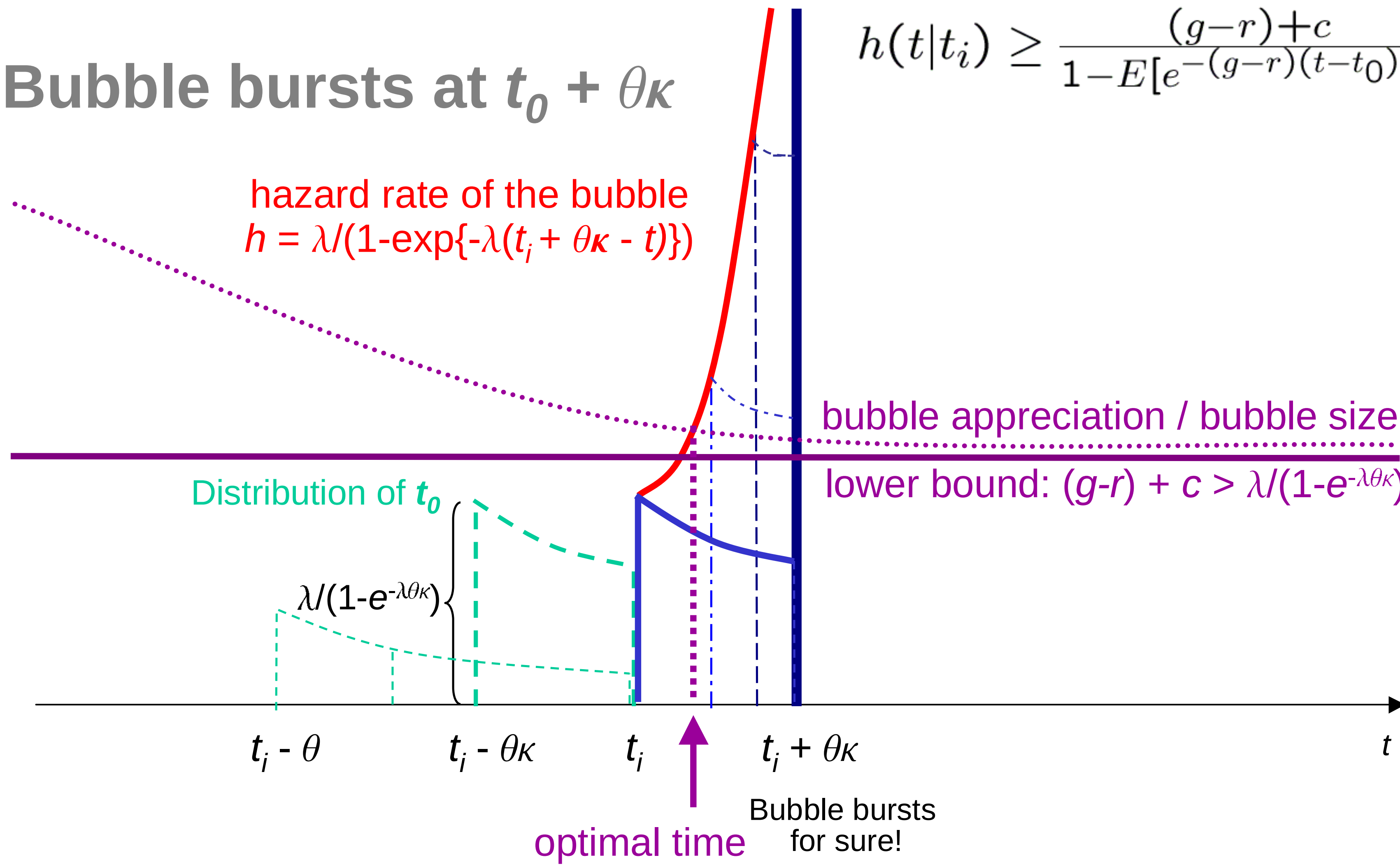


Conj. 1 (ctd.): Immediate attack

Recall the attack condition:

$$h(t|t_i) \geq \frac{(g-r)+c}{1-E[e^{-(g-r)(t-t_0)}|\cdot]}$$

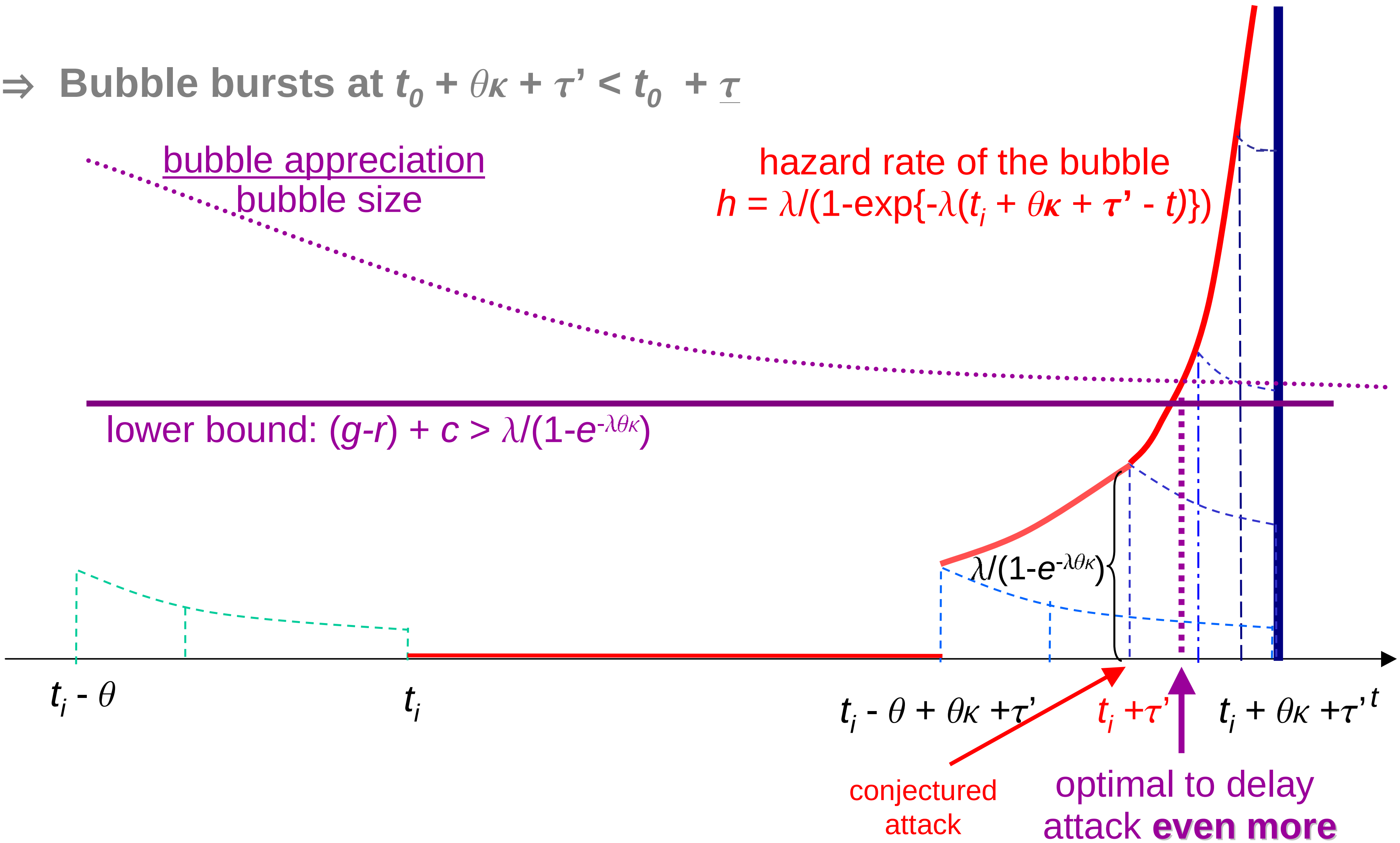
⇒ **Bubble bursts at $t_0 + \theta\kappa$**



⇒ **"delayed attack is optimal"**
no "immediate attack" equilibrium!

Conj. 2: Delayed attack by arbitrary τ'

⇒ Bubble bursts at $t_0 + \theta\kappa + \tau' < t_0 + \underline{\tau}$



⇒ **attack is never successful**

⇒ **bubble bursts for exogenous reasons at $t_0 + \underline{\tau}$**

Formal analysis for symmetric strategies

- Suppose endogenous selling pressure would burst bubble at $t = t_0 + \hat{\tau}$, where $\hat{\tau} < \overline{\tau}$
  - for $t < t_i - \theta + \hat{\tau}$ $\quad h(t|\underline{t}_i) = 0$
  - for $t \geq t_i - \theta + \hat{\tau}$ $\quad h(t|\underline{t}_i) = \frac{\lambda}{1 - e^{-\lambda(t_i + \hat{\tau} - t)}}$
- (from attack condition) sell shares at

$$t_i + \hat{\tau} + \ln\left[\frac{(g-r) - \lambda + \lambda e^{-(g-r)\hat{\tau}}}{g-r+c}\right]\left[\frac{1}{\lambda}\right]$$

- mass of arbitrageurs aware of the bubble $\max\{\frac{1}{\theta}(t - t_0), 1)\}$
- mass of arbitrageurs attacking (= selling pressure)
  - $\max\{\frac{1}{\theta}(t - \hat{\tau} - \ln[\frac{(g-r) - \lambda + \lambda e^{-(g-r)\hat{\tau}}}{g-r+c}](\frac{1}{\lambda}) - t_0), 1)\}$
  - for $t = t_0 + \hat{\tau}$ $\quad -\frac{1}{\theta\lambda} \ln[\frac{(g-r) - \lambda + \lambda e^{-(g-r)\hat{\tau}}}{g-r+c}] < \kappa$
  - *contradiction!*

April 13th - Pre-emption Lemma

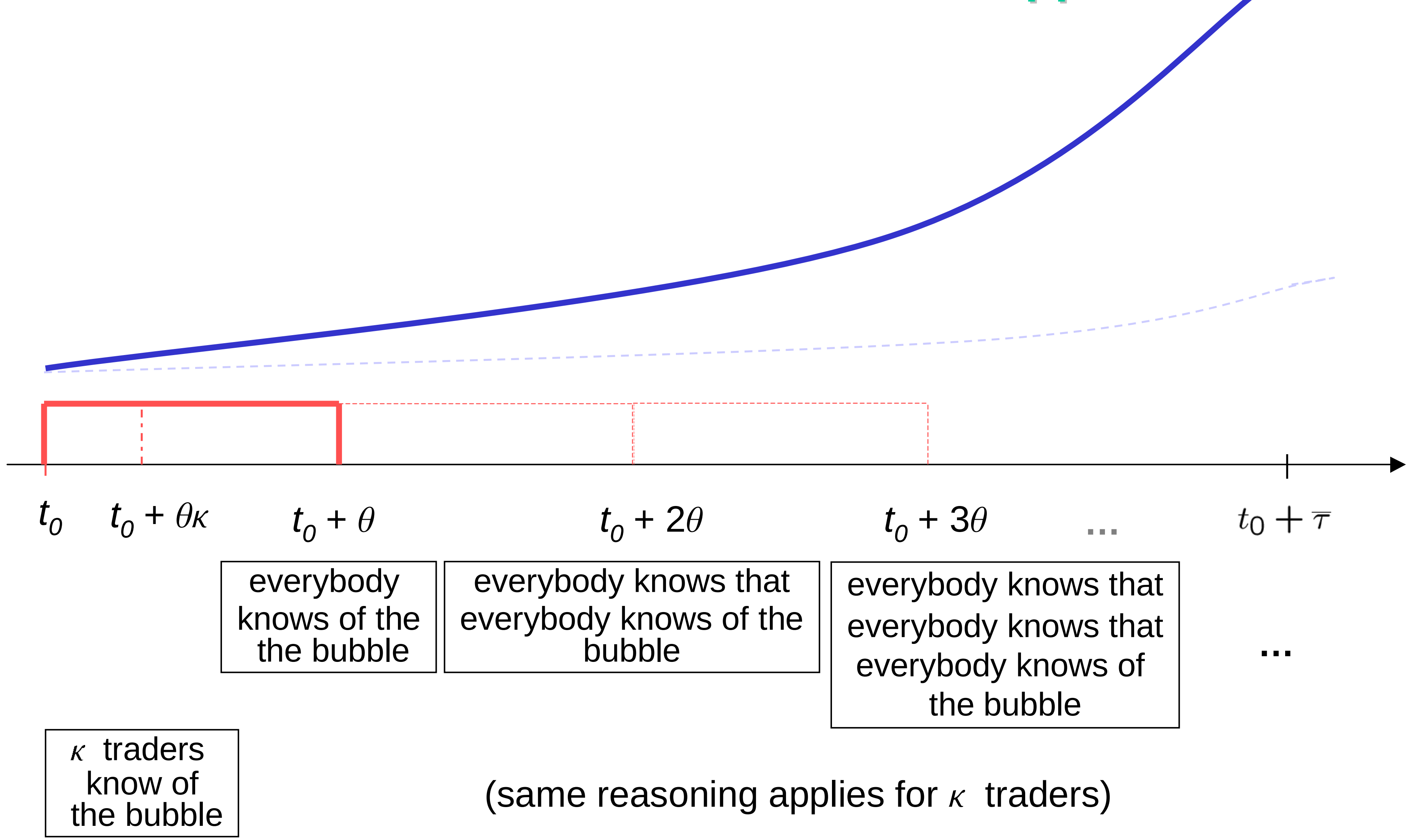
- $\hat{\tau}$ might depend on t_0 in asymmetric equilibria
  - *Example:* all start attacking on Friday, April 13th.

$$\hat{\tau}^{13} = \begin{cases} \hat{\tau} & \text{if } t_0 > t^{13} - \theta\kappa \\ t^{13} - t_0 & \text{if } t_0 \leq t^{13} - \theta\kappa \end{cases}$$

    - bubble would burst with strictly positive probability.
    - selling pressure $s_{t=13} > \kappa$, $p_{t=13}$ drops already.
    - Individual incentive to attack a little bit earlier.
  - Not an equilibrium!

Lack of common knowledge

⇒ **standard backwards induction can't be applied**



Related theoretical literature

- Asynchronized clocks
  - Halpern & Moses (1984) [computer science]
  - Morris (1995)
    - restricted strategy space: condition only on own clock
      no conditioning on calendar time, past payoffs, etc.
- Global Games
  (uniqueness of equilibrium in static games with strategic complementarities)
  - Carlson & van Damme (1994)
  - Morris & Shin (1998)

introduction

model setup

persistence of **bubbles**

endogenous crashes

- endogenous life-span of the bubble
- comparative statics

public events

conclusion

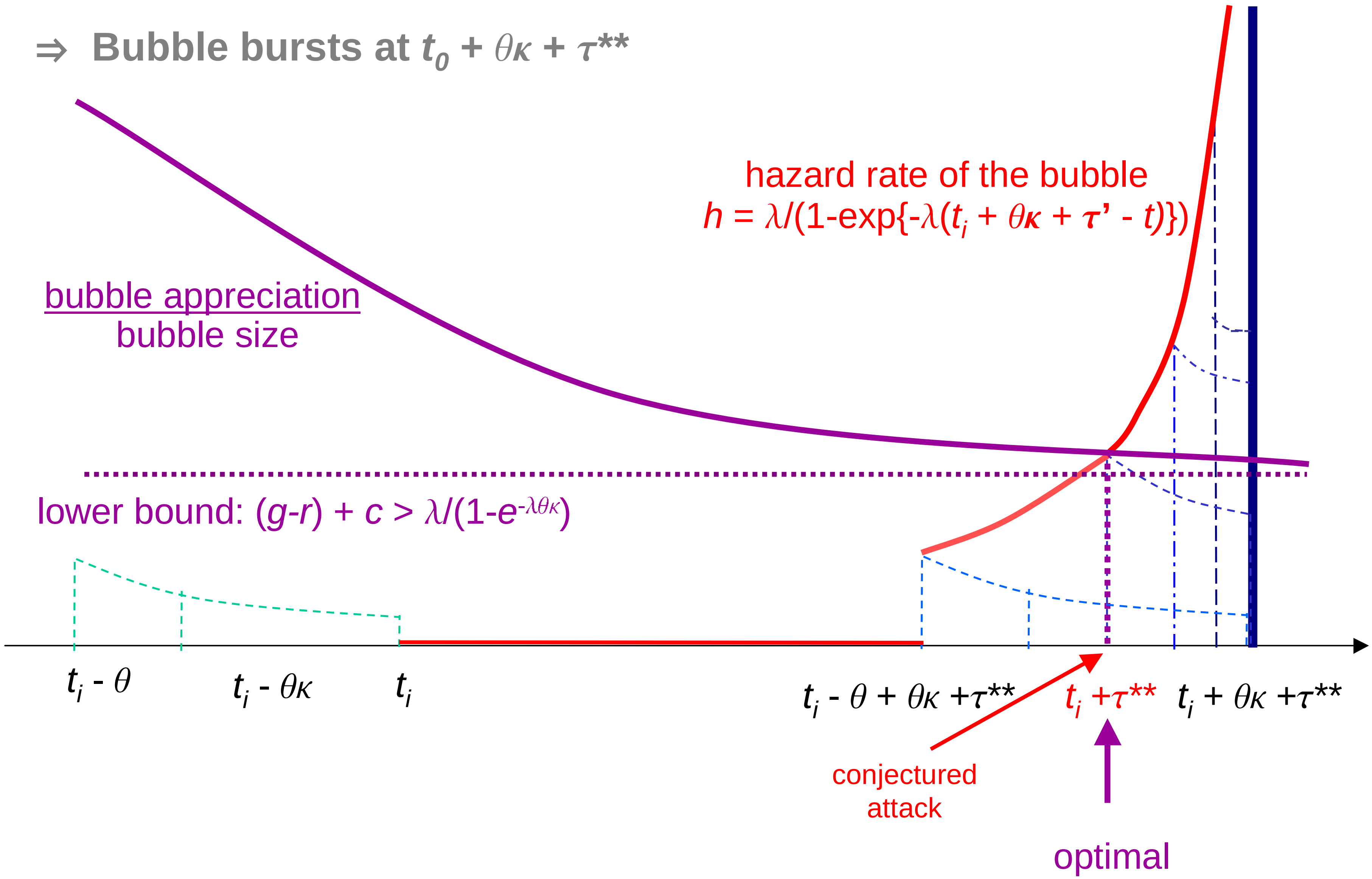
Endogenous crashes

- **Proposition 3:** Suppose $\theta\kappa < -\ln(1-\frac{\lambda-\lambda e^{-(g-r)\overline{\tau}}}{g-r+c})(\frac{1}{\lambda})$.
  - **'most aggressive'** trading equilibrium.
  - traders begin attacking after a delay of τ** periods.
  - bubble ***bursts*** due to endogenous selling pressure at

$$t_0 + \frac{-\ln[1-\frac{g-r+c}{\lambda}(1-e^{-\lambda\theta\kappa})]}{(g-r)}$$

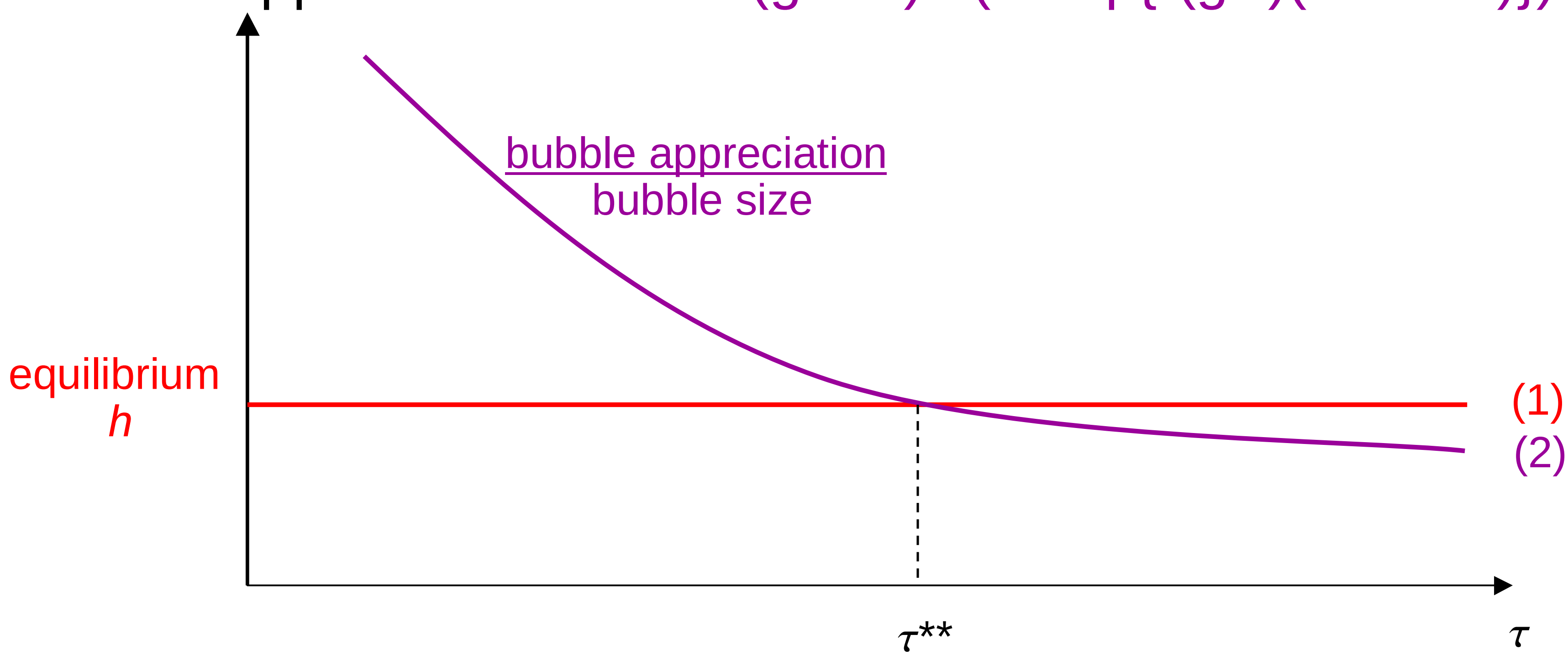
Endogenous crashes

⇒ **Bubble bursts at $t_0 + \theta\kappa + \tau^{**}$**



Endogenous crashes - deriving τ^{**}

- In symmetric equilibrium trader $t_i = t_0 + \theta\kappa$ bursts the bubble.
- When he sells his shares his support of t_0 is $[t_i - \theta\kappa, t_i]$,
  hence his hazard rate is $h = \lambda/(1-\exp\{-\lambda\theta\kappa\})$ (1)
- The bubble bursts at $t_i = t_0 + \theta\kappa + \tau^{**}$,
  hence it bursts at a size of $e^{gt}(1-\exp\{-(g-r)(\theta\kappa + \tau^{**})\})$
  bubble appreciation/ size = $(g-r+c) / (1-\exp\{-(g-r)(\theta\kappa + \tau^{**})\})$ (2)



Comparative statics

- Role of information dispersion λ, θ
  - Prior distribution of t_0 $F(t_0) = 1 - exp\{-\lambda t_0\}$
    - the smaller λ, the larger the life span of bubble
    - $\lambda \to \infty \Rightarrow t_0 = 0$, no info dispersion $\Rightarrow$ no bubble
    - $\lambda \to 0 \Rightarrow$ distributions $\to$ uniform [lifespan - $ln\{1-\theta\kappa(g-r+c)\}/(g-r)$]
  - Dispersion of opinion θ
    - as $\theta \uparrow$ $\Rightarrow$ bubble's life-span $\uparrow$
    - for $\theta \geq -\frac{1}{\kappa} \ln(1 - \frac{\lambda - \lambda e^{-(g-r)\bar{\tau}}}{g-r+c})(\frac{1}{\lambda})$ $\Rightarrow$ exogenous crash
- Role of momentum traders $\kappa \Rightarrow$ same as for θ
- excess growth rate $(g - r) \uparrow$ *[2 effects]*
  - instantaneous appreciation effect $\uparrow \Rightarrow$ life span of bubble $\uparrow$
  - size of bubble (past appreciation) $\uparrow \Rightarrow$ life span of bubble $\downarrow$

introduction

model setup

persistence of **bubbles**

endogenous **crashes**

synchronizing public events

- pre-scheduled versus unanticipated
- price cascades and rebounds

conclusion

Pre-scheduled vs. unanticipated public news

- Pre-scheduled public events
  - news is unknown, but timing is fixed in advance. (FOMC Meetings etc.)
  - “martingale news”: correctly reflected in the price
  - *⇒ pre-scheduled news will only move price by its fundamental content, but not beyond.*
    - Why? It cannot serve as a synchronization device.
    - If it would, then the bubble would burst with strictly positive probability on this date. In this case arbitrageurs have incentive to attack slightly earlier
(same as Friday 13th of July)

Pre-scheduled vs. unanticipated public news

- Unanticipated public events
  - pre-emption argument does not apply!
  - can serve as synchronization device.
  - there are millions of public events (weather, etc.)
  - viewing something as a public event is also a coordination problem in itself.
  - Extended setting
    - focus on news with *no* informational content (sunspots).
    - public event occurs with Poisson density λ_p .
    - Arbitrageurs who are aware of the bubble become increasingly worried about it over time.
      - » only traders who became aware of the mispricing more than τ_p periods ago observe (look out for) public events.

Public events & Market rebounds

- **Proposition 5:**
  Attack a) always at the time of a public event t_p,
  b) after $t_i + \tau^{***}$ (where $\tau^{***} < \tau^{**}$) ,
  except after a failed attack at t_p , **re-enter** the market
  for $t \in (t_p , t_p - \tau_p + \tau^{***}) \cap (t_i + \tau^{p,1})$.
- Intuition for re-entering the market:
  - for $t_p < t_0 + \theta\kappa + \tau_p$ attack fails, agents learn $t_0 > t_p - \tau_p - \theta\kappa$
  - without public event, they would have learnt this only at $t_p + \tau_p - \tau^{***}$.
    - the existence of bubble at t reveals that $t_0 > t - \tau^{***} - \theta\kappa$
    - that is, no additional information is revealed till $t_p - \tau_p + \tau^{***}$
    - density that bubble bursts for endogenous reasons is zero.

Role of information

- Only unanticipated public news can burst a bubble.
- News which is considered as important can be more important than real fundamental news.
- Fads and fashions in information.

Price cascades and rebounds

- Price drop as a synchronization device (public event).
  - through psychological resistance line
  - by more than, say 5 %
- **Exogenous price drop**
  - after a price drop
    - if bubble is ripe
      $\Rightarrow$ bubble bursts and price drops further.
    - if bubble is not ripe yet
      $\Rightarrow$ price bounces back and the bubble is strengthened for some time.

Price cascades and rebounds (ctd.)

- **Proposition 6:**

Attack a) after a price drop if $\tau_i \geq \tau'_p$

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

re-enter the market after a rebound at t'_p

for $t \in (t'_p, t'_p - \tau'_p + \tau^{****}) \cap (t_i + \tau'^{p,1})$.

- attack is costly, since price might jump back
  ⇒ only arbitrageurs who became aware of the bubble more than τ'_p periods ago attack the bubble.
- after a rebound, an endogenous crash can be temporarily ruled out and
  hence, arbitrageurs re-enter the market.

Conclusion

- 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.