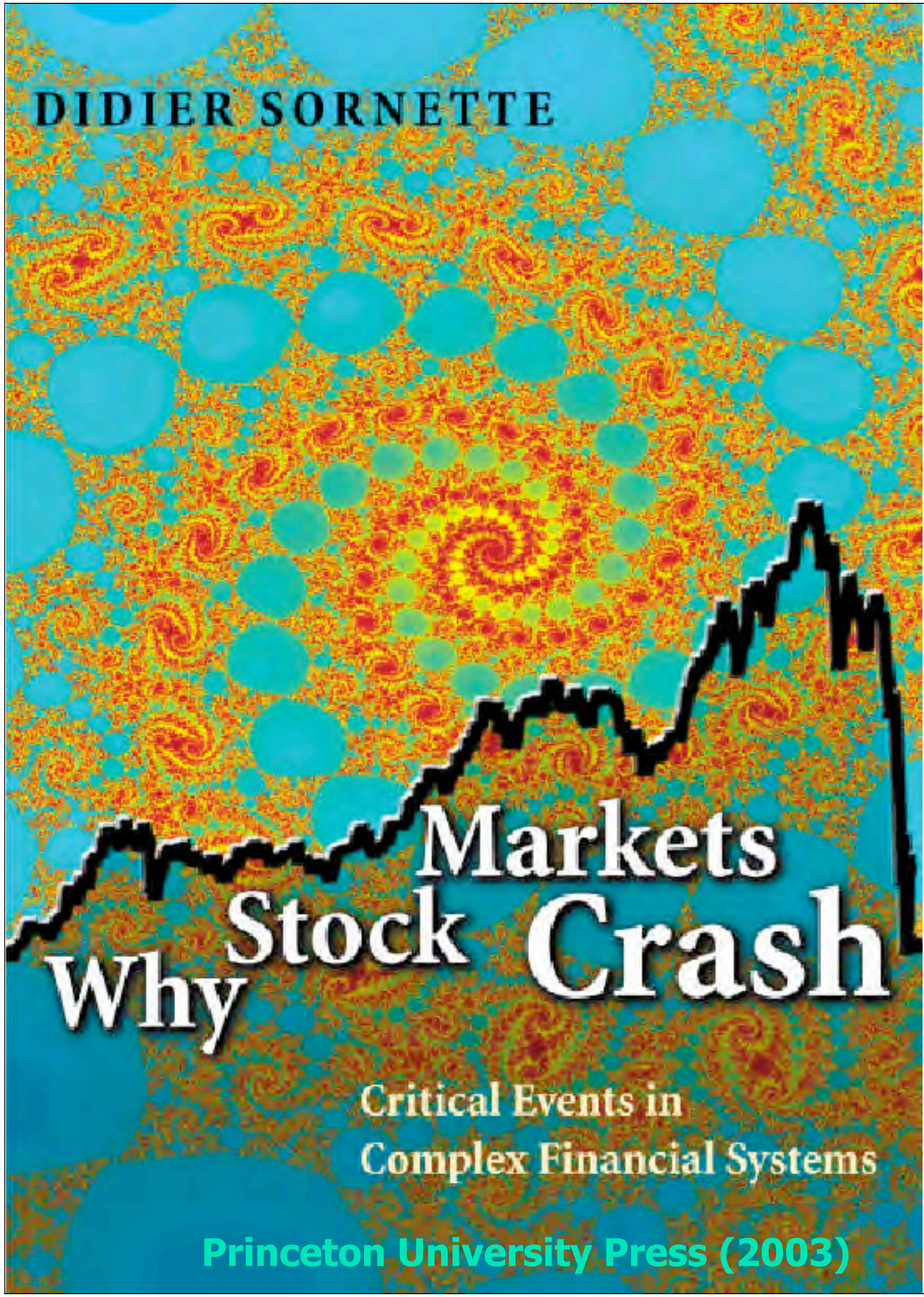
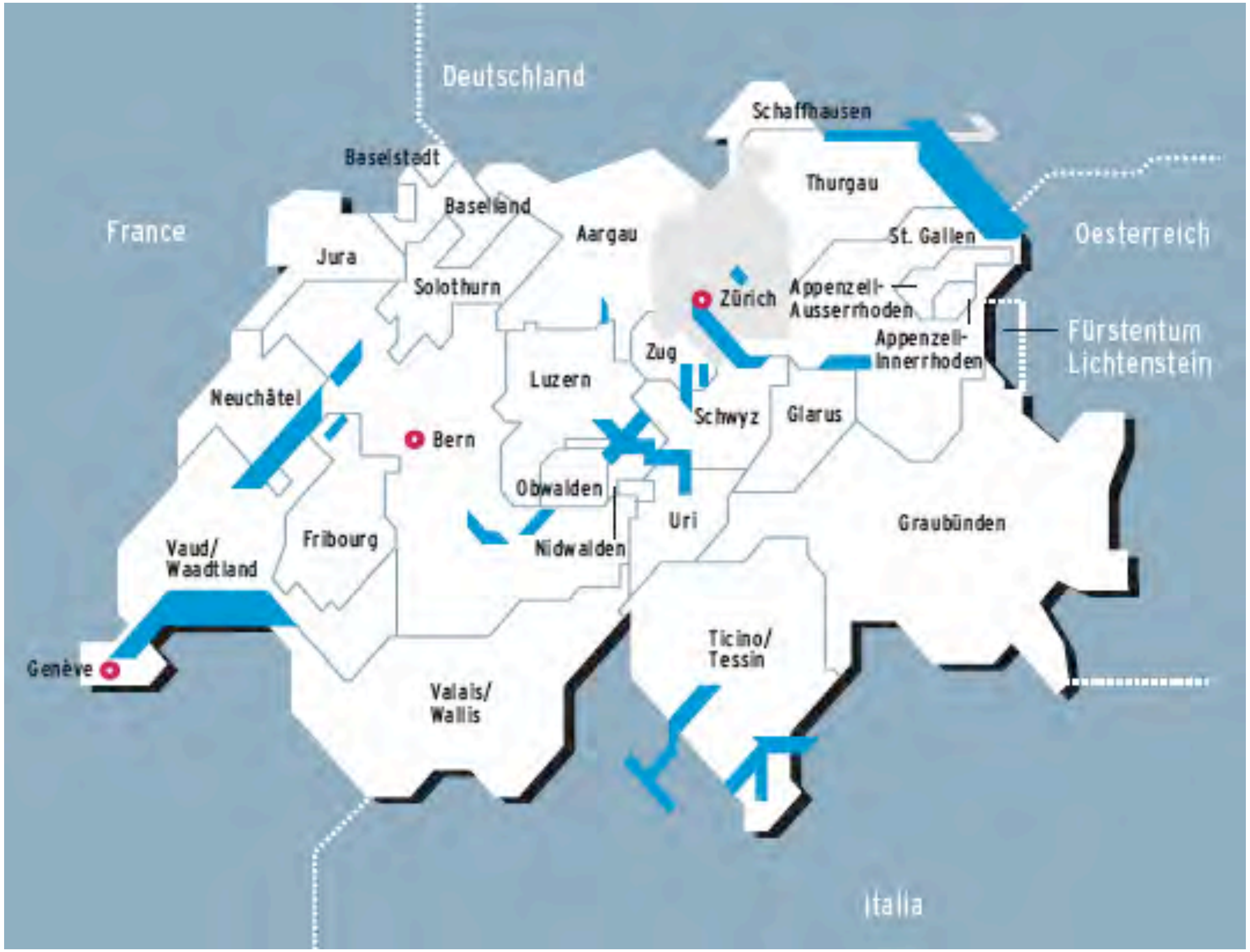


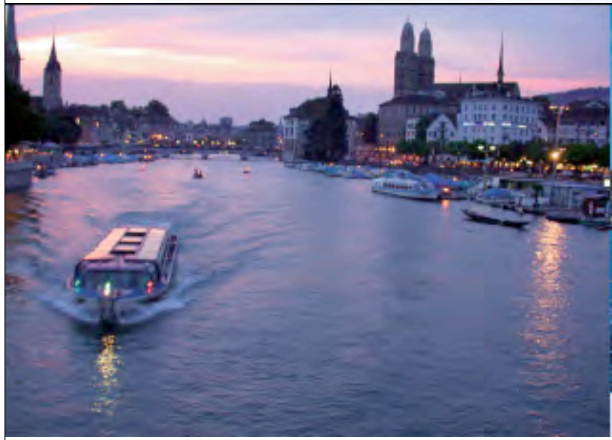
ETH-Zurich
Chair of Entrepreneurial Risks
Department of Management, Technology and Economics (D-MTEC), ETH Zurich
Switzerland
http://www.mtec.ethz.ch/

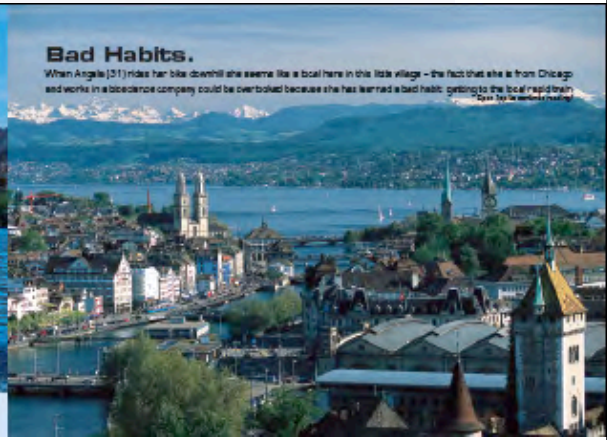
Collaborators:
Y. Ageon (CNRS, France)
J. Andersen (CNRS, France)
D. Darcet (Insight Research)
K. Ide (UCLA)
A. Johansen (Denmark)
Y. Malevergne (Univ. Lyon, France)
V: Pïsarenko (Acad. Sci. Moscow, Russia)
W.-X. Zhou (UCLA)

3 hour lectures to the students of Physics and of Mathematics of ENS Cachan, organized by the director of the department of Mathematics Frederic DIAS, http://www.cmla.ens-cachan.fr/Membres/dias,
11 Dec. 2007, Cachan (Paris, France).


Deutschland
Schaffhausen
Baselstadt
Baselland
Thurgau
France
Aargau
St. Gallen
Oesterreich
Jura
Solothurn
Zürich
Appenzell-
Ausserrhoden
Fürstentum
Lichtenstein
Appenzell-
Innerrhoden
Zug
Luzern
Neuchâtel
Schwyz
Glarus
Bern
Obwalden
Uri
Graubünden
Vaud/
Waadtland
Fribourg
Nidwalden
Ticino/
Tessin
Genève
Valais/
Wallis
Italia

This is ETH Zurich → 12 700 students → 350 professors → 3600 other teaching and research staff → 2 campuses → 21 Nobel Prizes → 136 labs → 21% international students → 90 nationalities → 36 languages

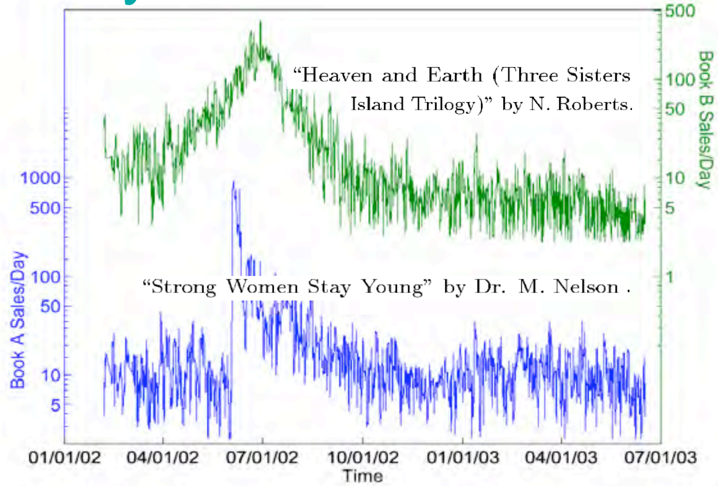


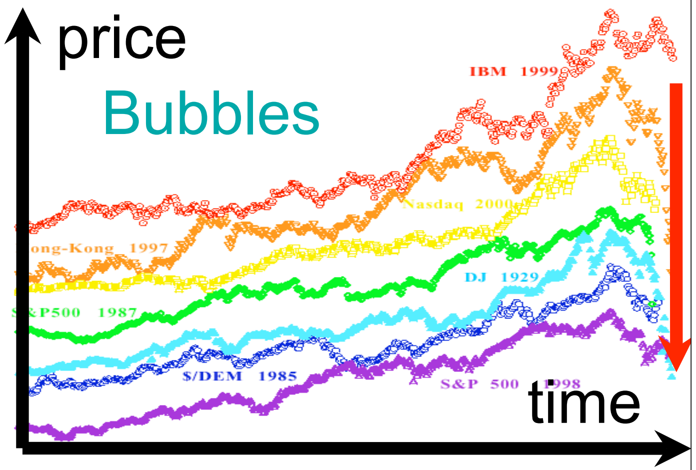


- Collective dynamics and organization of social agents (Commercial sales,YouTube, Open source softwares, Cyber risks)
- Agent-based models of bubbles and crashes, credit risks, systemic risks
- Prediction of complex systems, stock markets, social systems
- Asset pricing, hedge-funds, risk factors…
- Human cooperation for sustainability
- Natural and biological hazards (earthquakes, landslides, epidemics, critical illnesses…)

(2 guest-professors, 5 foreign associate professors, 2 post-docs, 6 PhD students, 2-6 Master theses)

Dynamics of success





MOTIVATIONS

- What are bubbles?
- Do they exist really?
- Why do we care?
- Can they be detected?
- Can their end (the CRASH) be predicted?
- Systemic risks? Sub-prime mess...
- What is ahead of us?

What are bubbles?
How do detect them?
How to predict them?

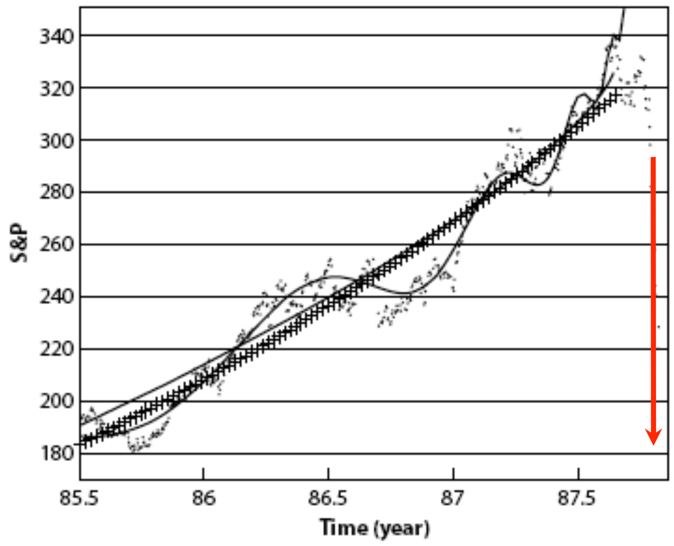
Academic Literature:
No consensus on what is a bubble...

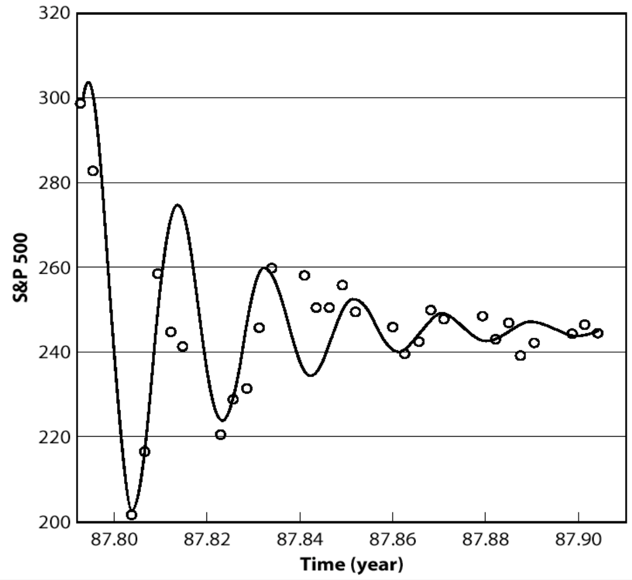
The Fed: A. Greenspan (Aug., 30, 2002):
"We, at the Federal Reserve…recognized that, despite our suspicions, it was very difficult to definitively identify a bubble until after the fact, that is, when its bursting confirmed its existence… Moreover, it was far from obvious that bubbles, even if identified early, could be preempted short of the Central Bank inducing a substantial contraction in economic activity, the very outcome we would be seeking to avoid."

THE CRASH OF OCTOBER 1987

Proximate explanations after the fact!

- Computer trading
- Derivatives
- Illiquidity
- Trade and budget deficits
- Over-valuation
- The auction system
- Off-market and off-hours trading
- Floor brokers
- Forward market effect
- Different investor styles

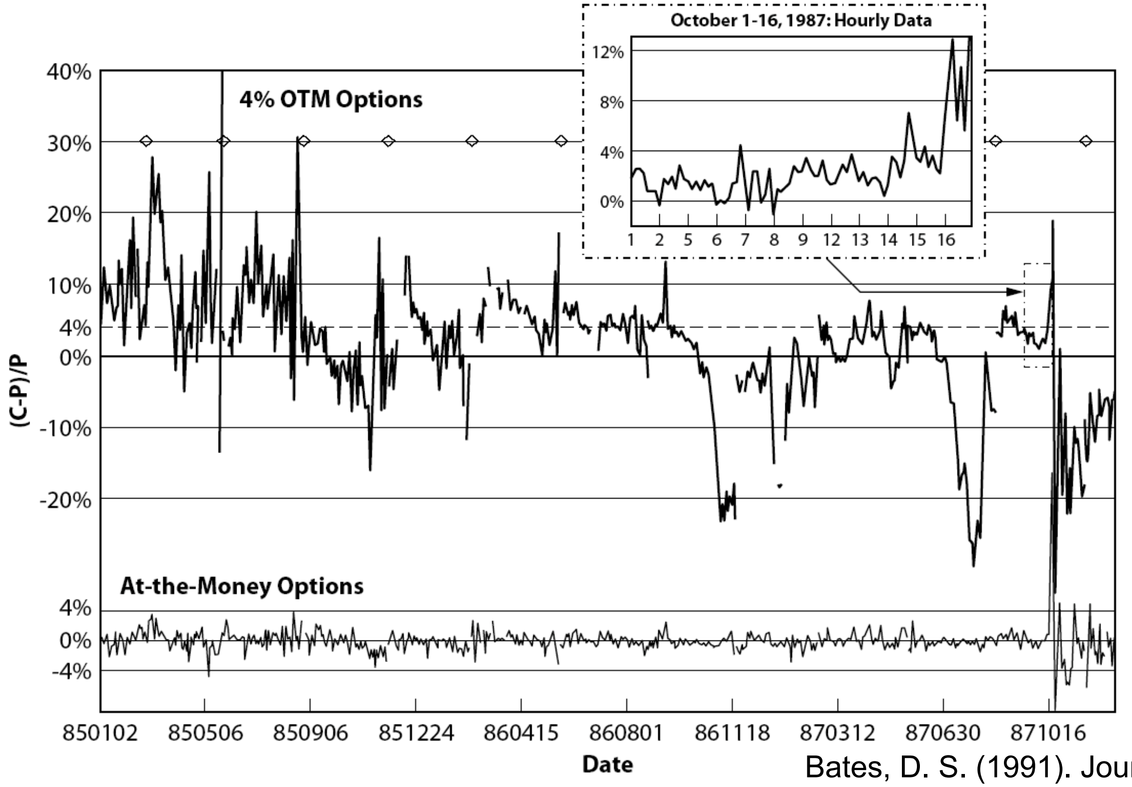




THE CRASH OF OCTOBER 1987

The Wall Street Journal on August 26, 1987, the day after the 1987 market peak: “In a market like this, every story is a positive one. Any news is good news. It’s pretty much taken for granted now that the market is going to go up.”

Intermittent anticipation of the crash reflected in out-of-the-money option prices



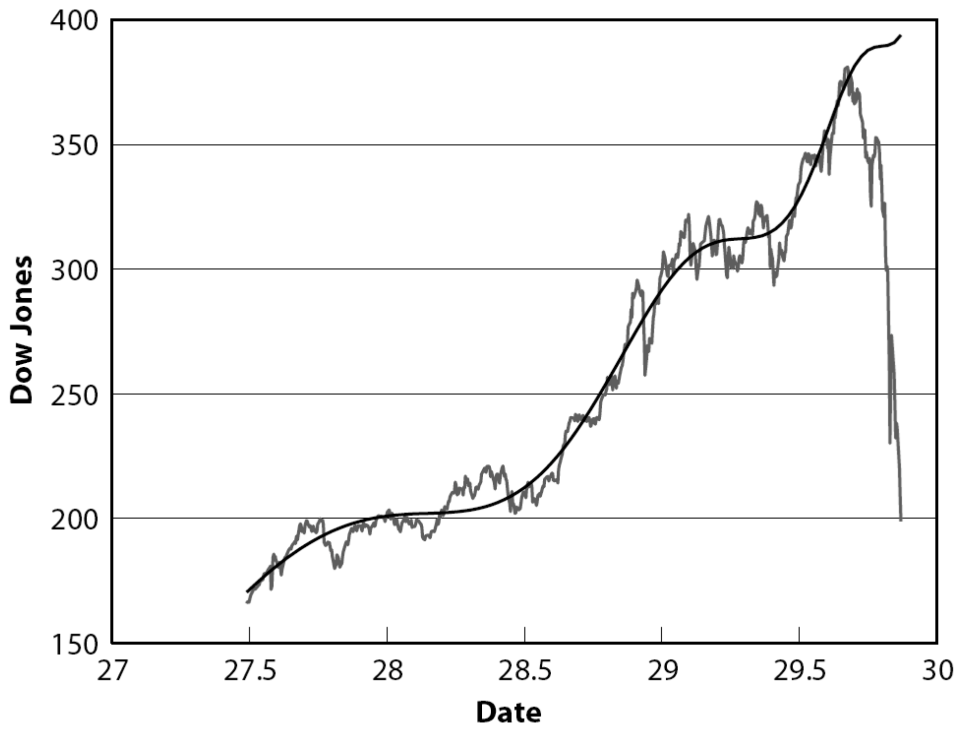
Percentage deviation (C-P)/P of call from put prices (skewness premium) for options at-the-money and 4% out-of-the-money, over 1985–87. The percentage deviation (C-P)/P is a measure of the asymmetry between the perceived distribution of future large upward moves compared to large downward moves of the S&P 500 index. Deviations above (below) 0% indicate optimism (fear) for a bullish market (of large potential drops). The inset shows the same quantity (C-P)/P calculated hourly during October 1987 prior to the crash: ironically, the market forgot its “fears” close to the crash.

Bates, D. S. (1991). Journal of Finance 46, 1009–1044.

THE CRASH OF OCTOBER 1929

Stock market crashes are often unforeseen for most people, especially economists. "In a few months, I expect to see the stock market much higher than today." Irving Fisher, famous economist and professor of economics at Yale University,14 days before Wall Street crashed on Black Tuesday, October 29, 1929.

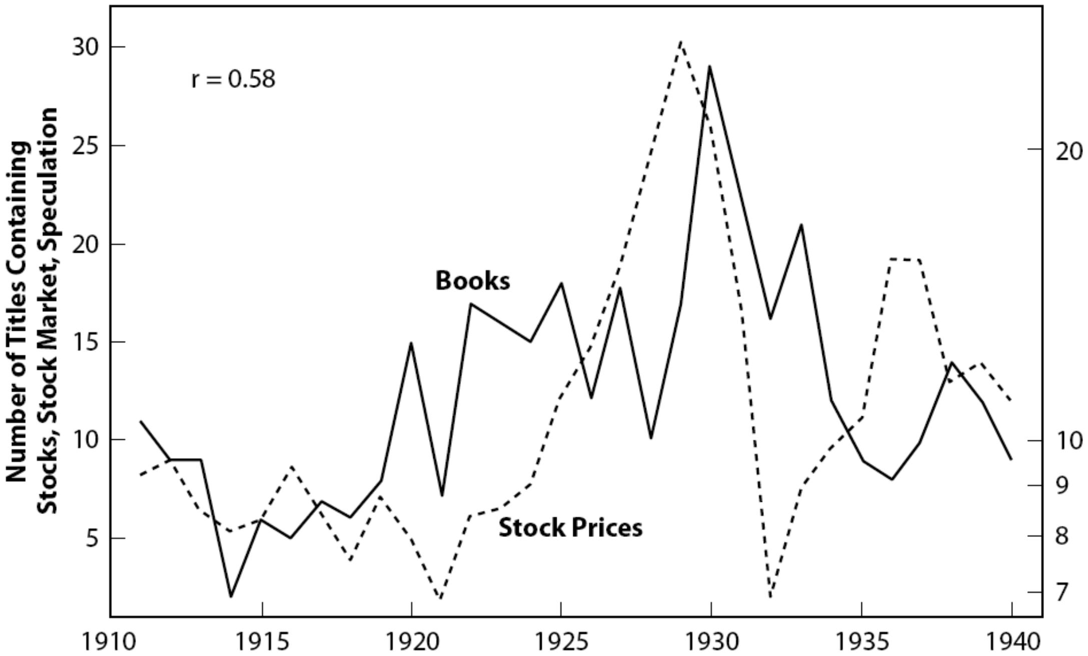
"A severe depression such as 1920–21 is outside the range of probability. We are not facing a protracted liquidation." This was the analysis offered days after the crash by the Harvard Economic Society to its subscribers… It closed its doors in 1932.



The DJIA prior to the October 1929 crash on Wall Street.

THE CRASH OF OCTOBER 1929

- A financial collapse has never happened when things look bad.
- Macroeconomic flows look good before crashes.
- Before every collapse, economists say the economy is in the best of all worlds.
- Everything looks rosy, stock markets go up…
- Macroeconomic flows (output, employment, etc.) appear to be improving further and further.
- A crash catches most people, especially economists, by surprise.
- The good times are extrapolated linearly into the future.
- Is it not perceived as senseless by most people in a time of general euphoria to talk about crash and depression?



growing interest in the public for the commodity in question,whether it consists of stocks, diamonds, or coins.

B.M. Roehner and D. Sornette, “Thermometers" of Speculative Frenzy”, European Physical Journal B 16, 729-739 (2000)

THE TULIP MANIA

•Between 1585 and 1650, Amsterdam became the chief commercial emporium, the center of the trade of the northwestern part of Europe, owing to the growing commercial activity in newly discovered America.

•The tulip as a cultivated flower was imported into western Europe from Turkey and it is first mentioned around 1554.

•The scarcity of tulips and their beautiful colors made them a must for members of the upper classes of society

FIG. 1.1. A variety of tulip (the Viceroy) whose bulb was one of the most expensive at the time of the tulip mania in Amsterdam, from *The Tulip Book* of P. Cos, including weights and prices from the years of speculative tulip mania (1637); Wageningen UR Library, Special Collections.

THE TULIP MANIA

•What we now call the "tulip mania" of the seventeenth century was the "sure thing" investment during the period from the mid-1500s to 1636.

•Before its devastating end in 1637, those who bought tulips rarely lost money. People became too confident that this "sure thing" would always make them money.

•At the period's peak, the participants mortgaged their houses and businesses to trade tulips.

•Some tulip bulbs of a rare variety sold for the equivalent of a few tens of thousands of dollars.

•Before the crash, any suggestion that the price of tulips was irrational was dismissed by all the participants.

THE TULIP MANIA

- The conditions now generally associated with the first period of a boom were all present:
    - -an increasing currency,
    - -a new economy with novel colonial possibilities, and
    - -an increasingly prosperous country

together had created the optimistic atmosphere in which booms are said to grow.

- The crisis came unexpectedly.
    - -On February 4, 1637, the possibility of the tulips becoming definitely unsalable was mentioned for the first time.
    - -From then until the end of May 1637, all attempts at coordination among florists, bulbgrowers, and the Netherlands government were met with failure.

Have We Learned the Lessons of Black Mondays?

19 October 1987

to

19 October 2007 to 2008...

THE NASDAQ CRASH OF APRIL 2000

•1995-2000: growing divergence between New Economy and Old Economy stocks, between technology and almost everything else.

•Over 1998 and 1999, stocks in the Standard & Poor's technology sector rose nearly fourfold, while the S&P 500 index gained just 50%. And without technology, the benchmark would be flat.

•In January 2000 alone, 30% of net inflows into mutual funds went to science and technology funds, versus just 8.7% into S&P 500 index funds.

•The average price-over-earnings ratio (P/E) for Nasdaq companies was above 200.

•New Economy was also hot in the minds and mouths of investors in the 1920s and in the early 1960s. In 1929, it was utilities; in 1962, it was the electronic sector.

•The Nasdaq composite consists mainly of stock related to the New Economy, that is, the Internet, software, computer hardware, telecommunication.

•The Nasdaq composite index dropped precipitously, with a low of 3,227 on April 17, 2000, corresponding to a cumulative loss of 37% counted from its all-time high of 5,133 reached on March10, 2000.

•A main characteristic of these companies is that their P/Es, and even more so their price-over-dividend ratios, often came in three digits prior to the crash. Some companies, such as VA LINUX, actually had a negative earnings/share of -1.68.

EXPECTATIONS of strong future growth

Proposed justifications of PRICES

•better business models (small required capital, reduced delay in payments…)

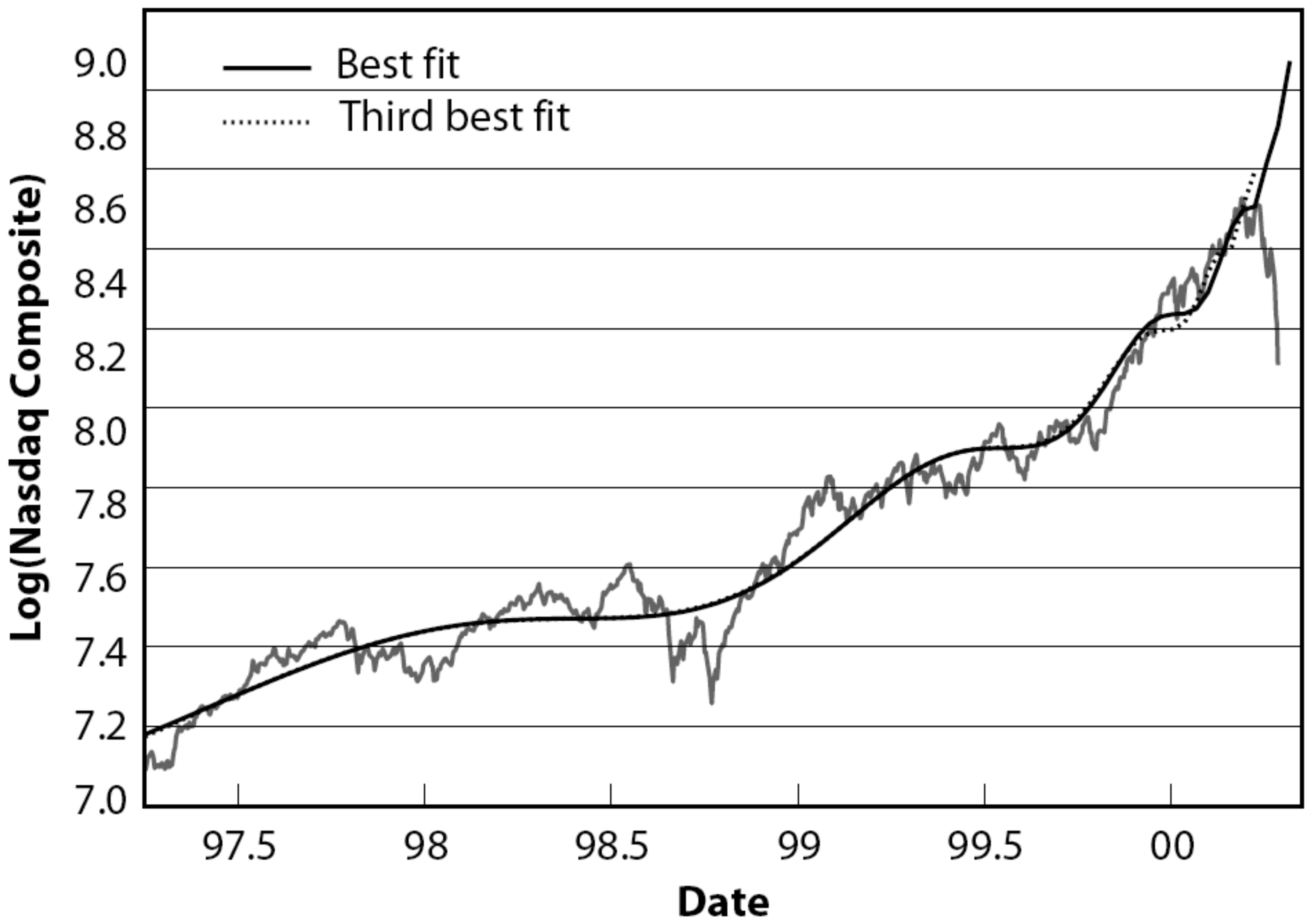
•the network effect (positive returns and positive feedbacks)

•first-to-scale advantages

•real options (value of fast adaptation to grasp new opportunities)

Probably true… but problem of timing…

THE NASDAQ CRASH OF APRIL 2000



Foreign capital inflow

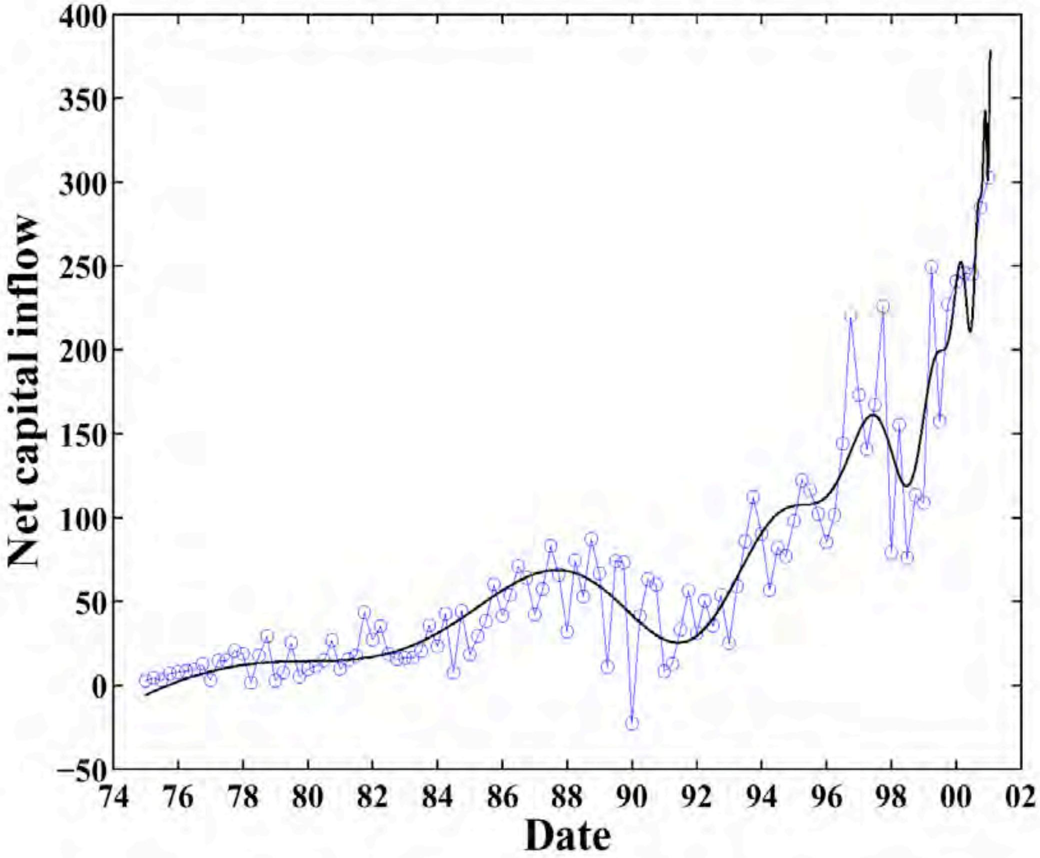
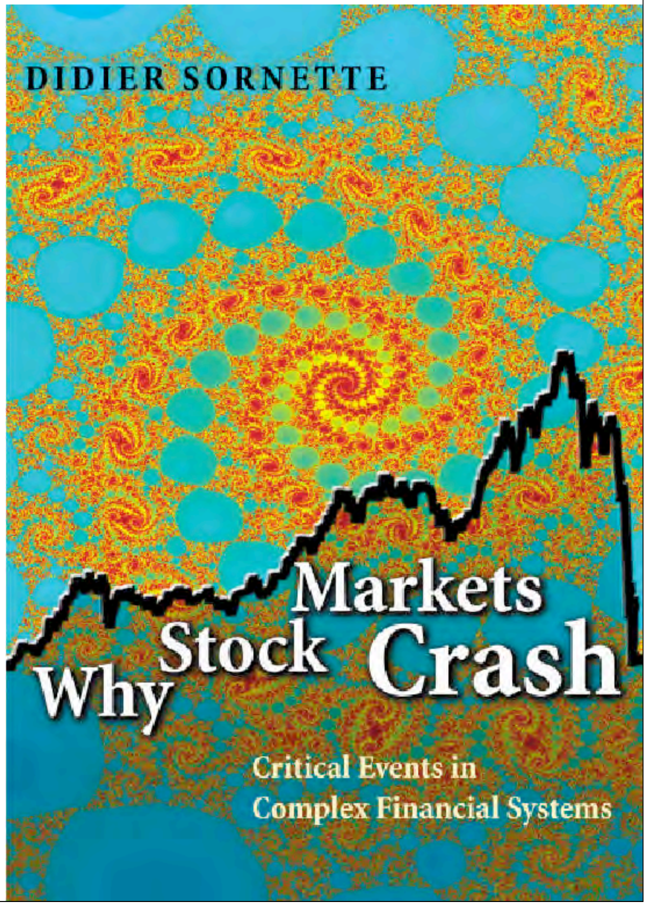


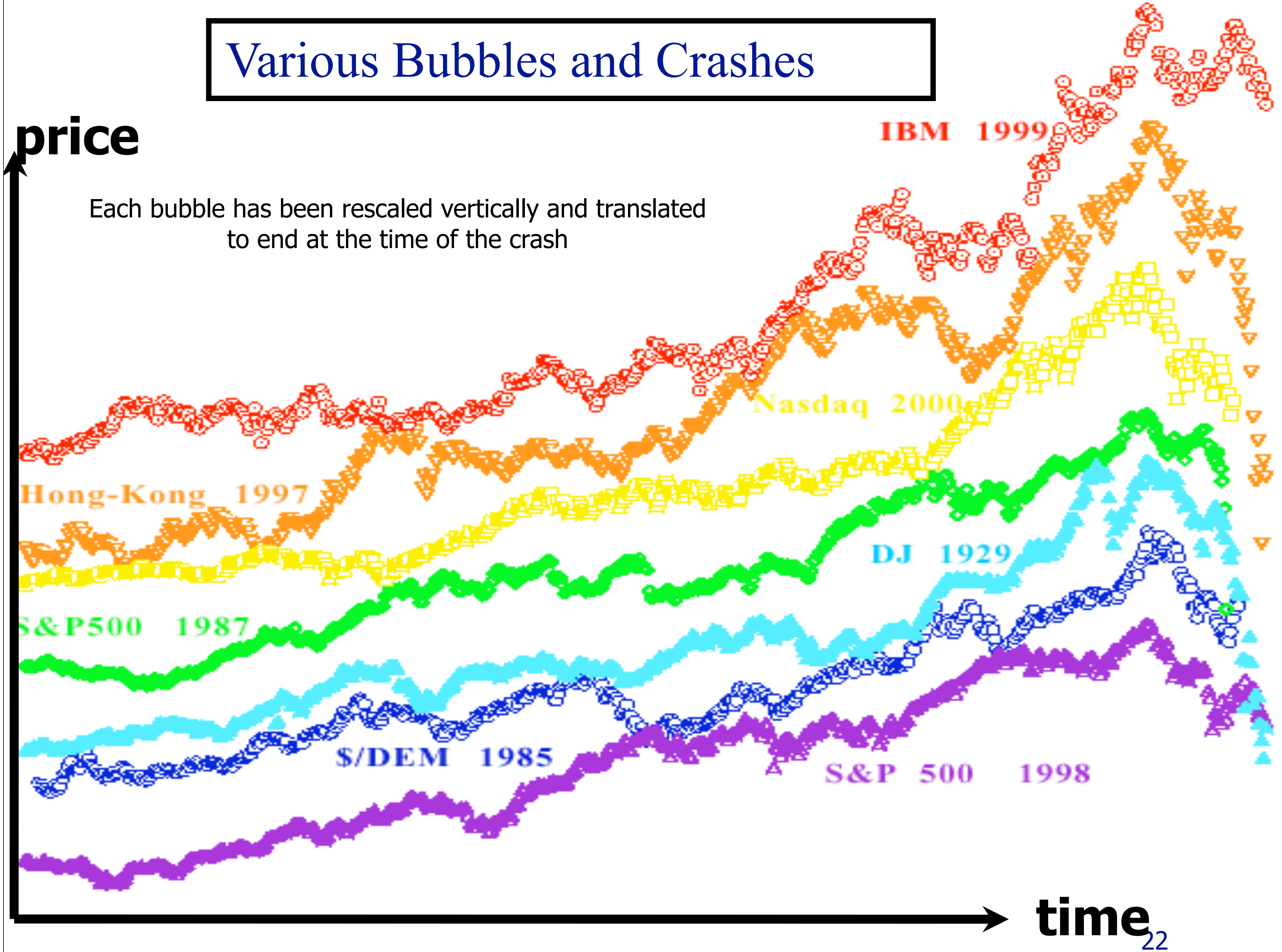
Fig. 2. Fit of the time evolution of the foreign net capital inflow $I(t)$ in the USA from 1975 till the first quarter of 2001 when it reached its maximum, by a second-order Weierstrass-type function given by expression (1). The predicted critical time is $t_c = 2001/03/12$, the power-law exponent is $m = 0.01$, and the angular log-frequency is $\omega = 4.9$. The fitted linear parameters are $A = 7355$, $B = -6719$, $C_1 = 21.5$ and $C_2 = 16.2$. The r.m.s. of the residuals of the fit is 22.810.

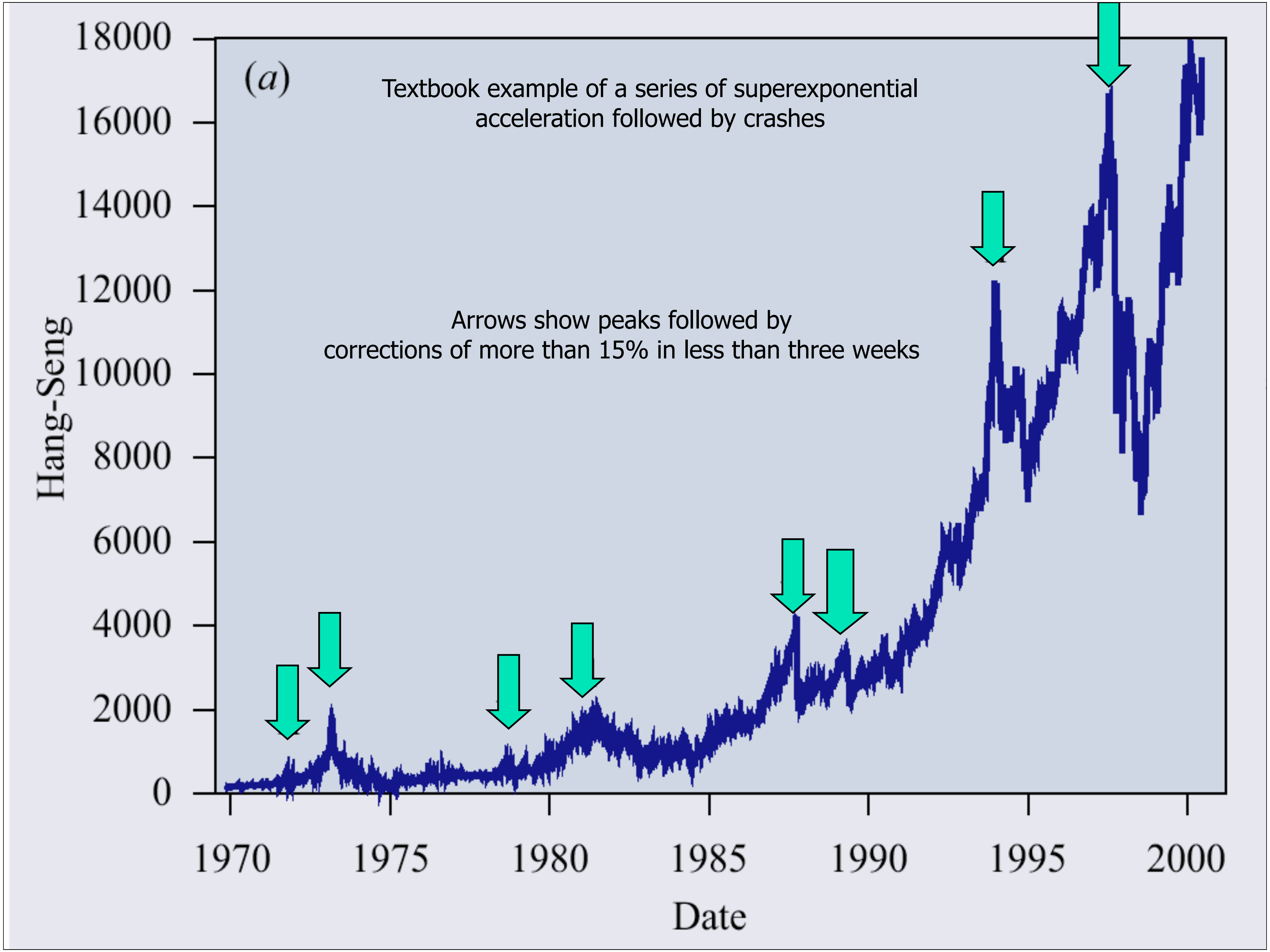
Many other bubbles and crashes

- Hong-Kong crashes: 1987, 1994, 1997 and many others
- October 1997 mini-crash
- August 1998
- Slow crash of spring 1962
- Latin-american crashes
- Asian market crashes
- Russian crashes
- Individual companies

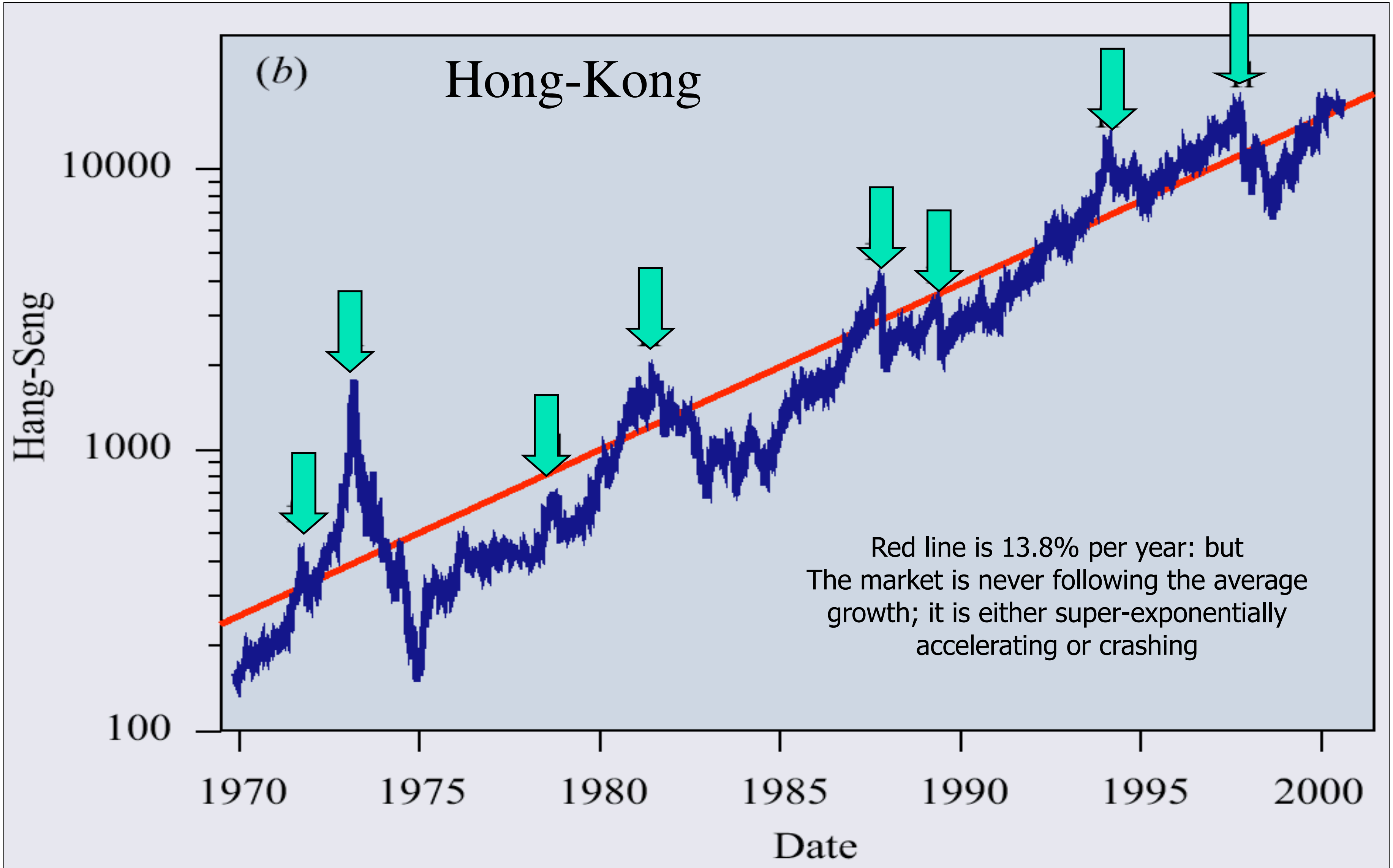


Various Bubbles and Crashes





(a)
Textbook example of a series of superexponential acceleration followed by crashes
Arrows show peaks followed by corrections of more than 15% in less than three weeks
Hang-Seng
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1970
1975
1980
1985
1990
1995
2000
Date



Patterns of price trajectory during 0.5-1 year before each peak: Log-periodic power law

Universal Bubble and Crash Scenario

1. The bubble starts smoothly with some increasing production and sales (or demand for some commodity) in an otherwise relatively optimistic market.

2. The attraction to investments with good potential gains then leads to increasing investments, possibly with leverage coming from novel sources, often from international investors. This leads to price appreciation.

3. This in turn attracts less sophisticated investors and, in addition, leveraging is further developed with small downpayment (small margins), which leads to the demand for stock rising faster than the rate at which real money is put in the market.

4. At this stage, the behavior of the market becomes weakly coupled or practically uncoupled from real wealth (industrial and service) production.

5. As the price skyrockets, the number of new investors entering the speculative market decreases and the market enters a phase of larger nervousness, until a point when the instability is revealed and the market collapses.

What is the cause of the crash?

- ✓ Proximate causes: many possibilities

- ✓ Fundamental cause: maturation towards an instability

An instability is characterized by

- large or diverging susceptibility to external perturbations or influences
- exponential growth of random perturbations leading to a change of regime, or selection of a new attractor of the dynamics.

Complex Systems

-positive feedbacks

-non sustainable regimes

-rupture

Thomas Robert Malthus (1766–1834)

1798

autocatalitic proliferation: $\frac{dx}{dt} = a \cdot x$

with a =birth rate - death rate

exponential solution: $X(t) = X(0)e^{a\,t}$

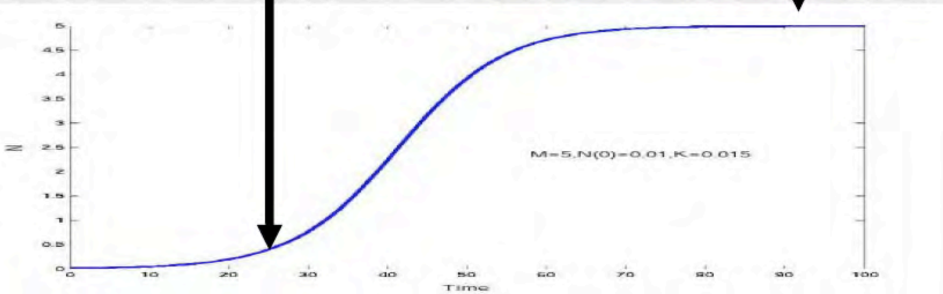
contemporary estimations= doubling of the population every 30yrs

Pierre François Verhulst (1804-1849)

way out exponential explosion:

$dX/dt = a\,X - c\,X^2$ **1838**

Solution: exponential ==========→saturation at X= a / c



For humans data at the time could not discriminate between:

1. exponential growth of Malthus
2. logistic growth of Verhulst

But data fit on animal population: sheep in Tasmania

- exponential in the first 20 years after their introduction and completely saturated after about half a century. ==> Verhulst

Positive feedbacks and finite-time singularity

Conjecture: Many systems exhibit transient FTS as "ghost-like" solutions that the system follows for a while before being attenuated.
Analogous to exponential sensitivity to initial condition with reinjection → chaos **but** here FTS blow-up.

$$\frac{dp}{dt} = rp(t)[K - p(t)]$$

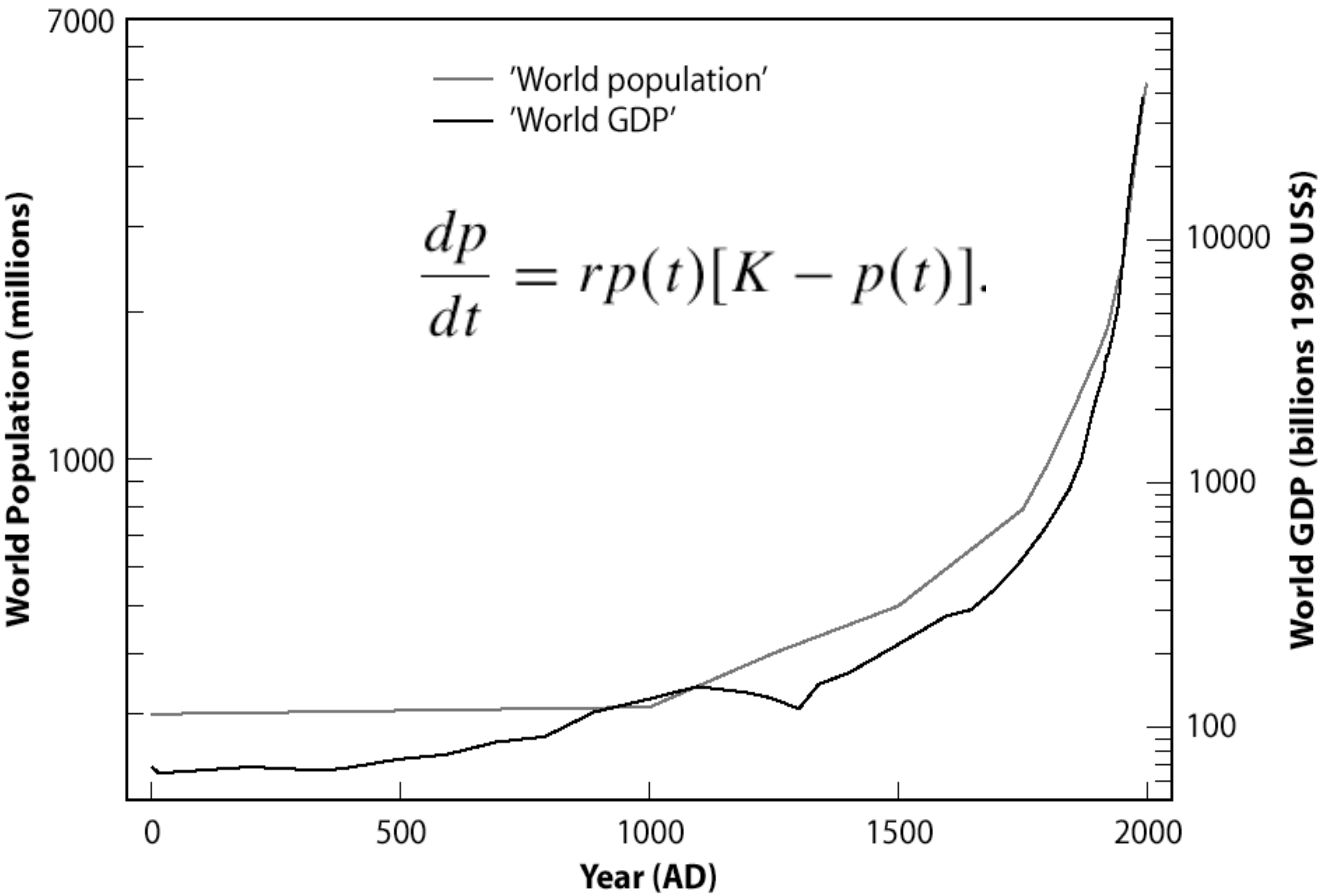
$$\frac{dp}{dt} = r[p(t)]^{1+\delta}$$

with $K \propto p^{\delta}$

$$p(t) \propto (t_c - t)^z, \text{ with } z = -\frac{1}{\delta} \text{ and } t \text{ close to } t_c.$$

Multi-dimensional generalization: multi-variate positive feedbacks

Super-exponential growth



Faster than exponential growth

Suppose GROWTH RATE doubles when POPULATION doubles

POPULATION	GROWTH RATE	DOUBLING TIME
1000	1%	69y
2000	2%	69/2y
4000	4%	69/4y
…	…	…
2^n x 1000	2^n %	$69/2^n$ y

Population diverges in finite time

$$69+69/2+69/4+69/8\ldots=69x(1+1/2+1/4+1/8+\ldots)=69x2=138y$$

Zeno paradox

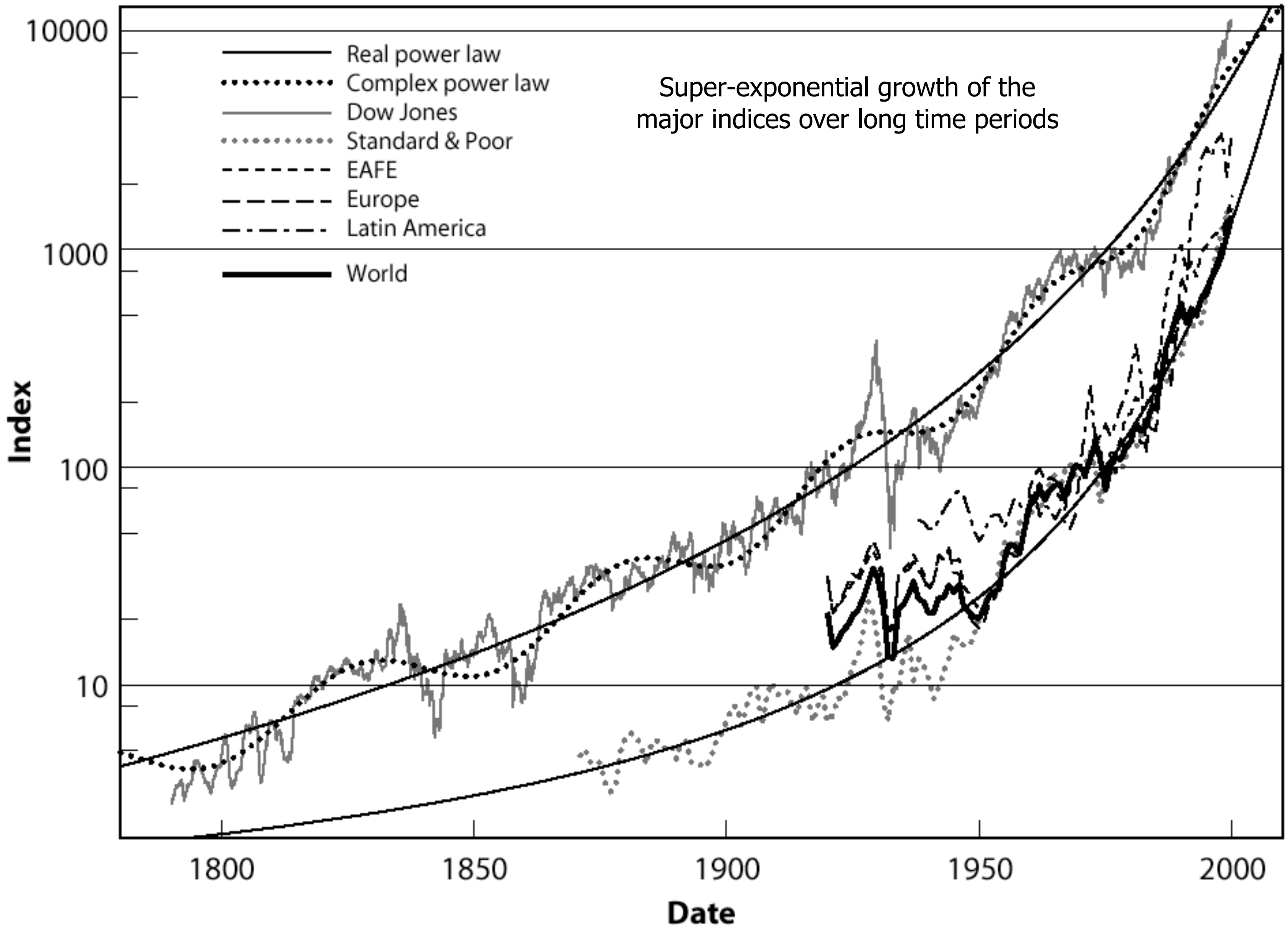
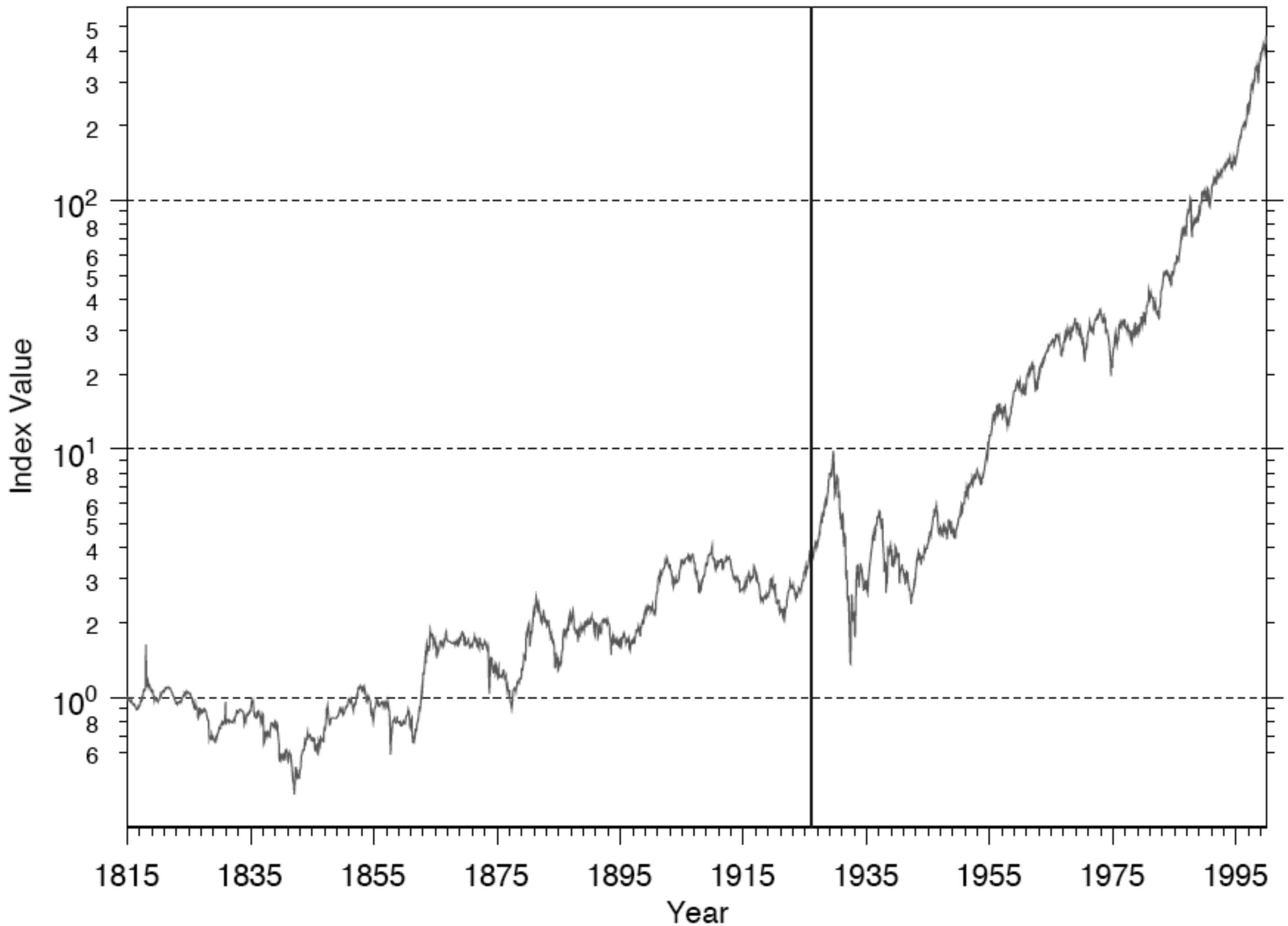

10000
1000
100
10
Index
Real power law
Complex power law
Dow Jones
Standard & Poor
EAFE
Europe
Latin America
World
Super-exponential growth of the major indices over long time periods
1800
1850
1900
1950
2000
Date

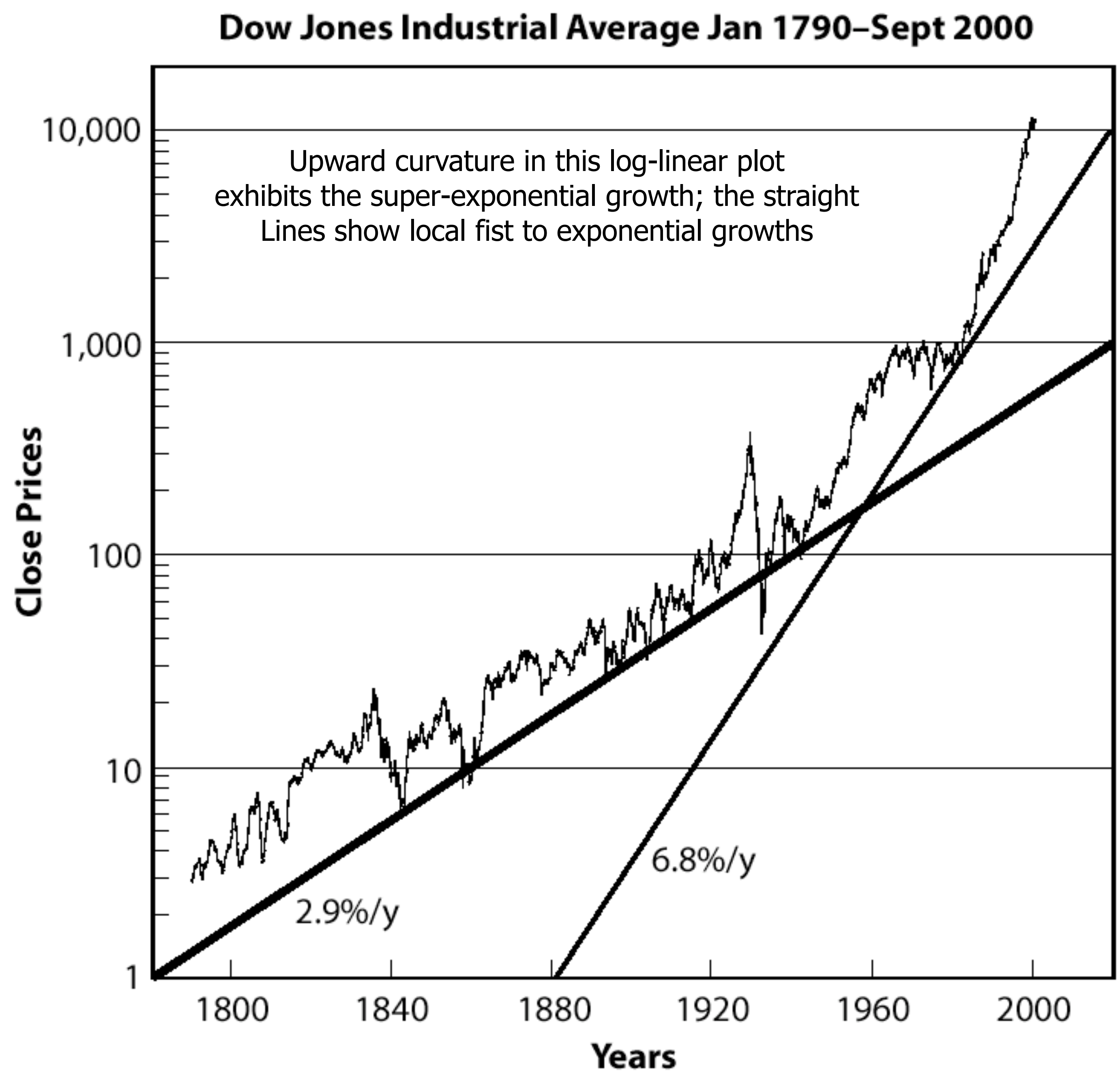
Figure 1: Monthly Capital Appreciation Index 1/1815-12/1999



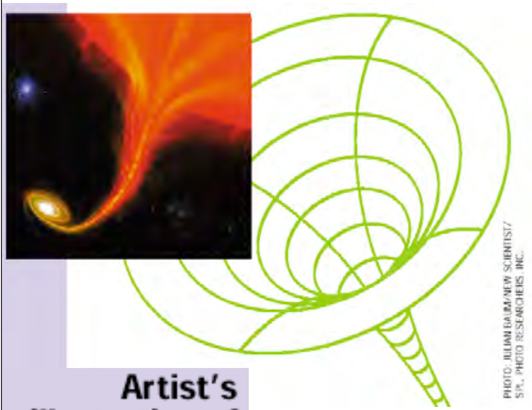
Price-weighted NYSE Index (1/1815-12/1925) with Ibbotson and Sinquefield Index (1/1926-12/1999)

A NEW HISTORICAL DATABASE FOR THE NYSE 1815 TO 1925: PERFORMANCE AND PREDICTABILITY

W.N. Goetzmann, R.G. Ibbotson and L. Peng
Yale School of Management, July 14, 2000


Dow Jones Industrial Average Jan 1790–Sept 2000
Upward curvature in this log-linear plot
exhibits the super-exponential growth; the straight
Lines show local fist to exponential growths
10,000
1,000
100
10
1
Close Prices
2.9%/y
6.8%/y
1800
1840
1880
1920
1960
2000
Years

Finite-time Singularity



Artist's illustration of matter from a red giant star being pulled toward a black hole.

- Planet formation in solar system by run-away accretion of planetesimals
- PDE's: Euler equations of inviscid fluids and relationship with turbulence
- PDE's of General Relativity coupled to a mass field leading to the formation of black holes
- Zakharov-equation of beam-driven Langmuir turbulence in plasma
- rupture and material failure
- Earthquakes (ex: slip-velocity Ruina-Dieterich friction law and accelerating creep)
- Models of micro-organisms chemotaxis, aggregating to form fruiting bodies
- Surface instability spikes (Mullins-Sekerka), jets from a singular surface, fluid drop snap-off
- Euler's disk (rotating coin)
- Stock market crashes...

Mechanisms for positive feedbacks in the stock market

- Technical and rational mechanisms
  1. Option hedging
  2. Insurance portfolio strategies
  3. Trend following investment strategies
  4. Asymmetric information on hedging strategies

- Behavioral mechanisms:
  1. Breakdown of "psychological Galilean invariance"
  2. Imitation(many persons)
     a) It is rational to imitate
     b) It is the highest cognitive task to imitate
     c) We mostly learn by imitation
     d) The concept of "CONVENTION" (Orléan)

Utility theory

$$\sum_i p_i\, u(w_i) > \sum_i q_i\, u(w_i)$$

Von Neumann and Morgenstern

Behavioral Finance:one person

- Fear and Greed
- Over-confidence
- Anchoring
- Law of small numbers (gambler's fallacy)
- Representativeness (=>weight recent past too heavily)
- Availability and rational inattention
- Allais' paradox: relative reference level
- Subjective probabilities
- Procedure Utility

$$\sum_i \pi(p_i) v(\Delta w_i) > \sum_i \pi(q_i) v(\Delta w_i)$$

*Prospect theory

Kahneman and Tversky

Are two heads better than one?

Yes IF:

1. Only one solution (otherwise "average of Nice and LA is in the Atlantic")
2. Independence between decisions (otherwise: inadequate sampling)
3. No feedbacks between people's decisions (otherwise: self-reinforcing bias)

Dresdner Kleinwort Wasserstein | Seven Sins of Fund Management

Groupthink is often characterised by:

- A tendency to examine too few alternatives
- A lack of critical assessment of each other's ideas
- A high degree of selectivity in information gathering
- A lack of contingency plans
- Poor decisions are often rationalized
- The group has an illusion of invulnerability and shared morality
- True feelings and beliefs are suppressed
- An illusion of unanimity is maintained
- Mind guards (essentially information sentinels) may be appointed to protect the group from negative information

Kal


JUST A NORMAL DAY AT THE NATION'S MOST IMPORTANT FINANCIAL INSTITUTION...
I'VE GOT A STOCK HERE THAT COULD REALLY EXCEL
REALLY EXCEL?
EXCEL?
SELL?
SELL?
SELL
SE
SELL!
SELL!
KAL
SELL!
SELL!
ELL!
SELL!
THIS IS MADNESS! I CAN'T TAKE ANYMORE
GOOD BYE!
GOOD BYE?
BYE?
Buy?
BUY!
Buy!
BUY!!
Buy!
Buy
BUY!
I'VE GOT A STOCK HERE..
CARTOONISTS & WRITERS SYNDICATE http://CartoonWeb.com


THIS WAY TO THE
Bull Market!
Almost there. . . 300 feet. . . Don't Miss The Fun!
I'm a trader.
Hey this Koolaid tastes great!
Must own Yahoo.
Don't be negative.
Stoopid bears.
Take a deep breath!
I'm flying mommy!
El Cliffo

Imitation

-Imitation is considered an efficient mechanism of social learning.

- Experiments in developmental psychology suggest that infants use imitation to get to know persons, possibly applying a ‘like-me’ test (‘persons which I can imitate and which imitate me’).

- Imitation is among the most complex forms of learning. It is found in highly socially living species which show, from a human observer point of view, ‘intelligent’ behavior and signs for the evolution of traditions and culture (humans and chimpanzees, whales and dolphins, parrots).

- In non-natural agents as robots, tool for easing the programming of complex tasks or endowing groups of robots with the ability to share skills without the intervention of a programmer. Imitation plays an important role in the more general context of interaction and collaboration between software agents and human users.

Thy Neighbor's Portfolio: Word-of-Mouth Effects in the Holdings and Trades of Money Managers

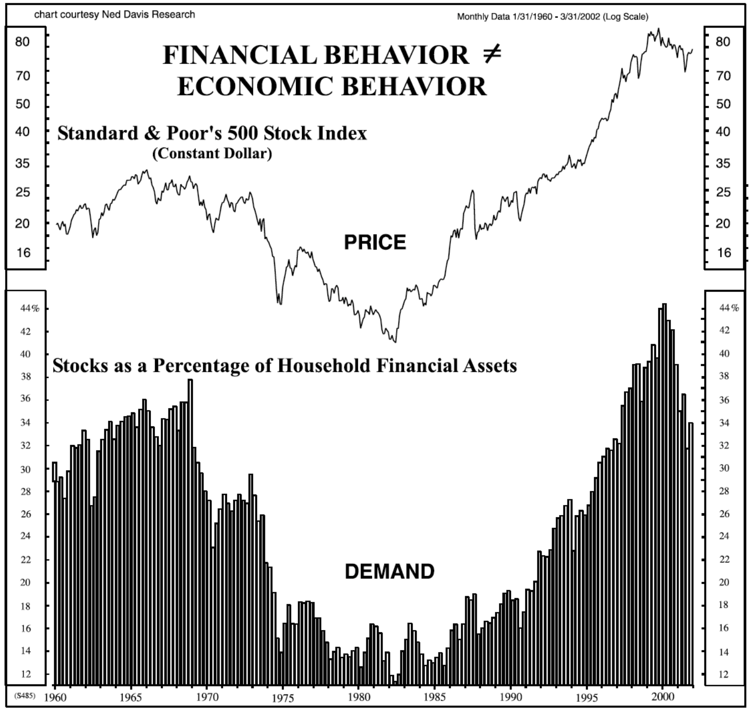
HARRISON HONG, JEFFREY D. KUBIK, and JEREMY C. STEIN*

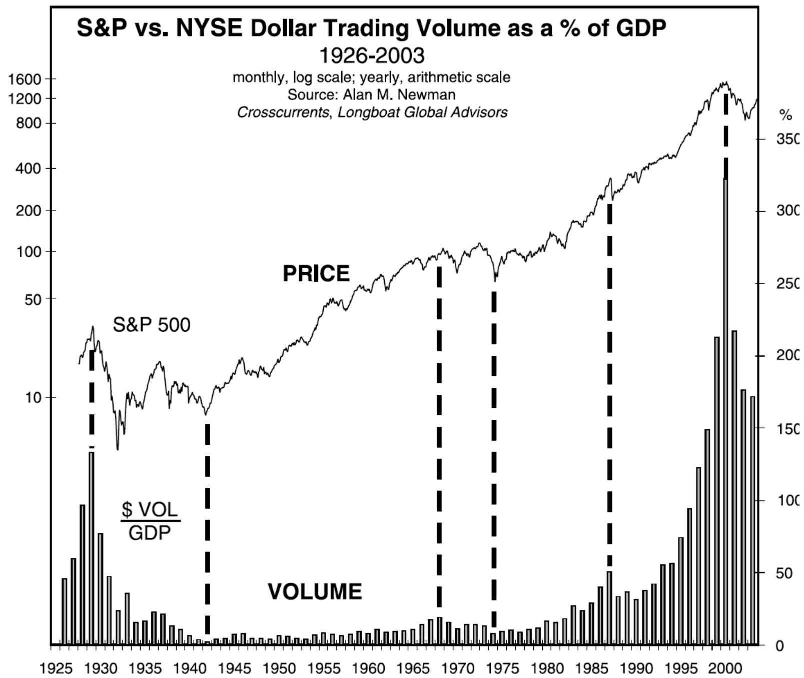
A mutual fund manager is more likely to buy (or sell) a particular stock in any quarter if other managers in the same city are buying (or selling) that same stock. This pattern shows up even when the fund manager and the stock in question are located far apart, so it is distinct from anything having to do with local preference. The evidence can be interpreted in terms of an epidemic model in which investors spread information about stocks to one another by word of mouth.

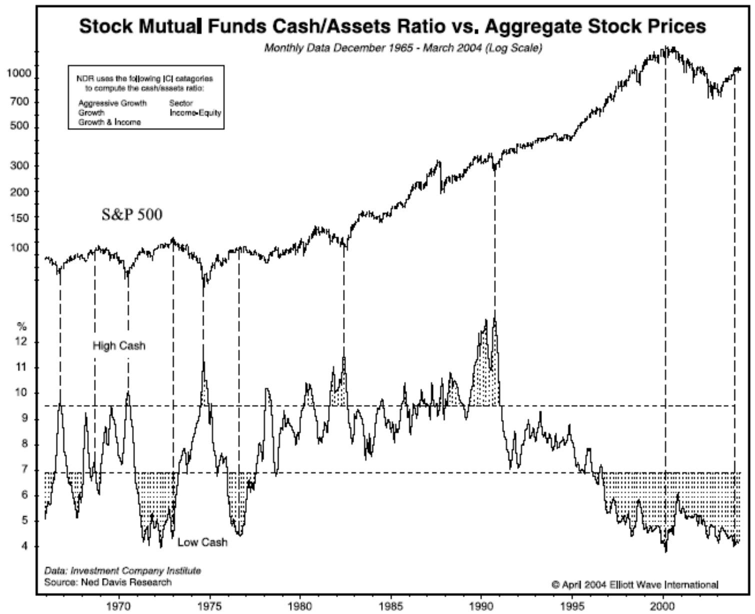
THE JOURNAL OF FINANCE • VOL. LX, NO. 6 • DECEMBER 2005

A fundamental observation about human society is that people who communicate regularly with one another think similarly. There is at any place and in any time a *Zeitgeist*, a spirit of the times.... Word-of-mouth transmission of ideas appears to be an important contributor to day-to-day or hour-to-hour stock market fluctuations. (pp. 148, 155)

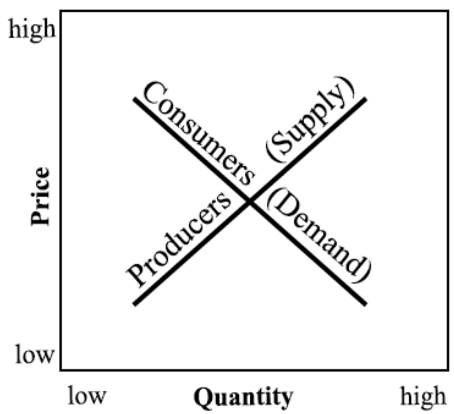
Shiller (2000)



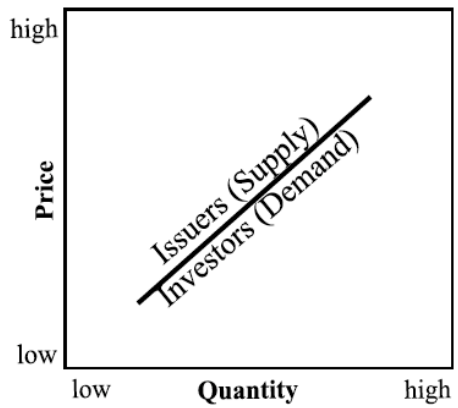




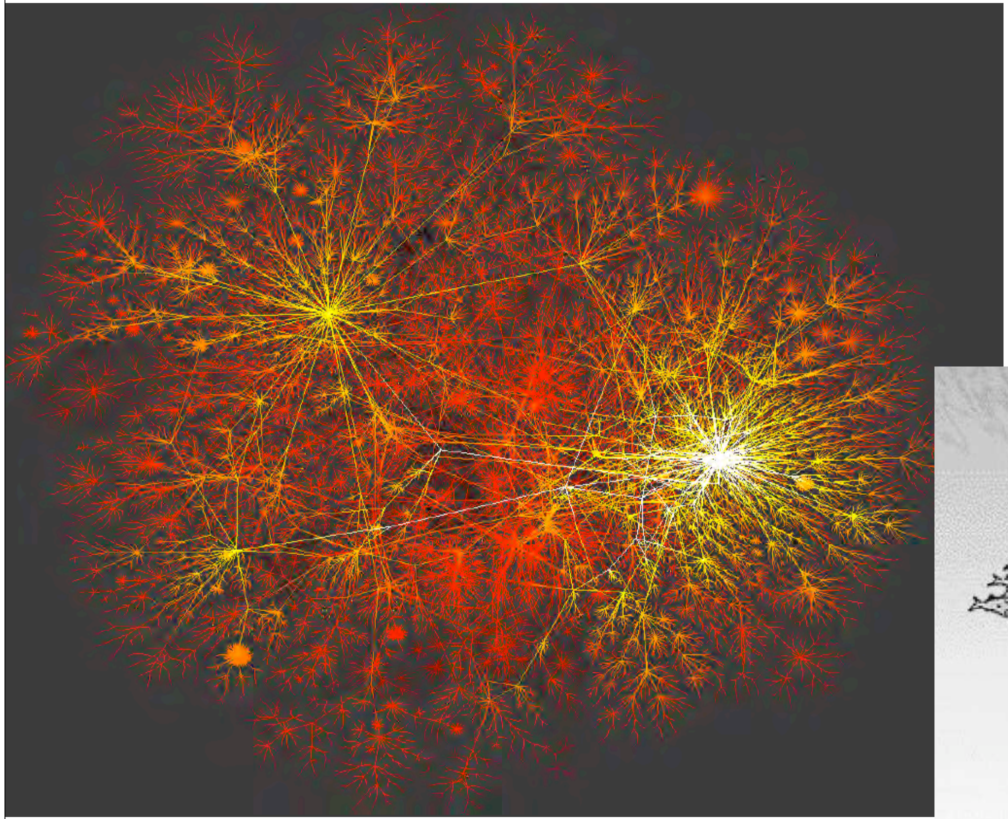
The Law of Supply & Demand in Utilitarian Economics

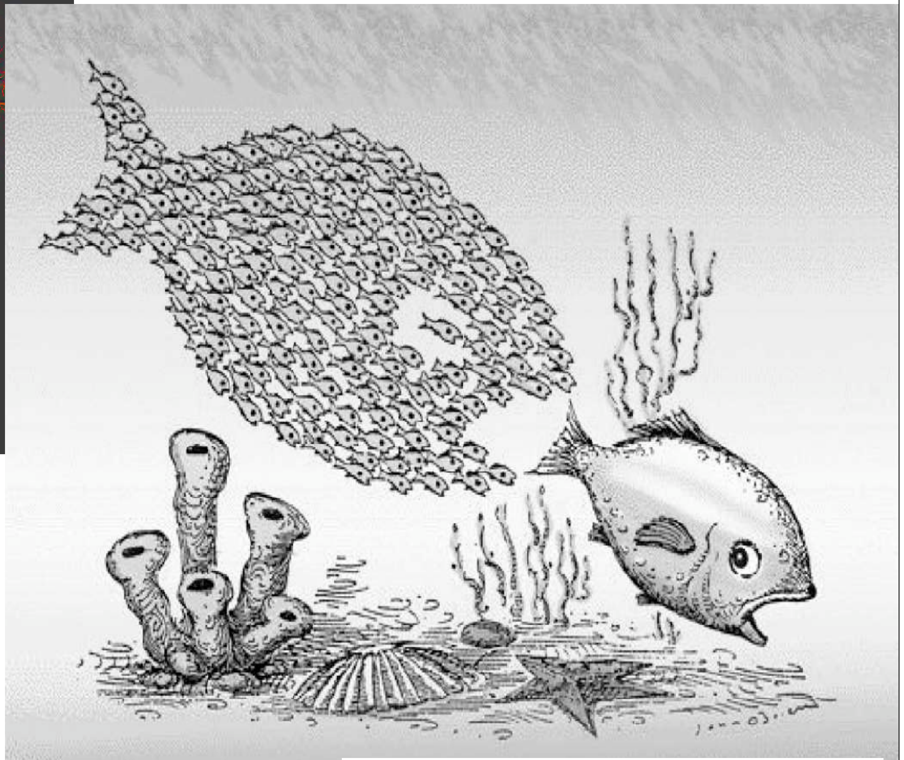


Herding Impulse in Finance



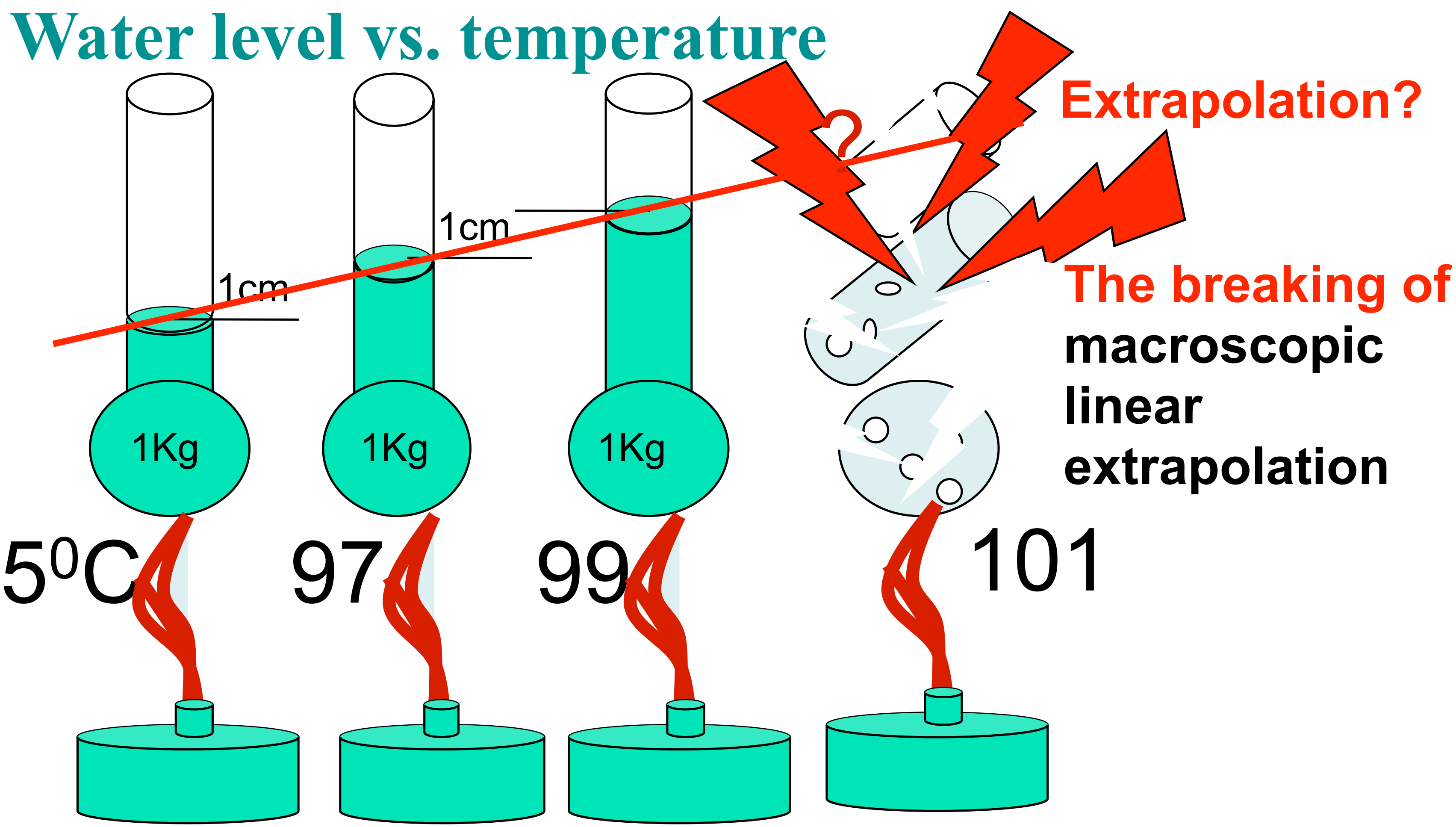
Network effects and Collective behavior





Courtesy of B. A. Huberman.

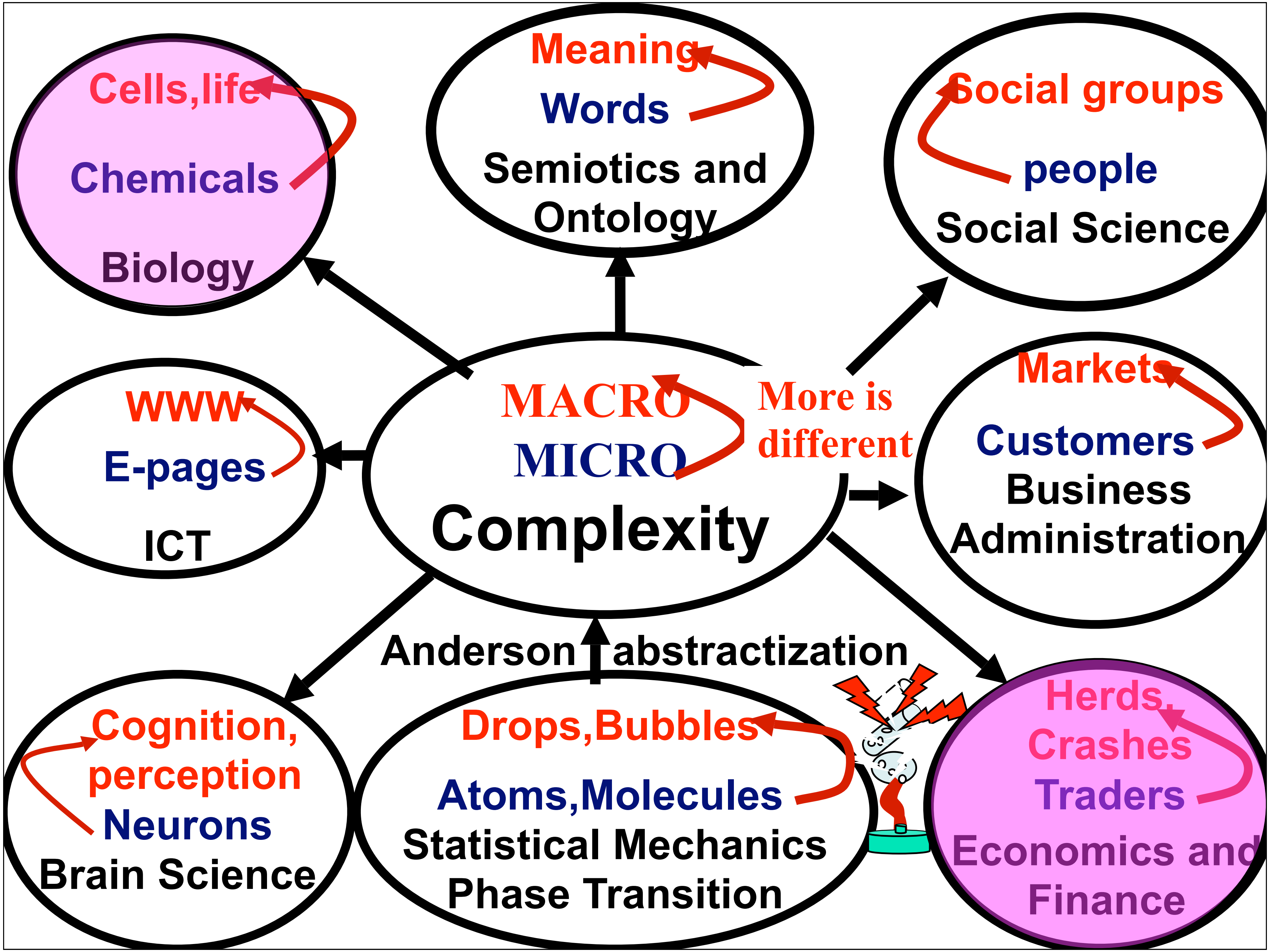
Simplest Example of a "More is Different" Transition



BOILING PHASE TRANSITION

More is different: a single molecule does not boil at 100C⁰

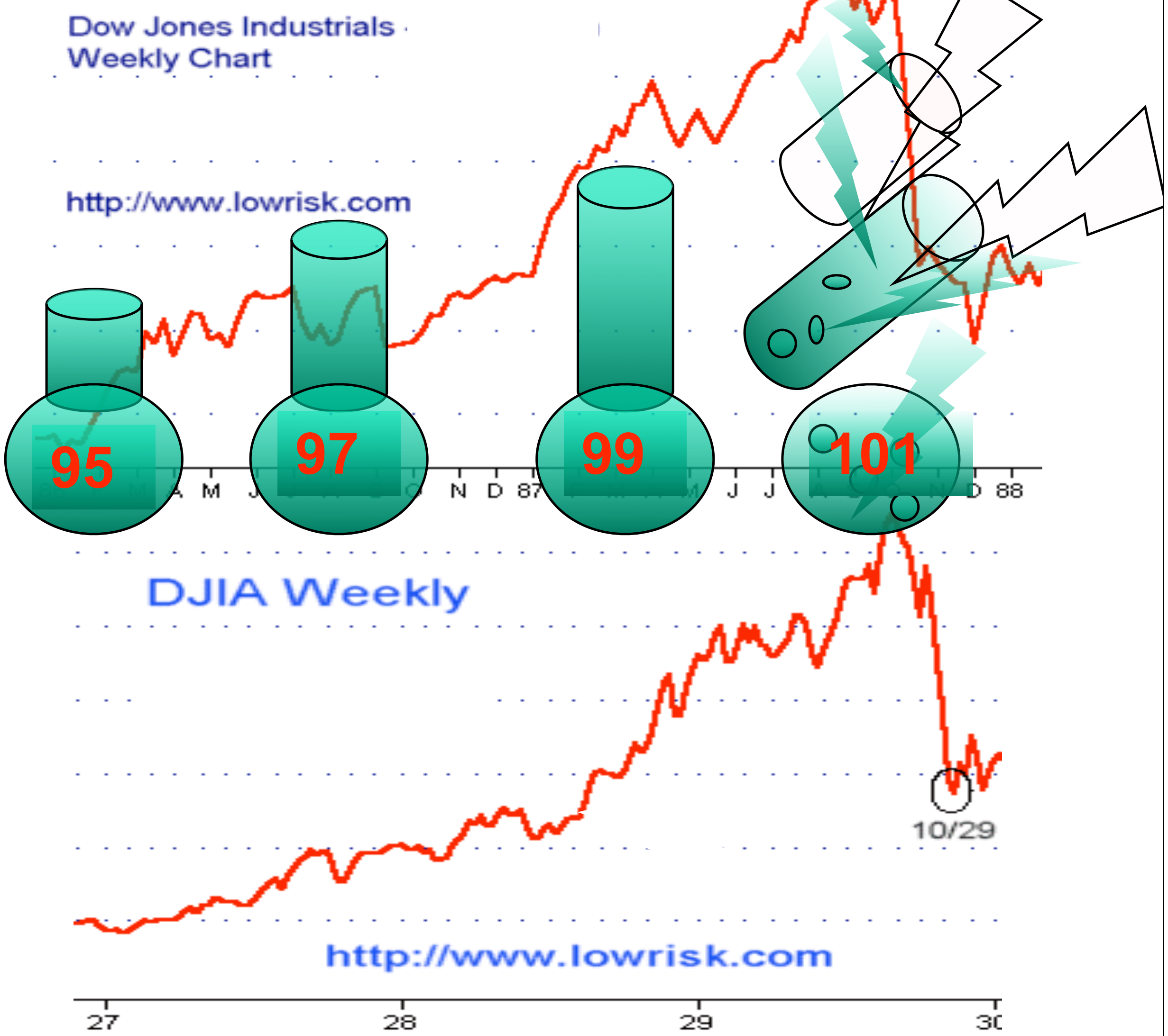
(S. Solomon)


Cells,life
Chemicals
Biology
Meaning
Words
Semiotics and Ontology
Social groups
people
Social Science
WWW
E-pages
ICT
MACRO
MICRO
Complexity
More is different
Markets
Customers
Business Administration
Anderson abstractization
Cognition, perception
Neurons
Brain Science
Drops,Bubbles
Atoms,Molecules
Statistical Mechanics
Phase Transition
Herds,
Crashes
Traders
Economics and Finance

Example of “MORE IS DIFFERENT” transition in Finance:

Instead of Water Level:

-economic index (Dow-Jones etc…)



Crash = result of collective behavior of individual traders

(S. Solomon)

Optimal strategy obtained under limited information

Equation showing optimal imitation solution of decision in absence of intrinsic information and in the presence of information coming from actions of connected "neighbors"

$$s_i(t+1) = \mathrm{sign}\left(K \sum_{j \in N_i} s_j + \varepsilon_i \right)$$

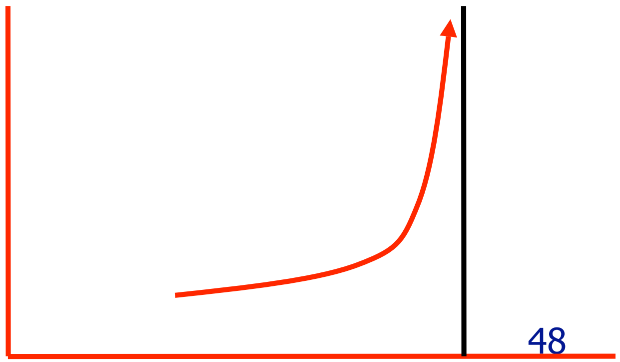
This equation gives rise to critical transition=bubbles and crashes

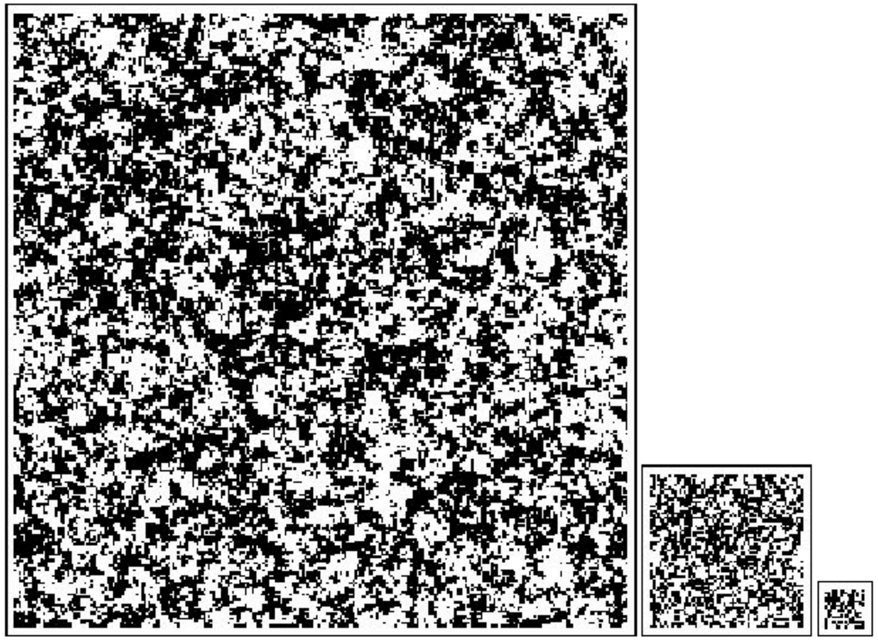
-Crash = coordinated sell-off of a large number of investors
-single cluster of connected investors to set the market off-balance
-Crash if 1) large cluster s>s* and 2) active

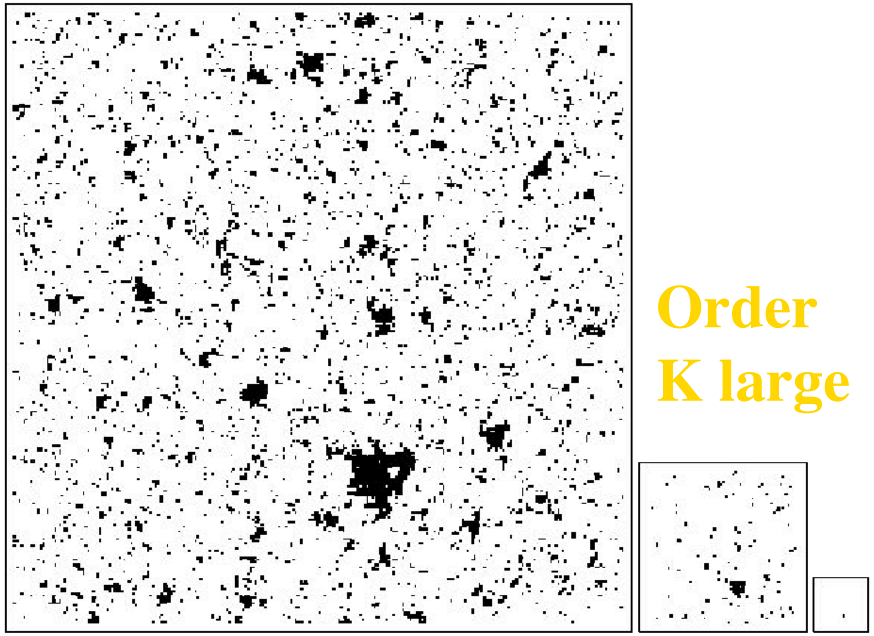
-Proba(1) = n(s)
-Proba(2) ~ s^a with 1 < a < 2 (coupling between decisions)

Proba(crash) ~ $\sum_{s>s^*} n(s)\, s^a$

If a=2, $\sum_{s>s^*} n(s)\, s^2 \sim |K-Kc|^{-\gamma}$





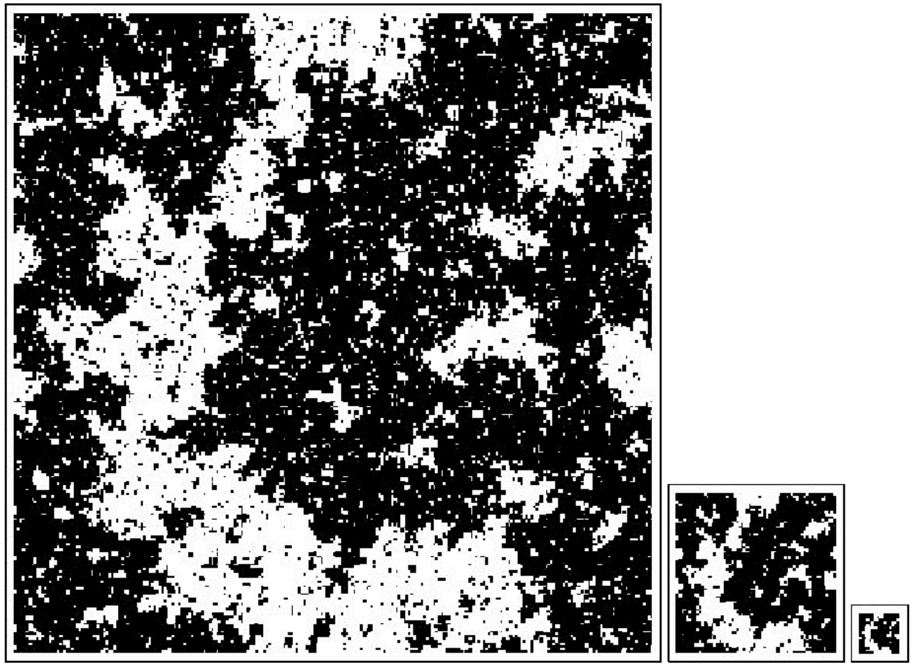


Order
K large

Disorder : K small

Renormalization group:
Organization of the description scale by scale

Critical:
K=critical value



INFORMATION: normal people's high level of general intelligence makes them too smart for their own good.

In 1909, a broker using the pseudonym Don Guyon wrote a small book called One-Way Pockets. He was utterly mystified as to why, after a full cycle of rise and fall after which stocks were valued just where they were at the start, all his clients lost money. His answer, in a nutshell, is herding. His clients felt fearful at the start of bull markets and so traded in and out constantly. At the market's peak, they felt confidently bullish and held much more stock "for the long run,"

Rats beat humans:

The rats and the humans had to look at a TV screen and press the lever anytime a dot appeared in the top half of the screen. The experimenters did not tell the human subjects that's' what they were supposed to do; they had to figure it out for themselves the same way the rats did. The experiment was set up so that 70% of the time the dot was in the top of the screen. Since there was no punishment for a wrong response, the smartest strategy was just to push the bar 100% of the time. That way, you get the reward 70% of the time, even though you have not clue of what is the pattern.

That's what the rats did.

But the humans never figured this out!
They kept trying to come up with a rule, so sometimes they pressed the bar and sometimes they would not, trying to figure it out. Some of them thought they had come up with a rule. But they were of course deluded and their performance was much less than the rats.

People makes STORIES! Normal people have an "interpreter" in their left brain that takes all the random, contradictory details of whatever they are doing or remembering at the moment, and smoothes everything in one coherent story. If there are details that do not fit, they are edited out or revised!

Temple Grandin and C. Johnson, Animals in translation (Scribner, New York, 2005)

Importance of Positive Feedbacks and Over-confidence in a Self-Fulfilling Ising Model of Financial Markets

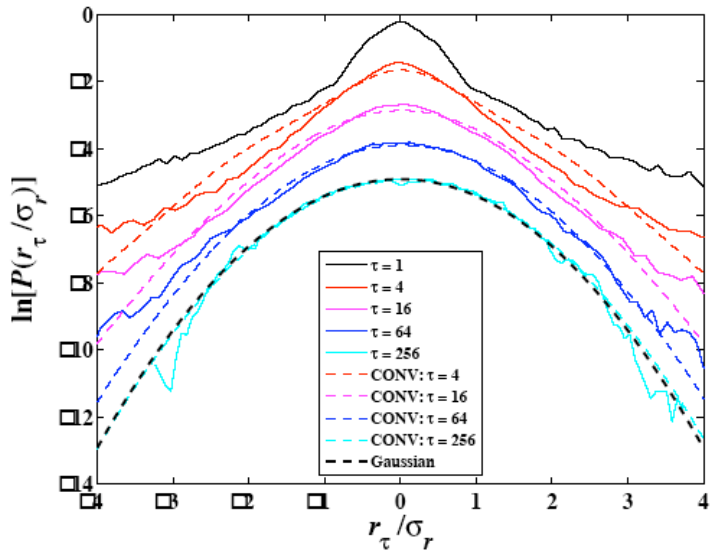
$$s_i(t) = \text{sign}\left[\sum_{j \in \mathcal{N}} K_{ij}(t)\text{E}[s_j](t) + \sigma_i(t)G(t) + \epsilon_i(t)\right]$$

Imitation **News** **Private information**

$$K_{ij}(t) = b_{ij} + \alpha_i K_{ij}(t-1) + \beta r(t-1)G(t-1)$$

β<0: rational agents

β>0: over-confident agents



Didier Sornette and Wei-Xing Zhou
Physica A 370 (2), 704-726 (2006))

Rational Expectation Bubbles and Crashes (Blanchard-Watson)

Martingale hypothesis ("no free lunch"):

$$\text{for all} \quad t' > t \qquad \mathrm{E}_t[p(t')] = p(t)$$

If crashes are depletions of bubbles:

$$dp = \mu(t)\, p(t)\, dt - \kappa[p(t) - p_1]dj$$

Martingale gives

$$\mu(t)p(t) = \kappa[p(t) - p_1]h(t) \ ,$$

i.e., if crash hazard rate $h(t)$ increases, so must the return (bounded rationality)

A. Johansen, D. Sornette and O. Ledoit
Predicting Financial Crashes using discrete scale invariance, Journal of Risk, vol. 1, number 4, 5-32 (1999)

A. Johansen, O. Ledoit and D. Sornette, Crashes as critical points, International Journal of Theoretical and Applied Finance Vol. 3, No. 2 219-255 (2000)

Bubble with stochastic finite-time singularity

$$\frac{dB(t)}{B(t)} = \mu dt + \sigma dW_t - \kappa dj$$

$$\mu(B)B = \frac{m}{2B}[B\sigma(B)]^2 + \mu_0[B(t)/B_0]^m$$
$$\sigma(B)B = \sigma_0[B(t)/B_0]^m ,$$

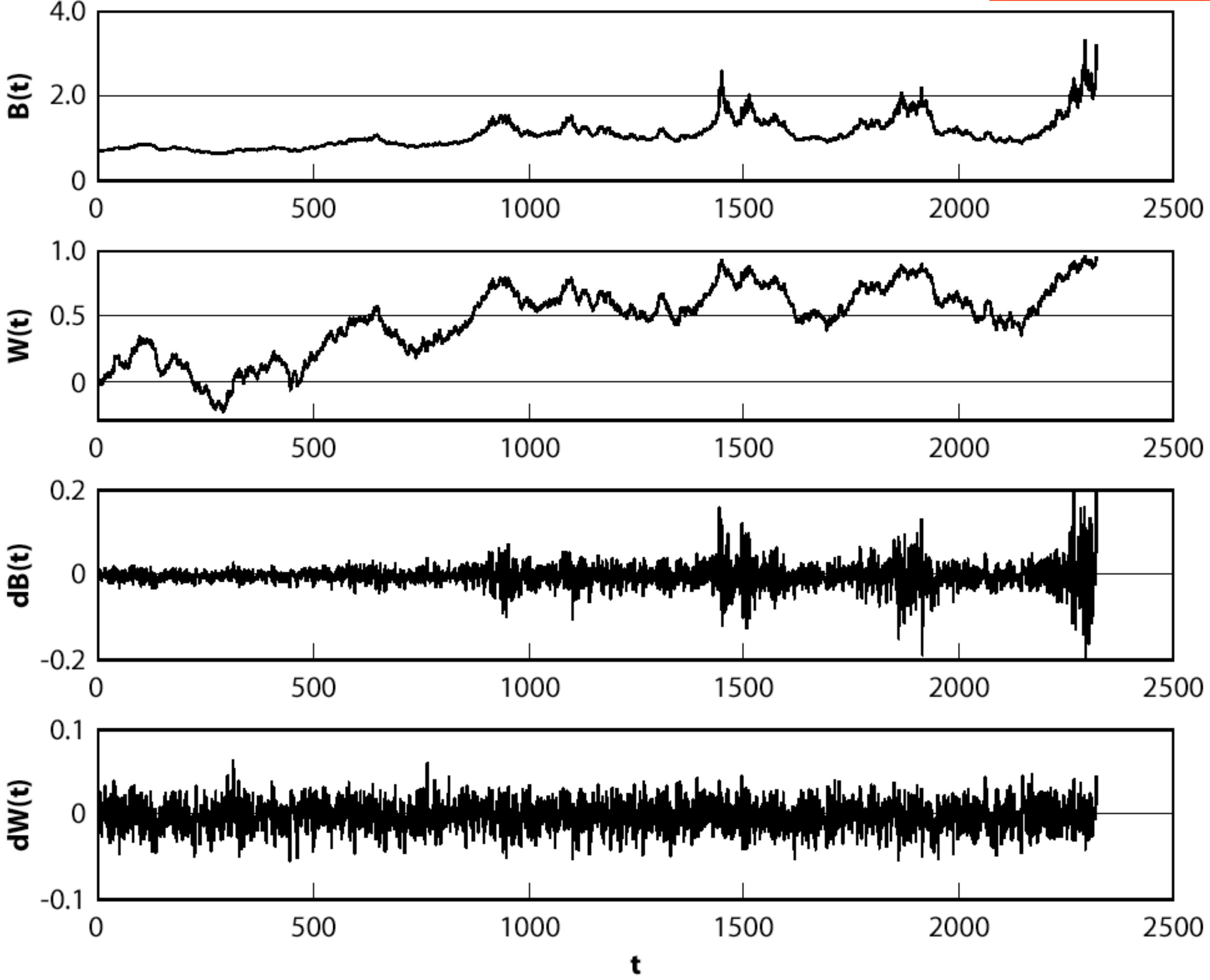
$$\frac{dB}{dt} = (a\mu_0 + b\eta)\ B^m - \kappa B dj \qquad h(t) = \frac{\mu(B(t))}{\langle\kappa\rangle}$$

$$B(t) = \alpha^\alpha \frac{1}{\left(\mu_0[t_c - t] - \frac{\sigma_0}{B_0^m} W(t)\right)^\alpha} , \quad \text{where } \alpha \equiv \frac{1}{m-1}$$

Stochastic finite-time singularity

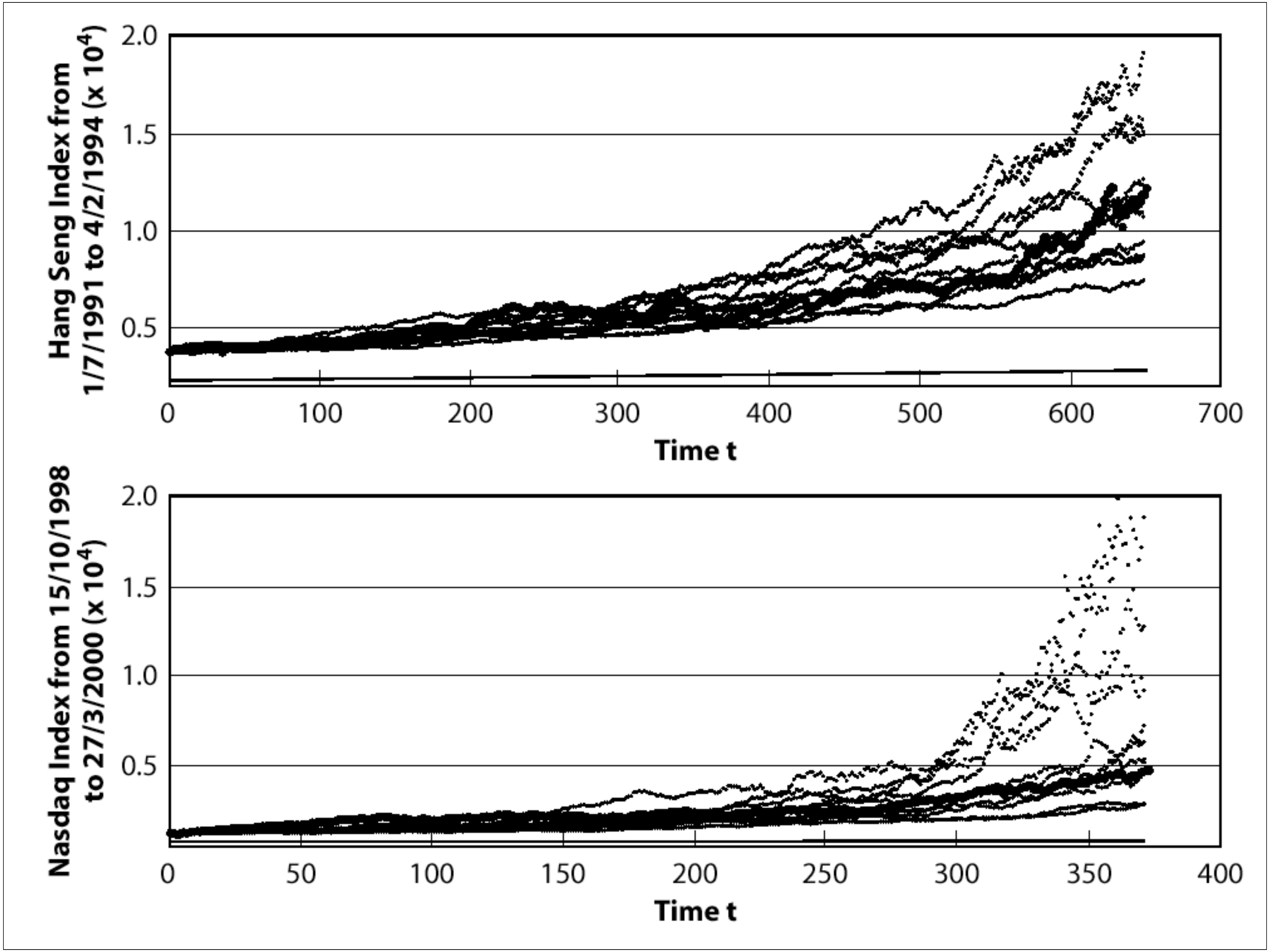
Nonlinear Super-Exponential Rational Model of Speculative Financial Bubbles

$$B(t) = \alpha^{\alpha} \frac{1}{(\mu_0[t_c - t] - (\sigma_0/B_0^m)W(t))^{\alpha}}$$



The price drives the crash hazard rate.

D. Sornette and J.V. Andersen
A Nonlinear Super-Exponential Rational Model of Speculative Financial Bubbles,
Int. J. Mod. Phys. C 13 (2), 171-188 (2002)



Hang Seng Index from 1/7/1991 to 4/2/1994 (x 10^4)
2.0
1.5
1.0
0.5
0
100
200
300
400
500
600
700
Time t
Nasdaq Index from 15/10/1998 to 27/3/2000 (x 10^4)
2.0
1.5
1.0
0.5
0
50
100
150
200
250
300
350
400
Time t

$$B(t) = \alpha^{\alpha} \frac{1}{(\mu_0[t_c - t] - (\sigma_0/B_0^m)W(t))^{\alpha}} \quad \text{where } \alpha \equiv 1/m - 1$$

Contains two ingredients:

(1) growth faster than exponential

(2) growth of volatility

$$\text{limit } 1/\alpha \rightarrow 0 \ (m \rightarrow 1)$$

$$B_{BS}(t) = \exp(\mu_0 t + \sigma_0 W(t))$$ **Standard Geometric random walk**

Wilks' test of embedded hypotheses

Test of the existence of both ingredients

J.V. Andersen, D. Sornette / Physica A 337 (2004) 565–585

DISCRETE HIERARCHY OF THE AGENT NETWORK

Presentation of three different mechanisms leading to discrete scale invariance, discrete hierarchies and log-periodic signatures

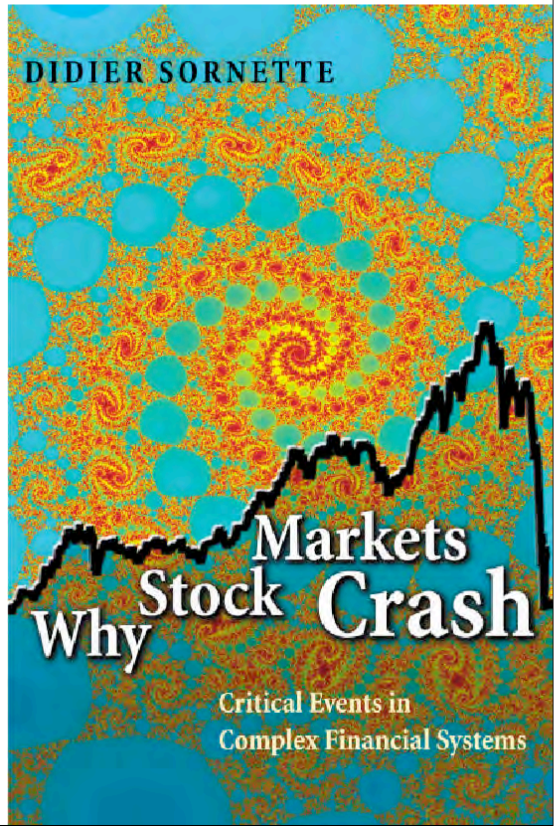
- Co-evolution of brain size and group size
  (Why do we have a big Brain?)

- Interplay between nonlinear positive and negative feedbacks and inertia

- Discrete scale invariance
  Complex fractal dimension
  Log-periodicity

Conclusions

- Discrete social hierarchies may be deeply rooted in the cognitive processing abilities of human brains.
- We suggest that this has observable consequences, such as in financial markets.
- Implications for the optimization of
  - Corporate management
  - Politics
  - Departments and universities



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  Log-periodicity

Oscillatory finite-time singularity

Another mechanism of LPPL (log-periodic power law)

The balance between supply and demand determines the price variation from $p(t)$ to $p(t+\delta t)$ over the time interval δt according to [Farmer, 1998]

$$\ln p(t+\delta t) - \ln p(t) = \frac{1}{L}[\Omega_{\text{value}}(t) + \Omega_{\text{tech}}(t)] \quad (10)$$

Fundamental value strategies

$$\Omega_{\text{value}}(t) = -c \ \ln[p(t)/p_f] \ |\ln[p(t)/p_f]|^{n-1}$$

Technical analysis strategies

$$\Omega_{\text{tech}}(t) = a_1[\ln p(t) - \ln p(t-\delta t)]$$

$$+a_2[\ln p(t) - \ln p(t-\delta t)]|\ln p(t) - \ln p(t-\delta t)|^{m-1}$$

Inertia + NL negative feedback + NL positive feedback

The essential element is the nonlinear (NL) nature (threshold like)
of the fundamental valuation-based and of the technical analysis-based strategies

The theory becomes critical when the "mass" term vanishes, i.e., when $a_1 = L$. Rescaling t and y_1 by α and posing $y_2 = dY_1/dt$ and $\gamma = \alpha^{-(n+1)} c/L(\delta t)^2$ where $\alpha \equiv a_2(\delta t)^{m-2}/L$, we obtain

$$\frac{dy_1}{dt} = y_2 \ ,$$
$$\frac{dy_2}{dt} = \alpha y_2 |y_2|^{m-1} - \gamma y_1 |y_1|^{n-1}$$

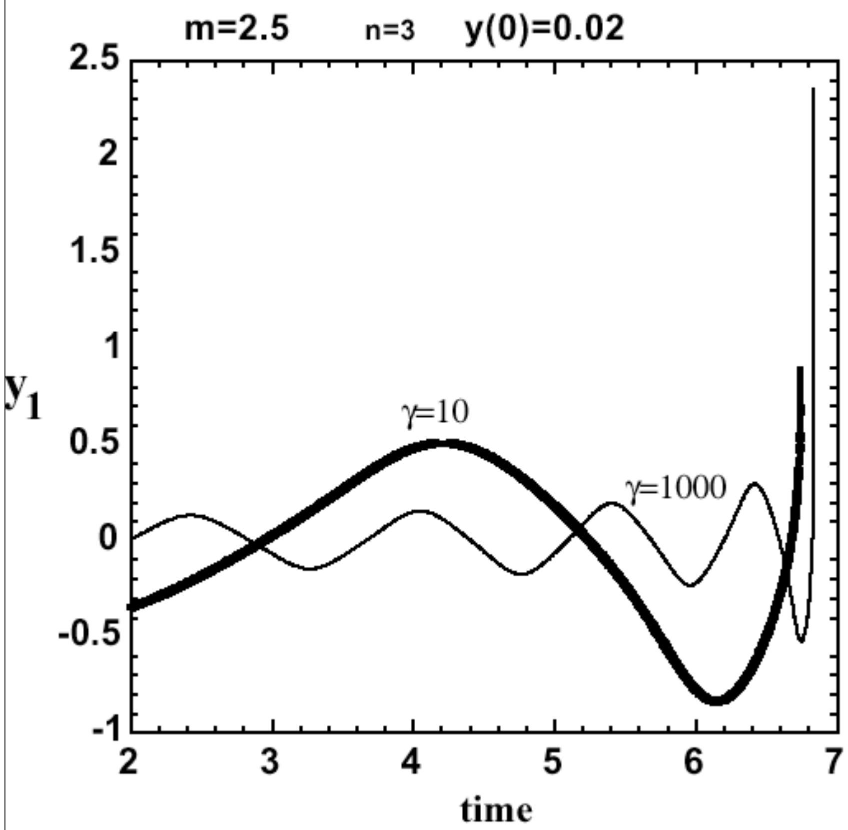
or

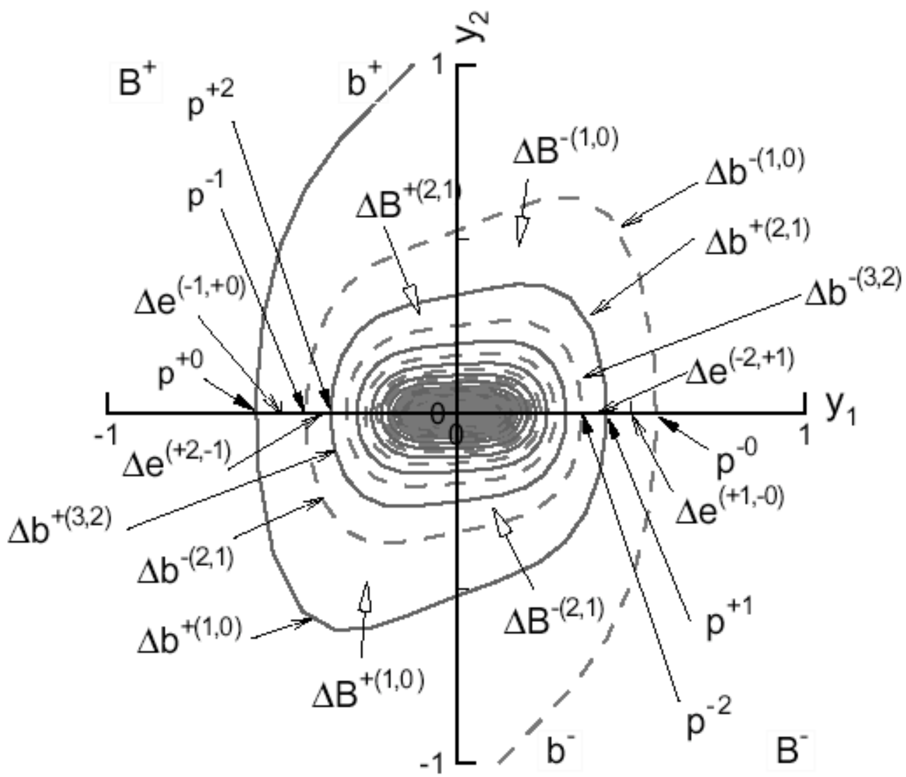
$$\frac{d^2 y_1}{dt^2} = -\gamma y_1 |y_1|^{n-1} + \alpha \frac{dy_1}{dt} \left|\frac{dy_1}{dt}\right|^{m-1}$$

Oscillatory finite-time singularity

-Non-linear fundamental value strategies
-Non-linear technical analysis strategies
-Inertia

K. Ide and D. Sornette
Oscillatory Finite-Time Singularities in Finance, Population and Rupture,
Physica A 307 (1-2), 63-106 (2002)





DISCRETE HIERARCHY OF THE AGENT NETWORK

Presentation of three different mechanisms leading to discrete scale invariance, discrete hierarchies and log-periodic signatures

- Co-evolution of brain size and group size
  (Why do we have a big Brain?)

- Interplay between nonlinear positive and negative feedbacks and inertia

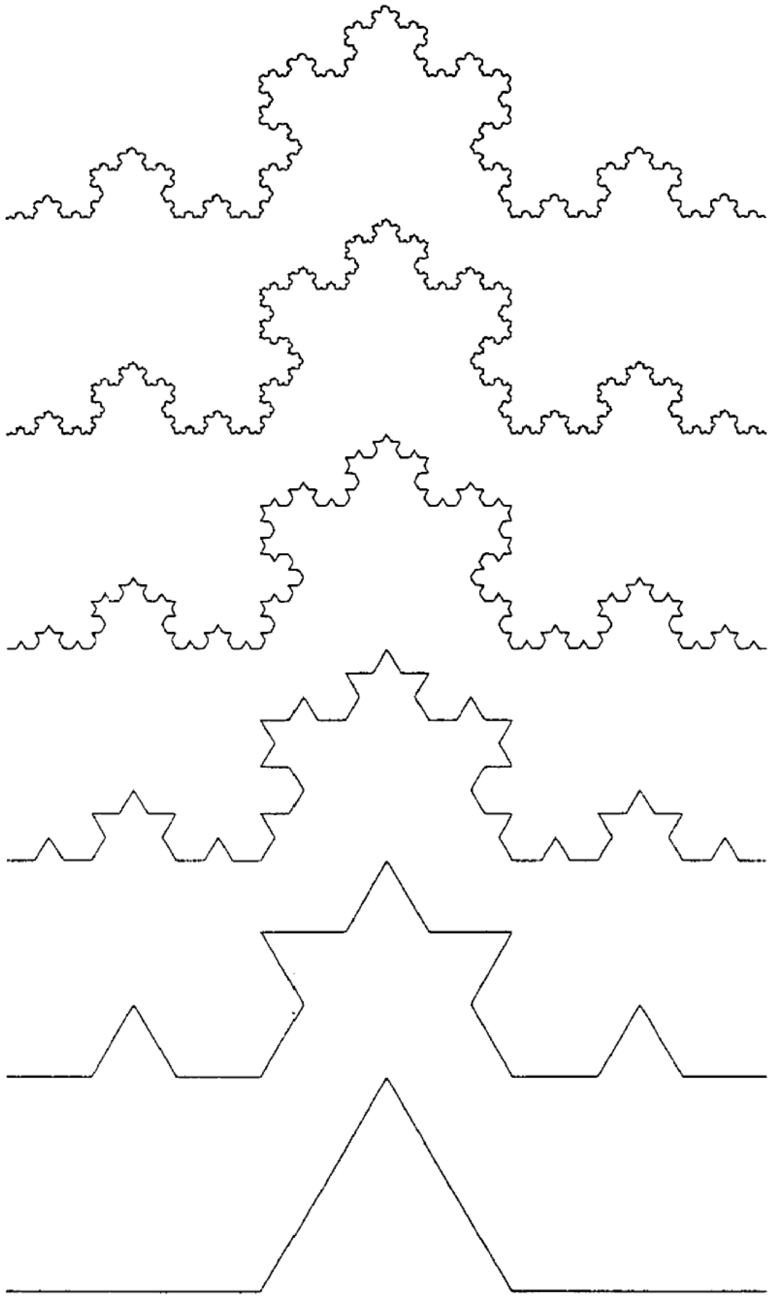
- Discrete scale invariance
  Complex fractal dimension
  Log-periodicity

FRACTALS

1) d ∈ N Euclid (ca. 325-270 BC)

2) d ∈ R Mandelbrot (1960-1980)
(Weierstrass, Hausdorff, Holder, …)

3) d ∈ C

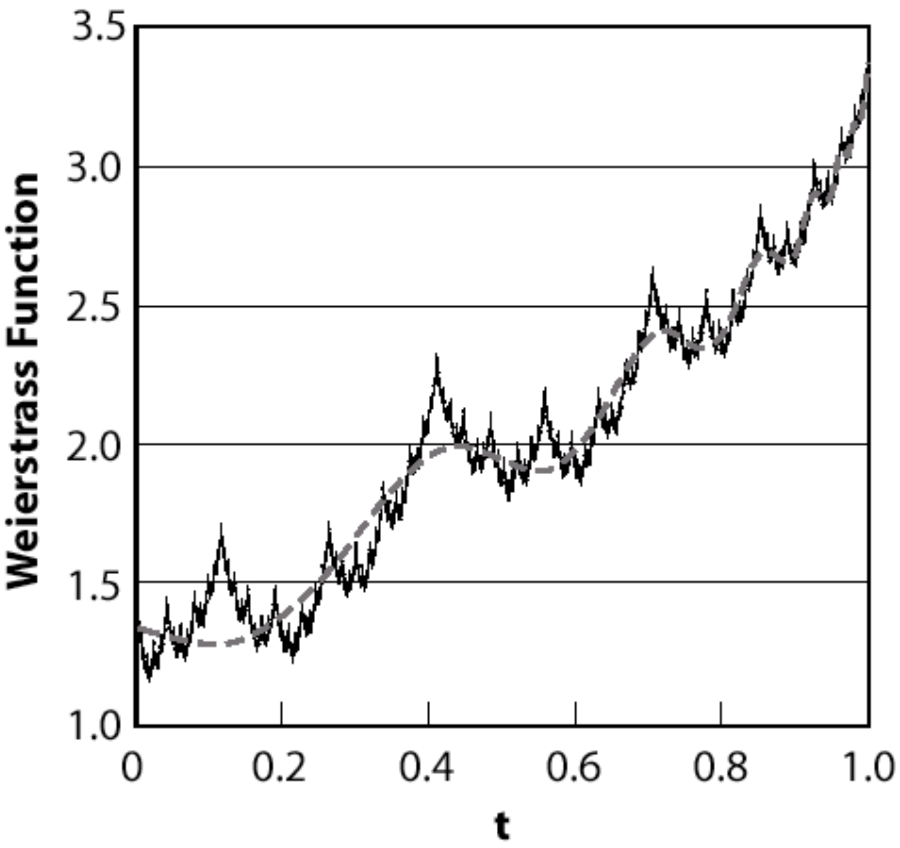


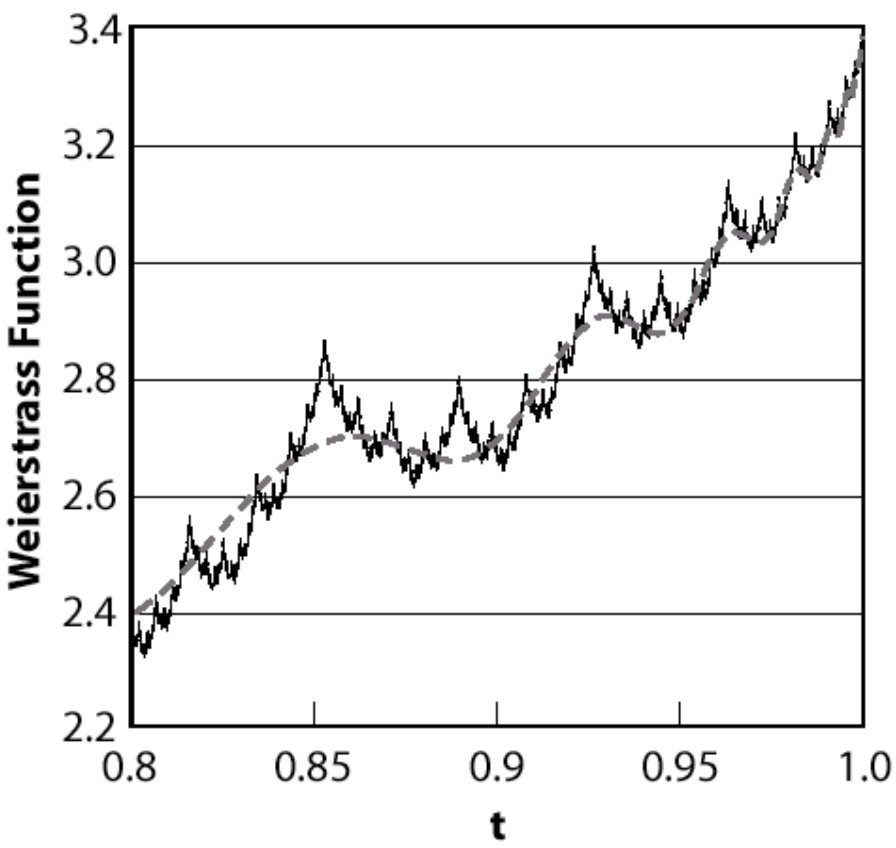
Discrete scale invariance
Complex fractal dimension
Log-periodicity

Prefered scaling ratio is 3

$$D(n) = \ln 4/\ln 3 + i\, 2\pi n/\ln 3$$

Fractal function
(Weierstrass)



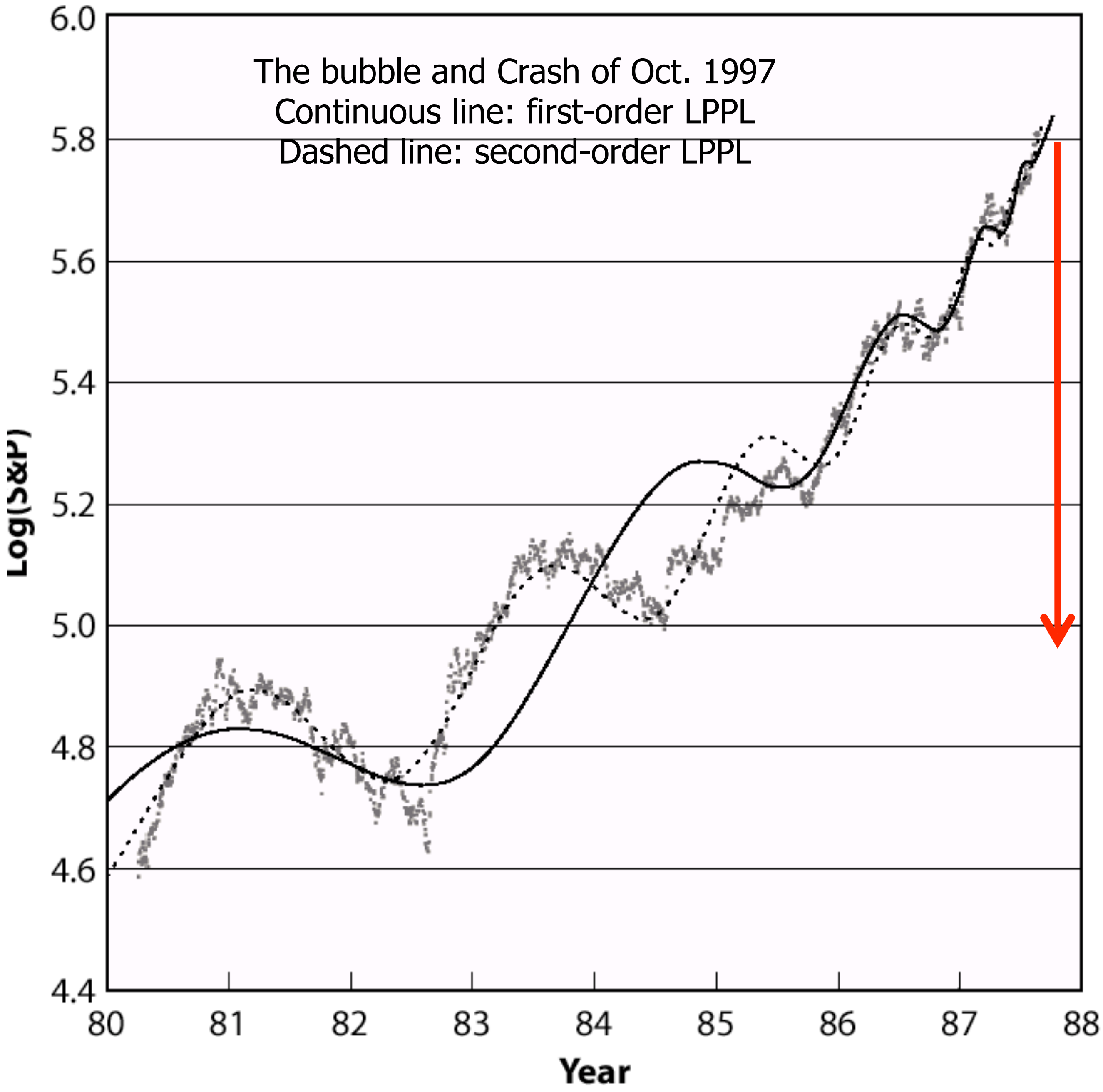


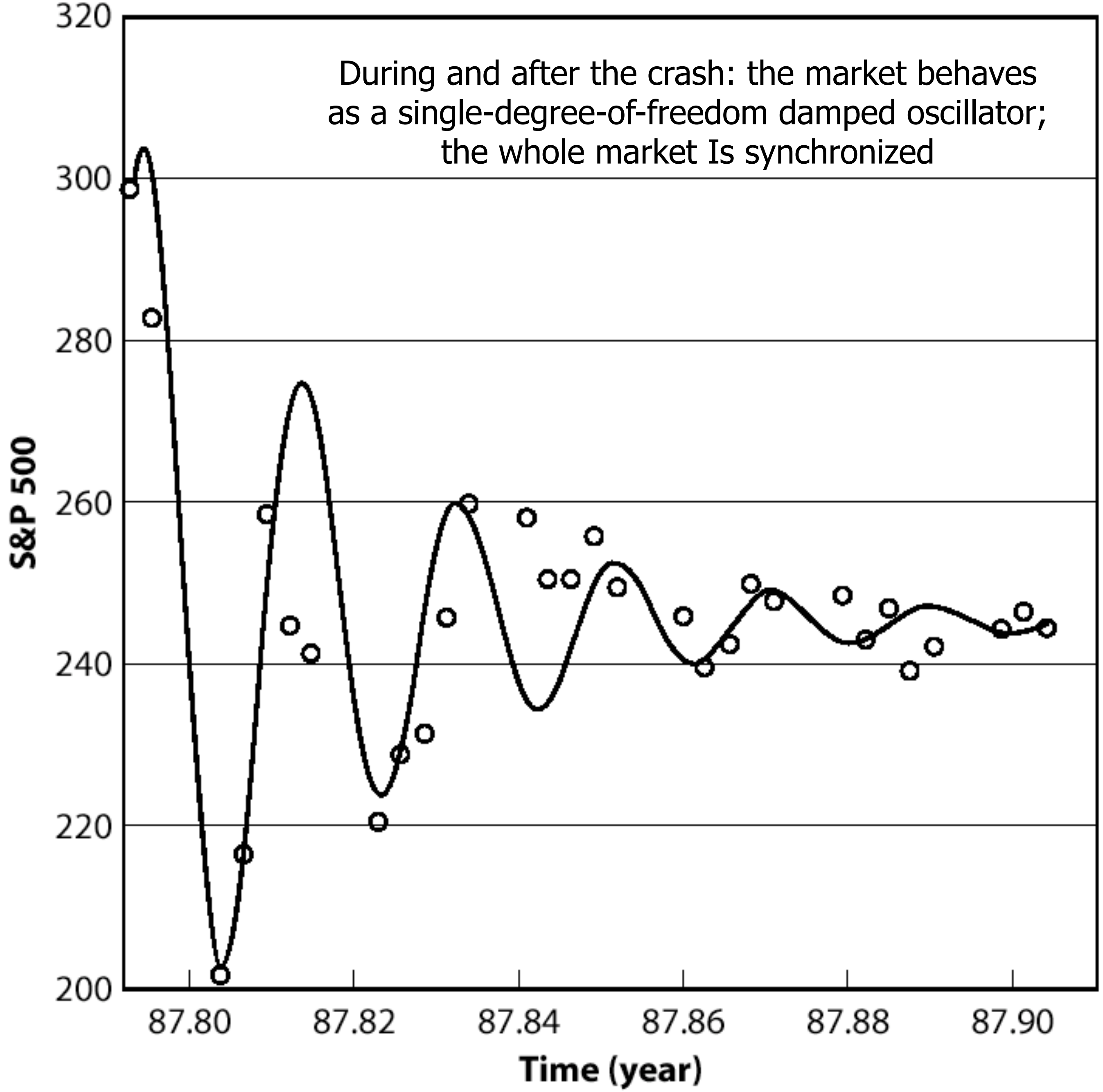
Positive feedbacks + hierarchies

↓

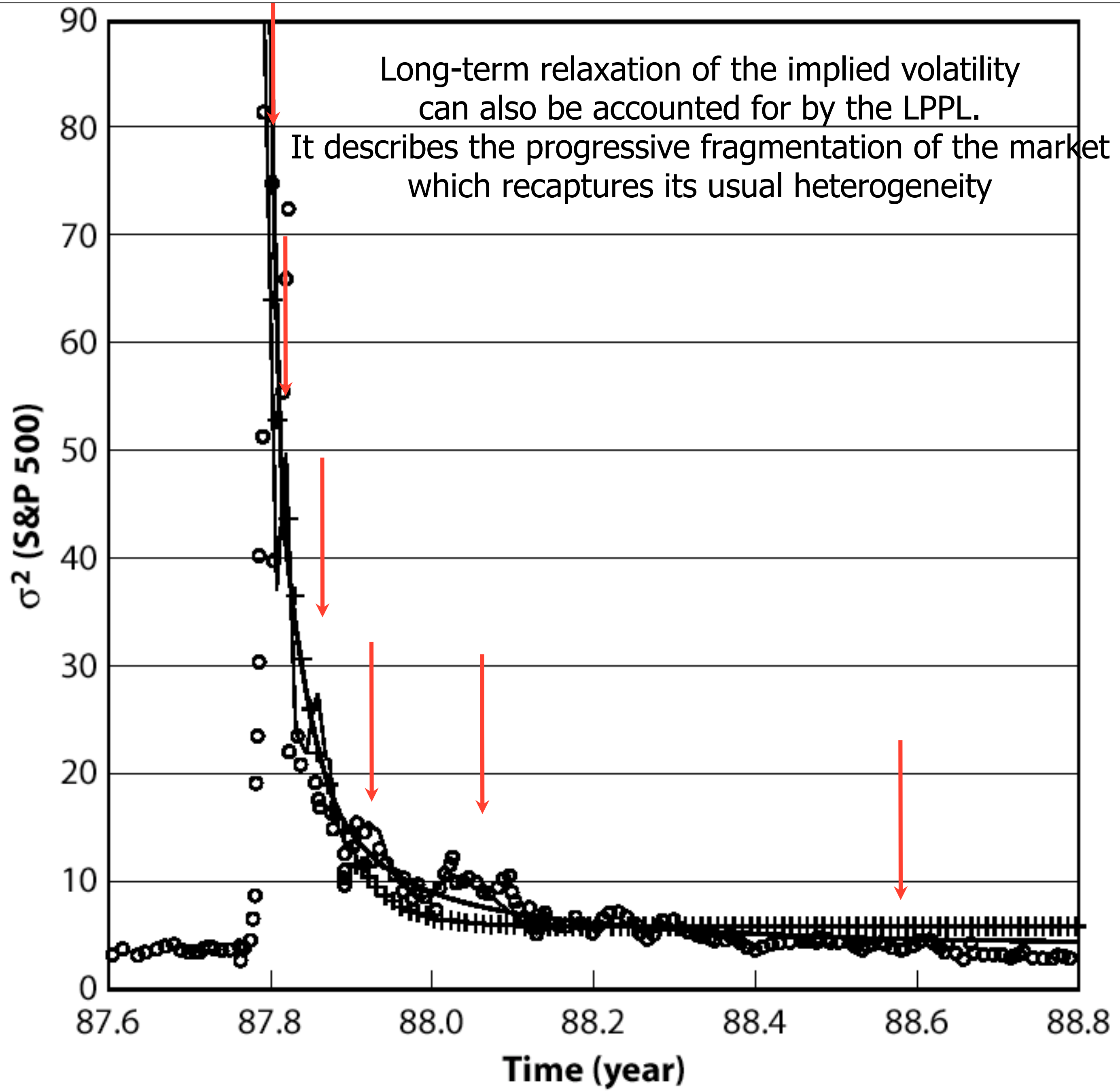
New theory of bubbles and crashes

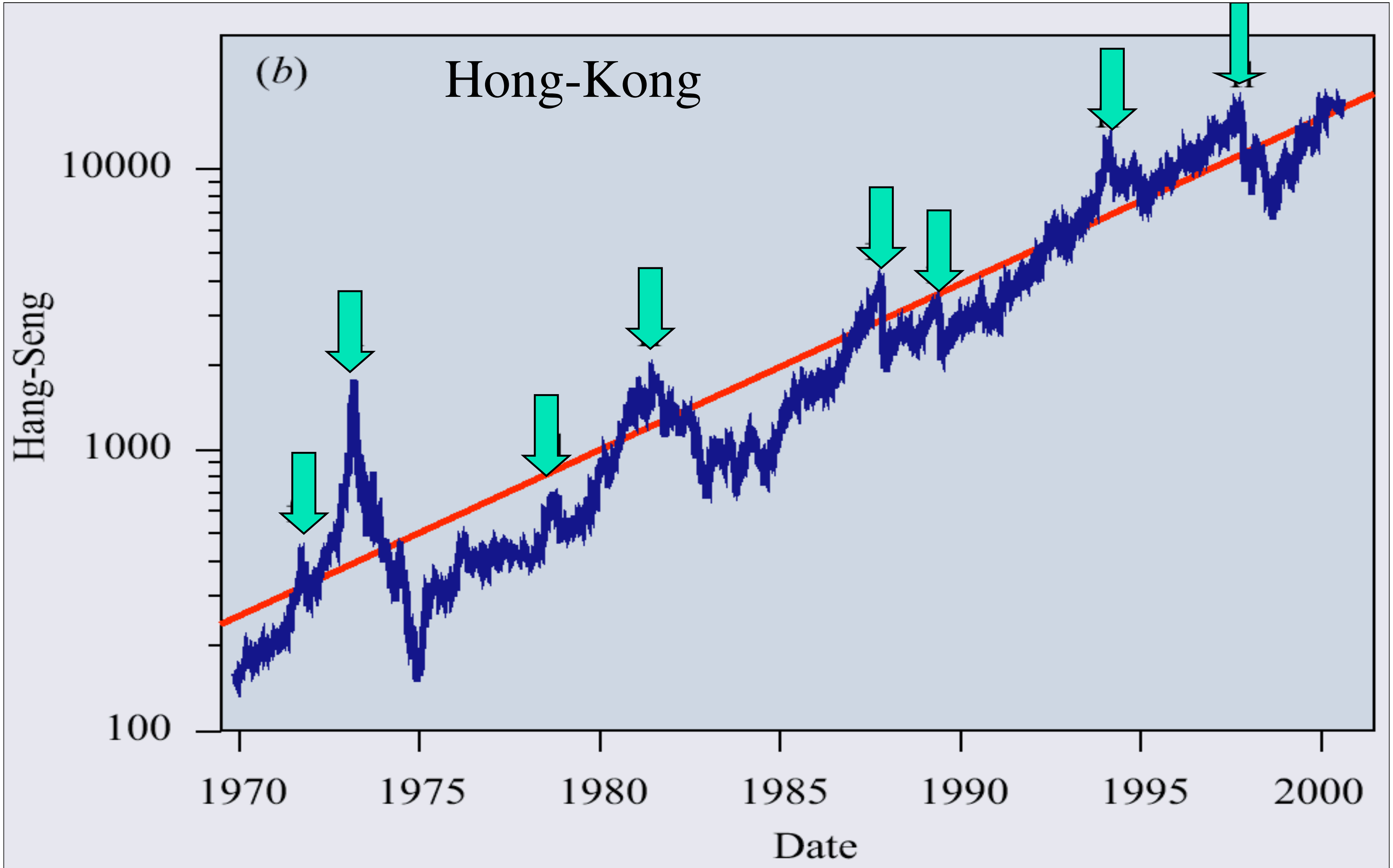
(Log-periodic power law)


The bubble and Crash of Oct. 1997
Continuous line: first-order LPPL
Dashed line: second-order LPPL
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
Log(S&P)
80
81
82
83
84
85
86
87
88
Year

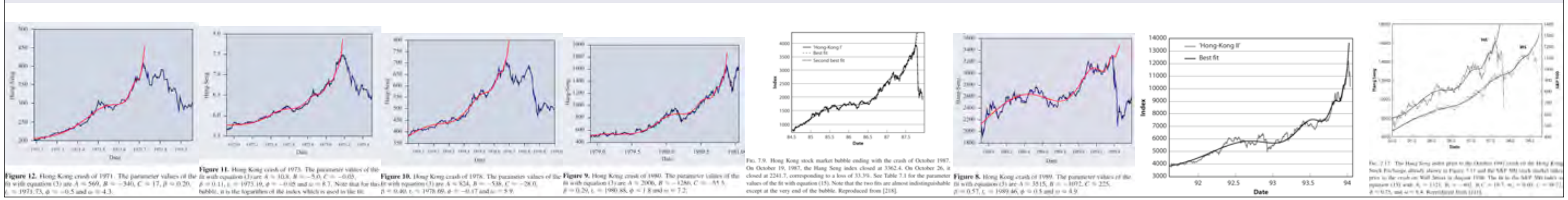


During and after the crash: the market behaves
as a single-degree-of-freedom damped oscillator;
the whole market Is synchronized
320
300
280
260
240
220
200
S&P 500
87.80
87.82
87.84
87.86
87.88
87.90
Time (year)


Long-term relaxation of the implied volatility
can also be accounted for by the LPPL.
It describes the progressive fragmentation of the market
which recaptures its usual heterogeneity
90
80
70
60
50
40
30
20
10
0
87.6
87.8
88.0
88.2
88.4
88.6
88.8
Time (year)
σ2 (S&P 500)



(b)
Hong-Kong
Hang-Seng
10000
1000
100
1970
1975
1980
1985
1990
1995
2000
Date



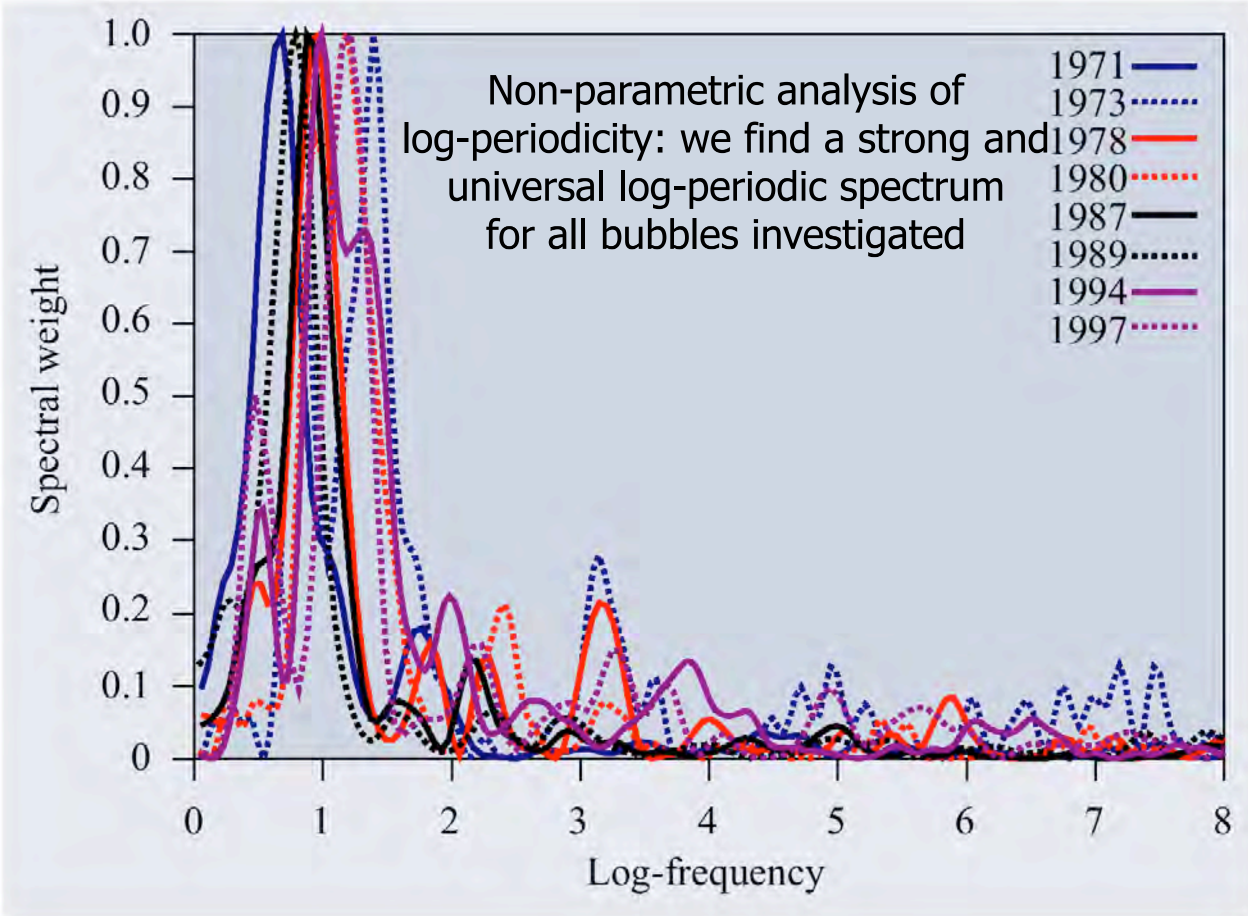


Figure 1. The Lomb periodogram of the log-periodic component of the Hang-Seng price index (Hong Kong) for the eight bubbles followed by crashes observed in figure 13, ending in October 1971, in February 1973, in September 1978, in October 1980, in October 1987, in April 1989, in January 1994 and in October 1997. See Johansen *et al* (1999) for details on how to calculate the Lomb periodogram.

Out-of-sample test over 20 years of the Heng Seng

Alarms were produced in the following nine time intervals containing the date of the last point used in the fit:

(a) 1981.60 to 1981.68. This was followed by a $\approx$ 30% decline.
(b) 1984.36 to 1984.41. This was followed by a $\approx$ 30% decline.
(c) 1985.20 to 1985.30; false alarm.
(d) 1987.66 to 1987.82. This was followed by a $\approx$ 50 % decline.
(e) 1989.32 to 1989.38. This was followed by a $\approx$ 35 % decline.
(f) 1991.54 to 1991.69. This was followed by a $\approx$ 7% single day decline; considered a false alarm, nevertheless.
(g) 1992.37 to 1992.58. This was followed by a $\approx$ 15% decline. This is a marginal case.
(h) 1993.79 to 1993.90. This was followed by a $\approx$ 20% decline. This can also be considered as a marginal case, if we want to be conservative.
(i) 1997.58 to 1997.74. This was followed by $\approx$ 35% decline.

Generalization and application to emergent markets: test of a systematic procedure to detect bubbles

A. Johansen and D. Sornette Bubbles and anti-bubbles in Latin-American, Asian and Western stock markets: An empirical study, International Journal of Theoretical and Applied Finance 4 (6), 853-920 (2001)

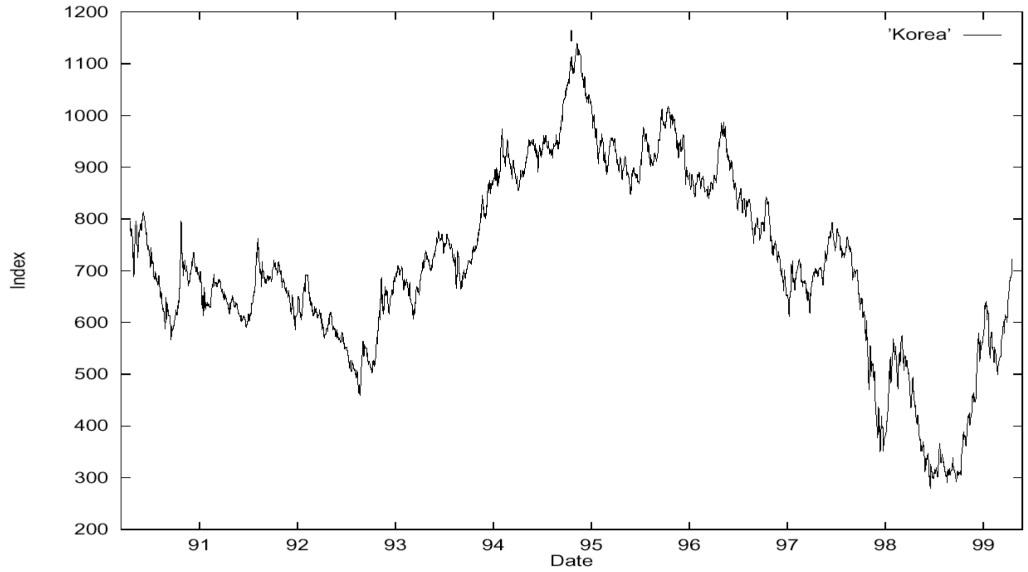


Figure 30: The Korean stock market index as a function of date. 1 bubble with a subsequent very large draw down can be identified. The approximate date is late 94.

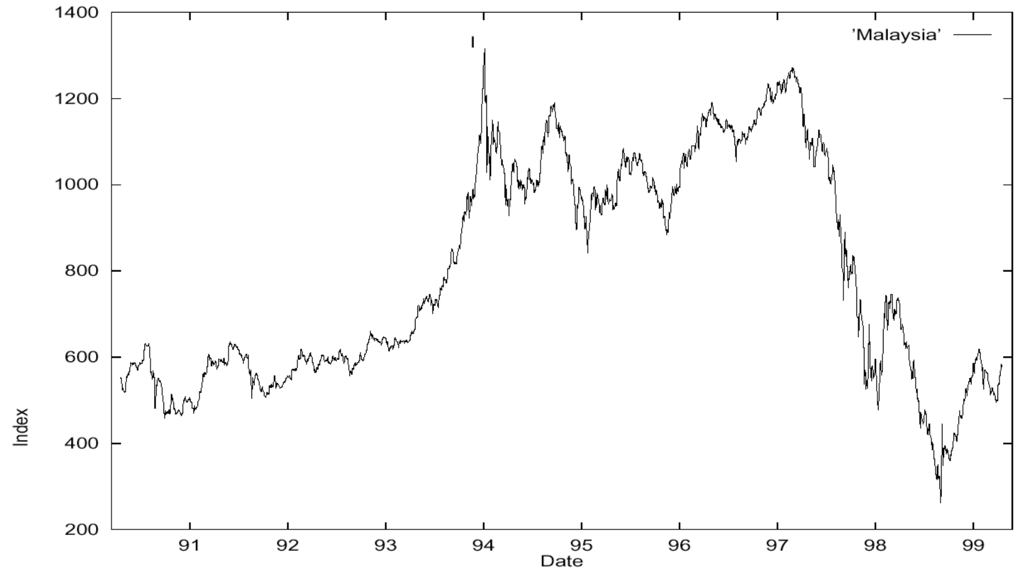


Figure 31: The Malaysian stock market index as a function of date. 1 extended bubble with a subsequent very large draw down can be identified. The approximate date for the draw down is early 94.

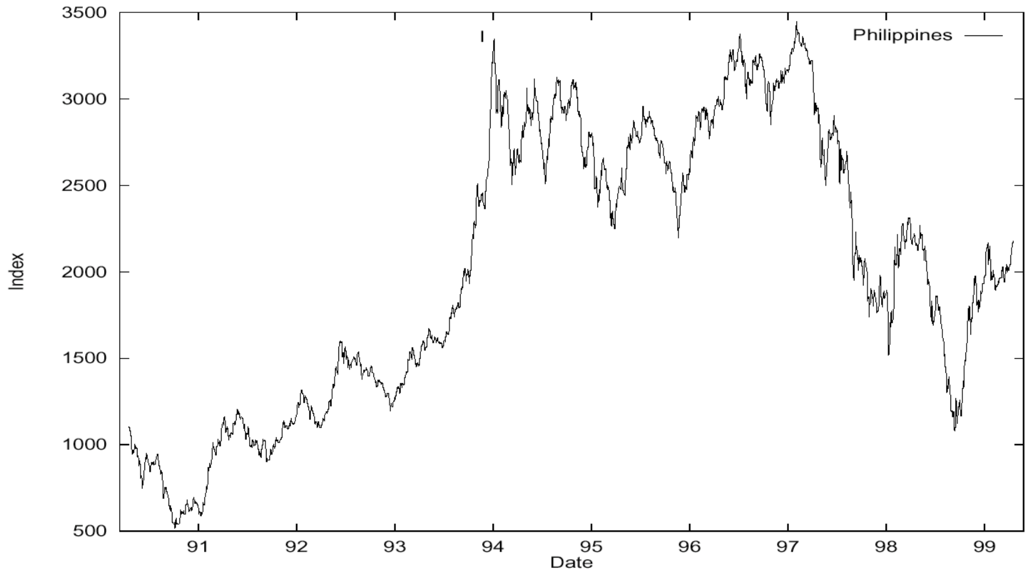


Figure 32: The Philippines stock market index as a function of date. 1 bubble with a subsequent very large draw down can be identified. The approximate date for the draw down is early 94.

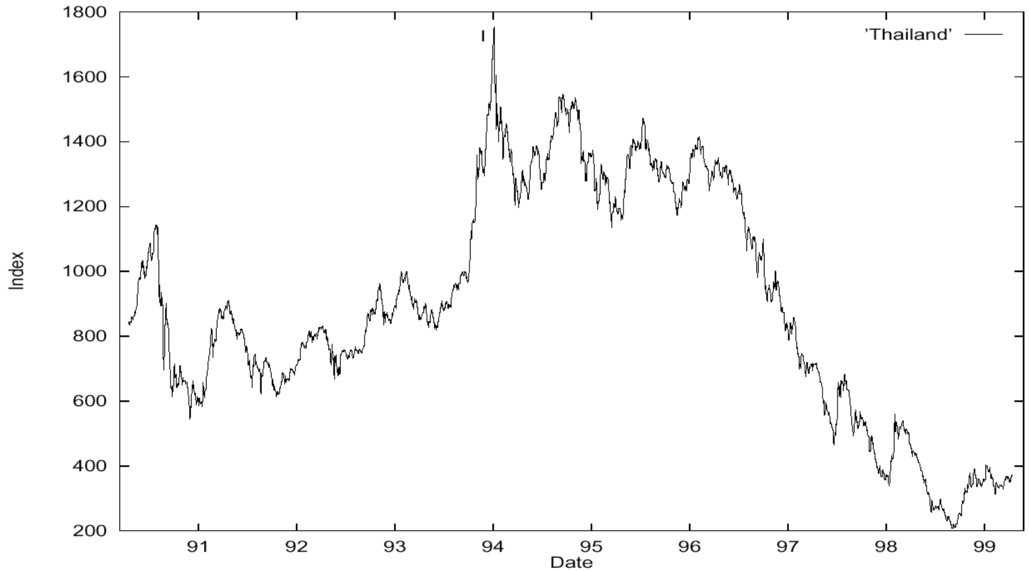


Figure 33: The Thai stock market index as a function of date. 1 bubble with a subsequent very large draw down can be identified. The approximate date for the draw down is early 94.

We show the parametric LPPL fits (left panels) and the non-parametric log-periodic spectral analyses (right panels)

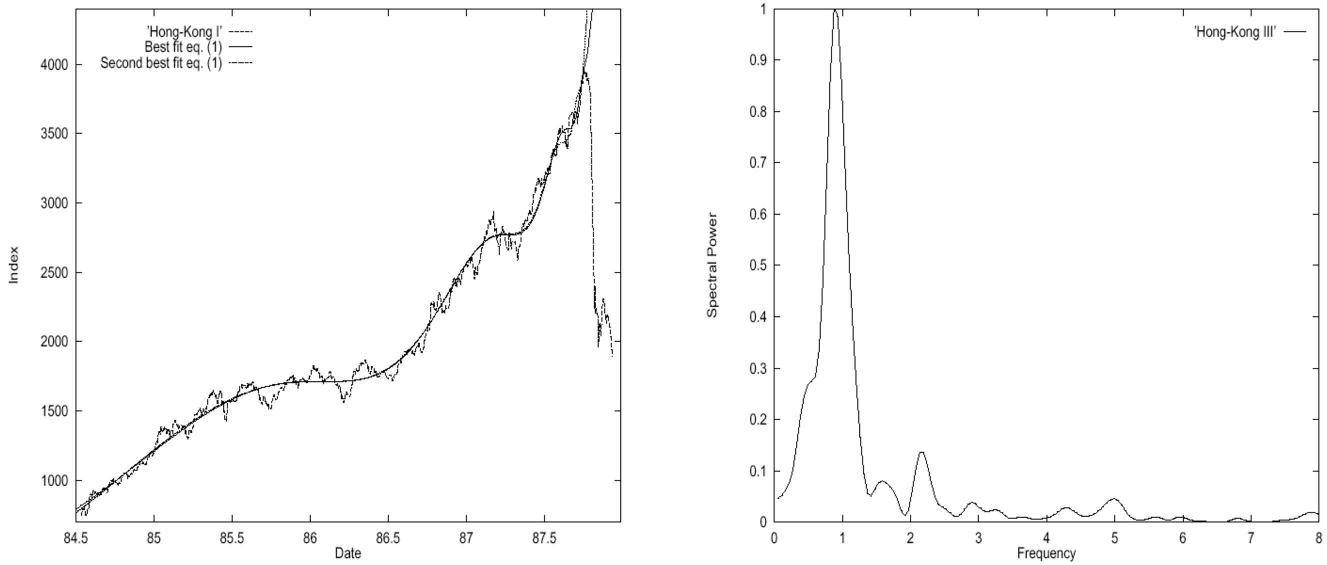


Figure 34: Hong Kong stock market bubble ending with the crash of Oct. 87. See table 5 for the parameter values of the fit with equation (1). Only the best fit is used in the Lomb periodogram.

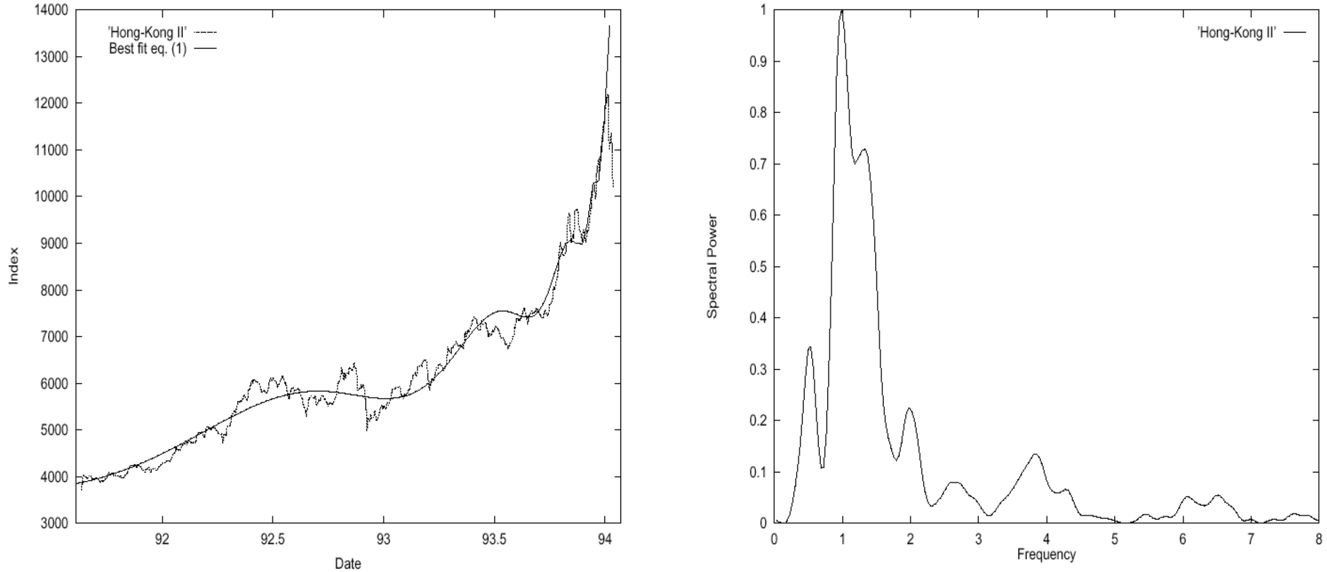


Figure 35: Hong Kong stock market bubble ending with the crash of Jan. 94. See table 5 for the parameter values of the fit with equation (1).

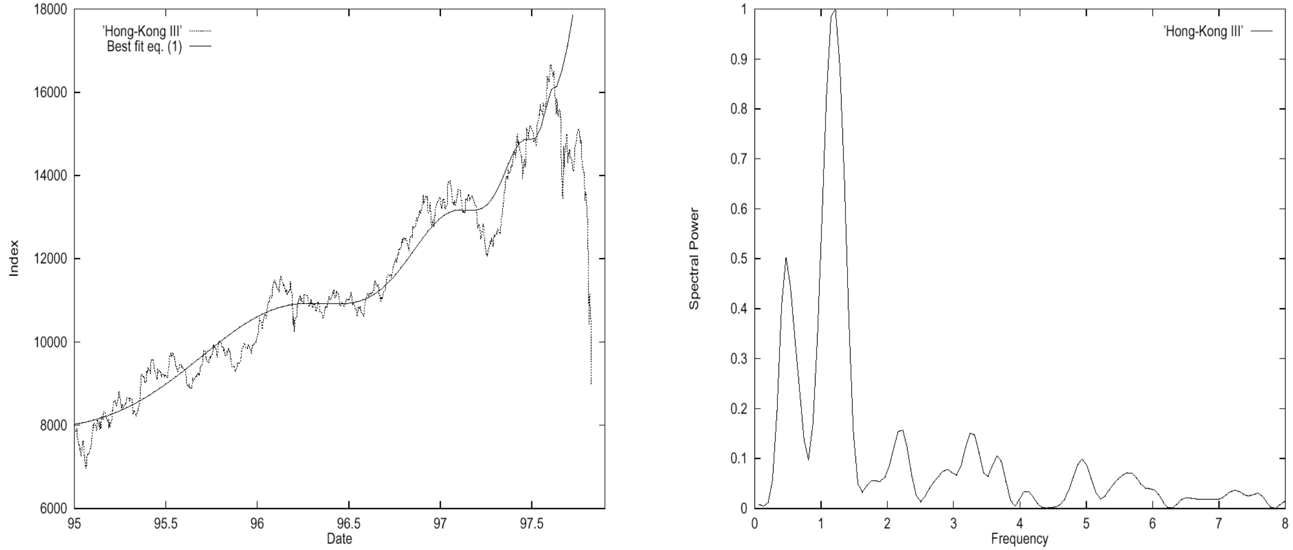


Figure 36: Hong Kong stock market bubble ending with the crash of Oct. 97. See table 5 for the parameter values of the fit with equation (1).

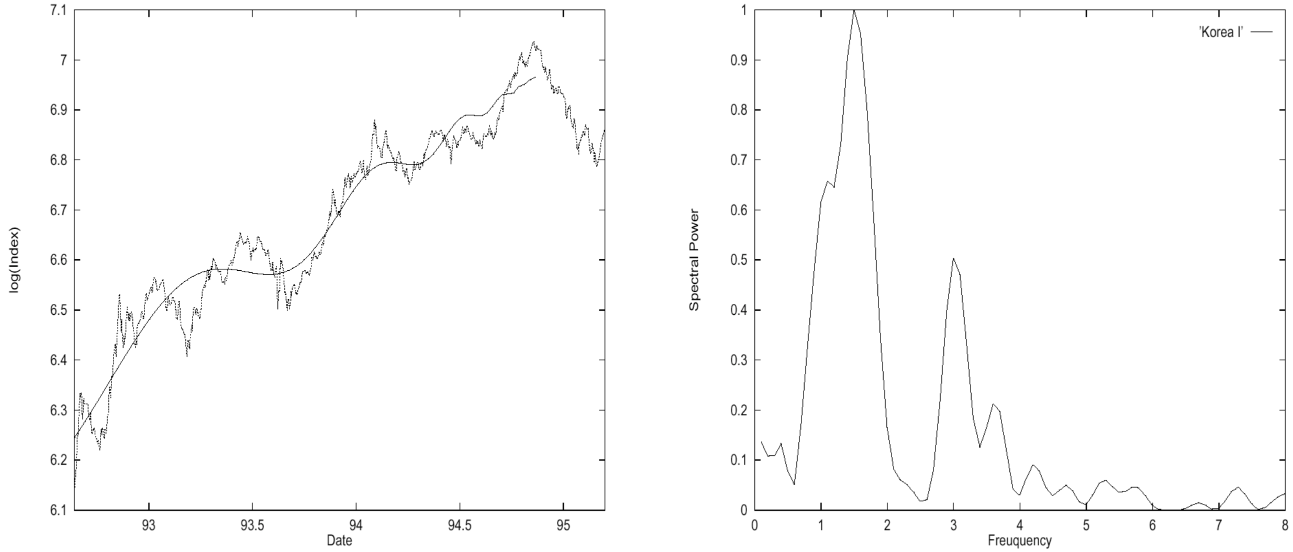


Figure 37: Korean stock market bubble ending in 1994. See table 5 for the parameter values of the fit with equation (1). The data set of the residue had to be truncated in order to eliminate a severe drift in the last part of the data close to t_c.

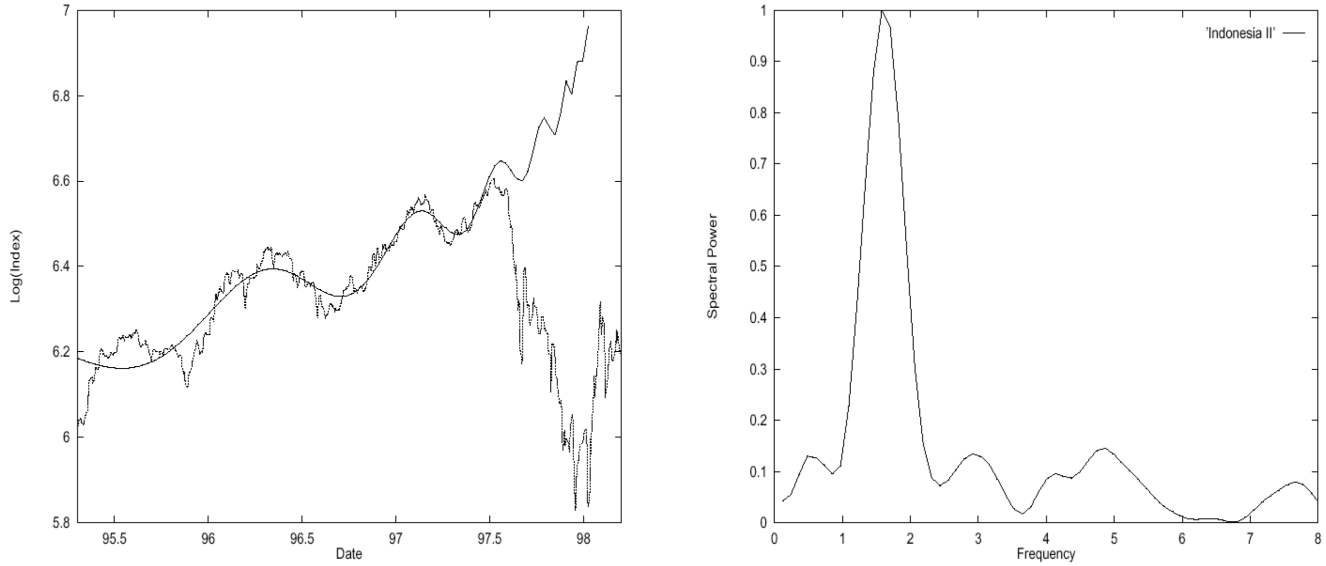


Figure 38: Indonesian stock market bubble ending in 1997. See table 5 for the parameter values of the fit with equation (1).

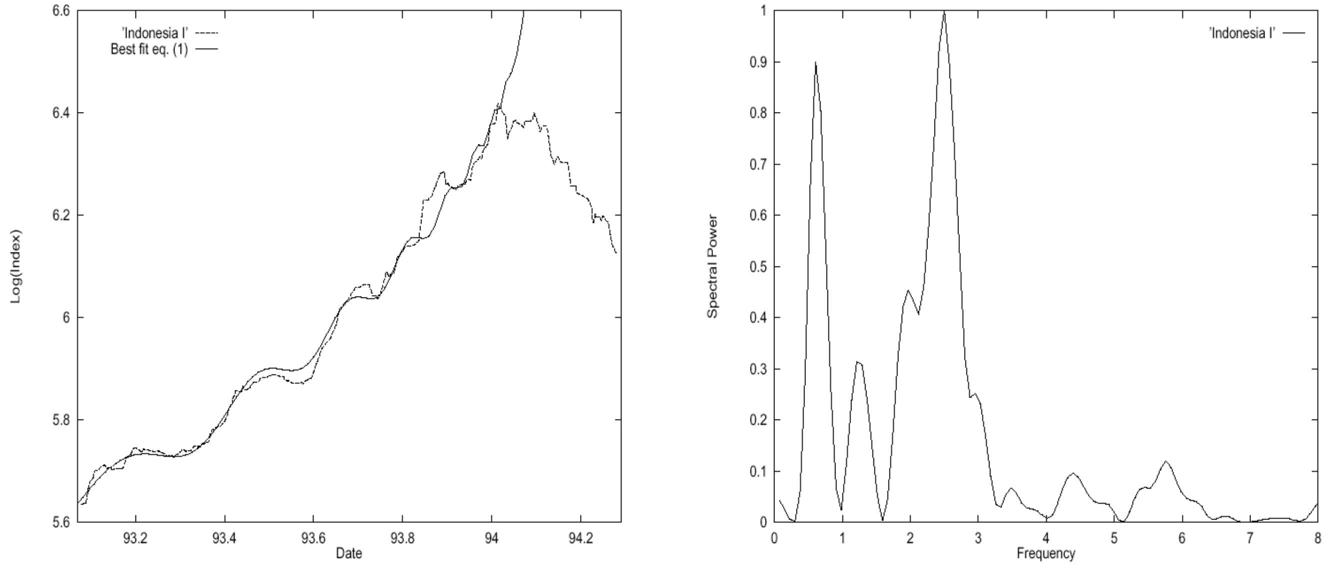


Figure 39: Indonesian stock market bubble ending in Jan. 1994. See table 5 for the parameter values of the fit with equation (1).

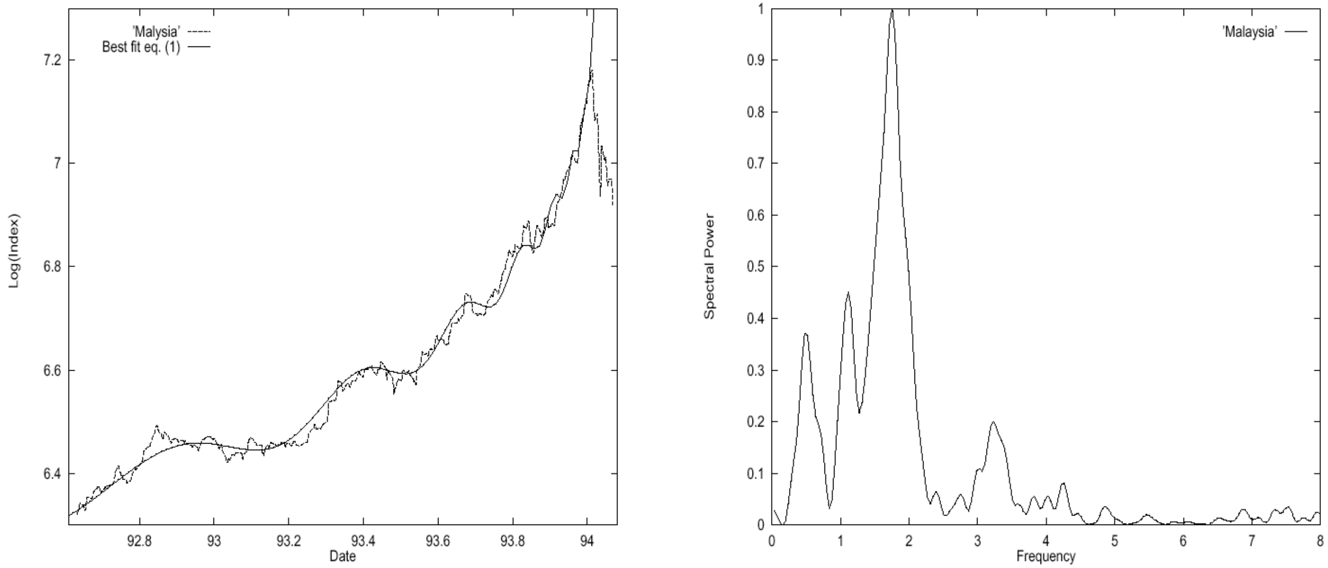


Figure 40: Malaysian stock market bubble ending with the crash of Jan. 94. See table 5 for the parameter values of the fit with equation (1).

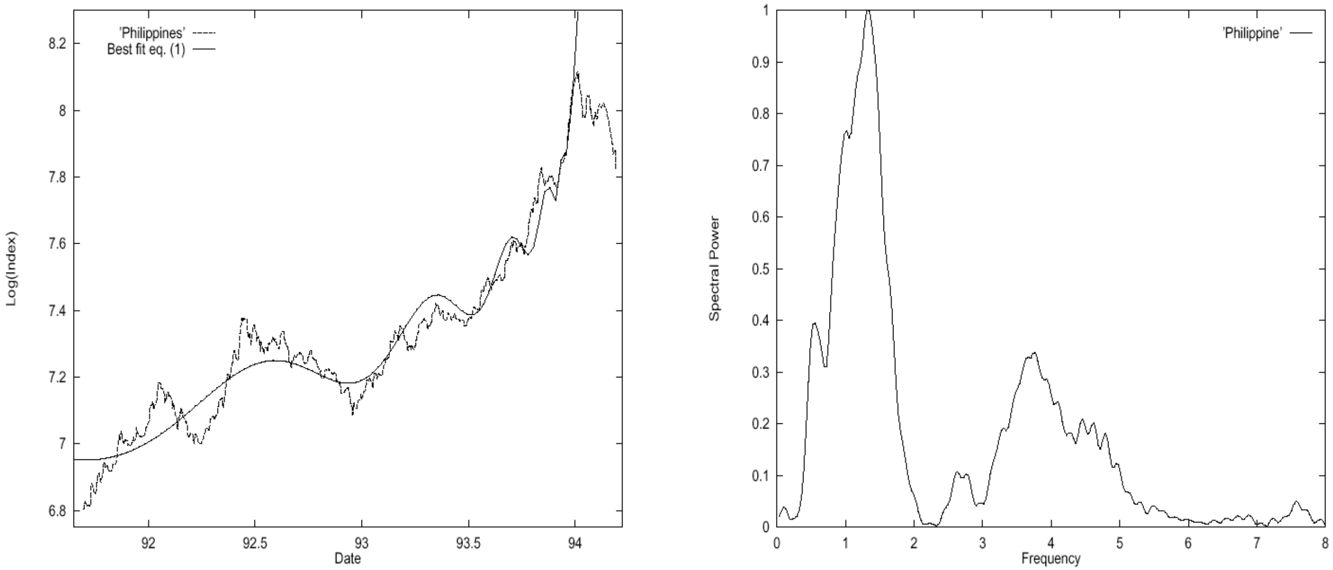


Figure 41: Philippine stock market bubble ending in Jan. 1994. See table 5 for the parameter values of the fit with equation (1).

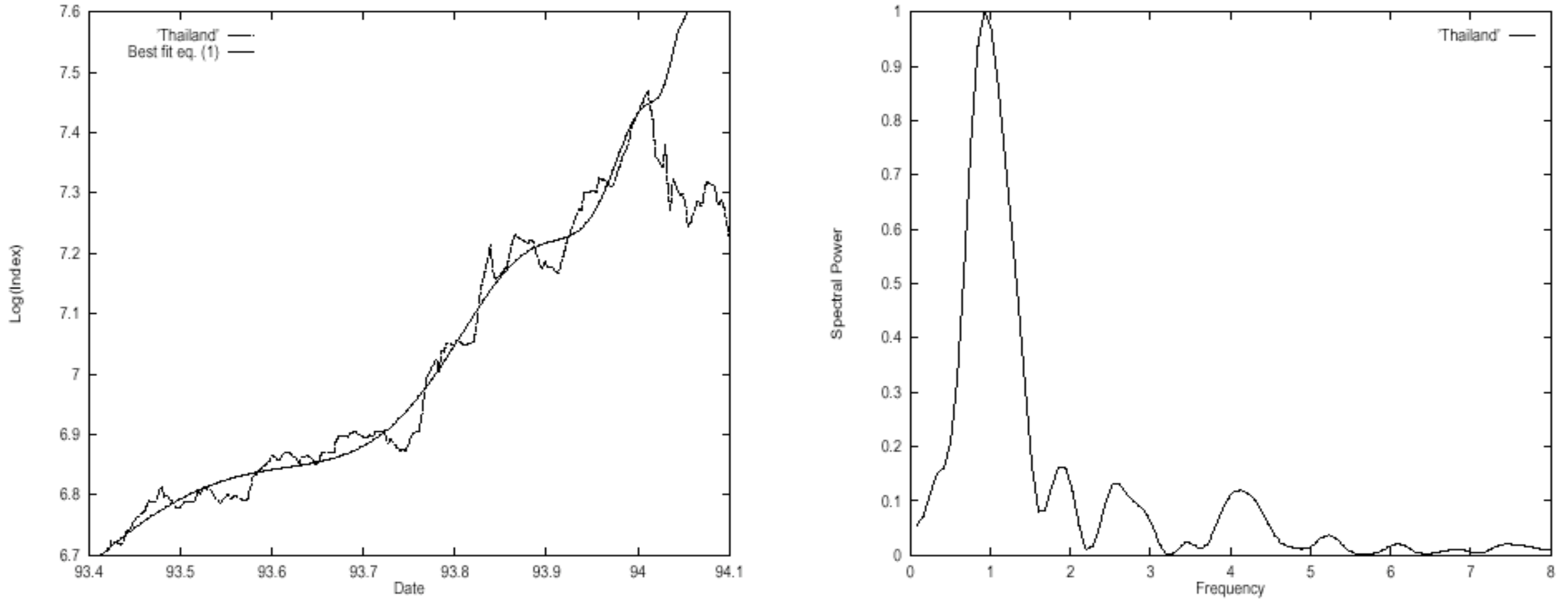


Figure 42: Thai stock market bubble ending with the crash of Jan. 94. See table 5 for the parameter values of the fit with equation (1).

$$I(t) = A + B(t_c - t)^z + C(t_c - t)^z \cos(\omega \log(t_c - t) - \phi)$$

Parameters of the log-periodic fits; z= critical exponent; omega=log-periodic frequency

Stock market	A	B	C	z	t_c	ω	ϕ
Hong-Kong I	5523; 4533	−3247; −2304	171; −174	0.29; 0.39	87.84; 87.78	5.6; 5.2	−1.6; 1.1
Hong-Kong II	21121	−15113	−429	0.12	94.02	6.3	−0.6
Hong-Kong III	20077	−8241	−397	0.34	97.74	7.5	0.8
Indonesia I	6.76	−1.11	0.039	0.44	94.09	15.6	−1.3
Indonesia II	7.38	−0.92	−0.06	0.23	98.05	10.08	5.8
Korea I	6.97	−0.28	−0.05	1.05	94.87	8.15	1.1
Malaysia I	7.61	−1.16	0.038	0.24	94.02	10.9	1.4
Philippines I	9.00	−1.74	−0.078	0.16	94.02	8.2	0.2
Thailand I	7.81	−1.41	−0.086	0.48	94.07	6.1	−0.2

$$I(t) = A + B(t_c - t)^z + C(t_c - t)^z \cos(\omega \log(t_c - t) - \phi)$$

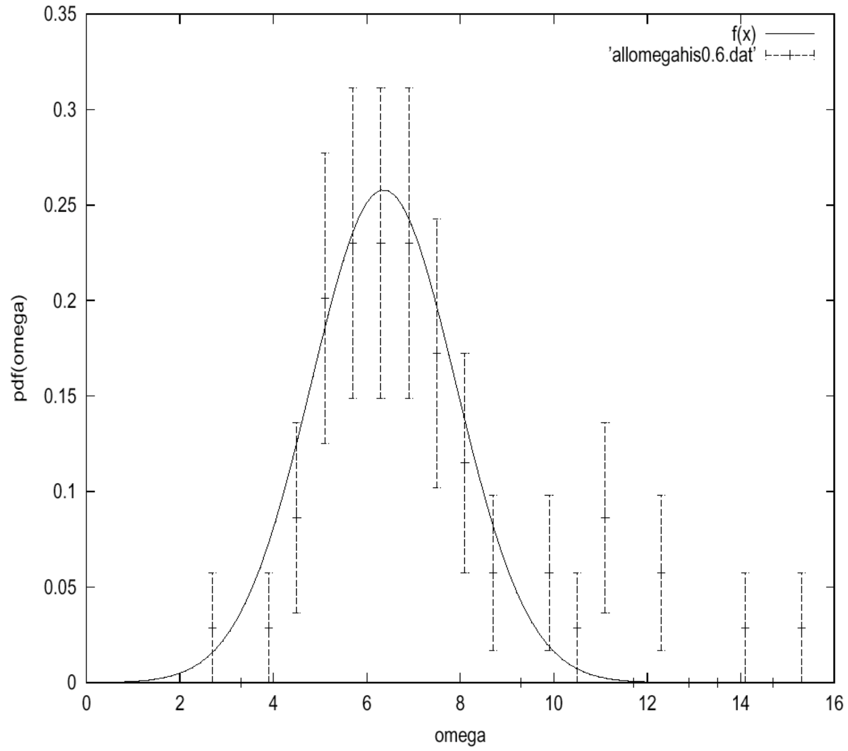


Figure 5: Empirical distribution of the log-periodic angular frequency ω in eq. (1) for over thirty case studies. The fit with a Gaussian distribution gives $\omega \approx 6.36 \pm 1.55$. The smaller peak centered on $11 - 12$ suggests the existence of a second discernable harmonics at $2\omega \approx 12$.

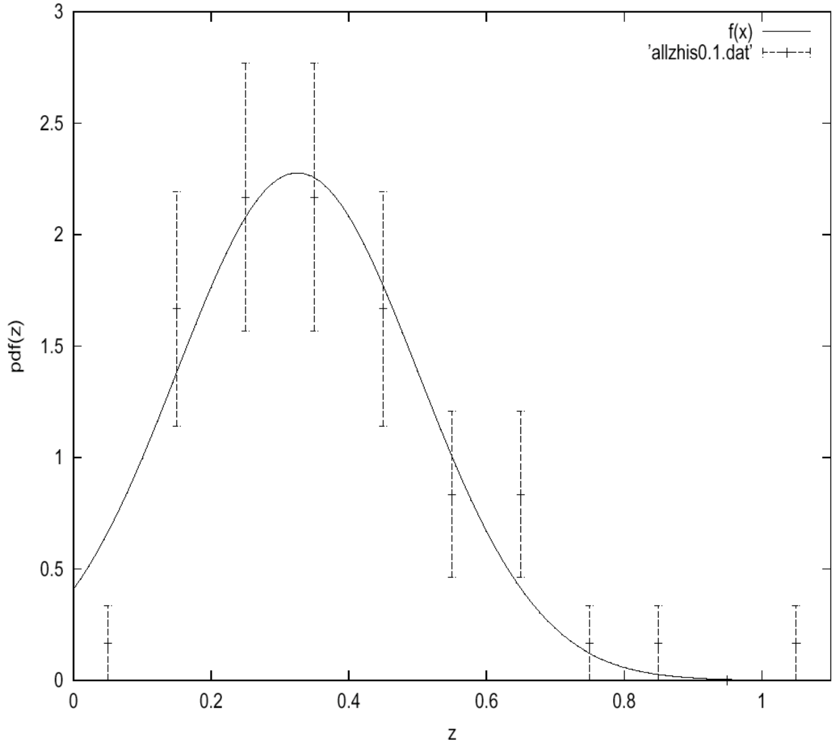


Figure 6: Empirical distribution of the exponent z of the power law in eq. (1) for over thirty case studies. The fit with a Gaussian distribution gives $\beta \approx 0.33 \pm 0.18$.

Demonstration of universal values of z and omega across many different bubbles at different epochs and different markets

A. Johansen and D. Sornette, Shocks, Crashes and Bubbles in Financial Markets, Brussels Economic Review (Cahiers economiques de Bruxelles), 49 (3/4), (2006)

Endogenous vs exogenous crashes

1. Systematic qualification of outliers/kings in pdfs of drawdowns

2. Existence or absence of a "critical" behavior by LPPL patterns found systematically in the price trajectories preceding this outliers

Results: In worldwide stock markets + currencies + bonds

- **21 endogenous crashes**
- **10 exogenous crashes**

A. Johansen and D. Sornette,
Endogenous versus Exogenous Crashes in Financial Markets,
in press in ``Contemporary Issues in International Finance''
(Nova Science Publishers, 2004)
(http://arXiv.org/abs/cond-mat/0210509)

What are bubbles?
How do detect them?
How to predict them?

Academic Literature:
No consensus on what is a bubble...

The Fed: A. Greenspan (Aug., 30, 2002):
"We, at the Federal Reserve…recognized that, despite our suspicions, it was very difficult to definitively identify a bubble until after the fact, that is, when its bursting confirmed its existence… Moreover, it was far from obvious that bubbles, even if identified early, could be preempted short of the Central Bank inducing a substantial contraction in economic activity, the very outcome we would be seeking to avoid."

What are bubbles?
How do detect them?
How to predict them?

Our proposition to the Academic Literature:
“Super exponential price acceleration” and “king” effect

Our proposition to the Fed:
Complex system approach with emphasis on
(i) positive and negative feedback interplay
(ii) collective behavior and organization lead to “EMERGENCE”

Towards a methodology to identify crash risks

- ❑ Development of methods to diagnose bubbles
- ❑ Crashes are not predictable
- ❑ Only the end of bubbles can be forecasted
- ❑ 2/3 ends in a crash
- ❑ Multi-time-scales
- ❑ Probability of crashes; alarm index
  - Successful forward predictions: Oct. 1997; Aug. 1998, April 2000
  - False alarms: Oct. 1997

- ❑ Towards an OBSERVATORY OF CRISES

Real-estate

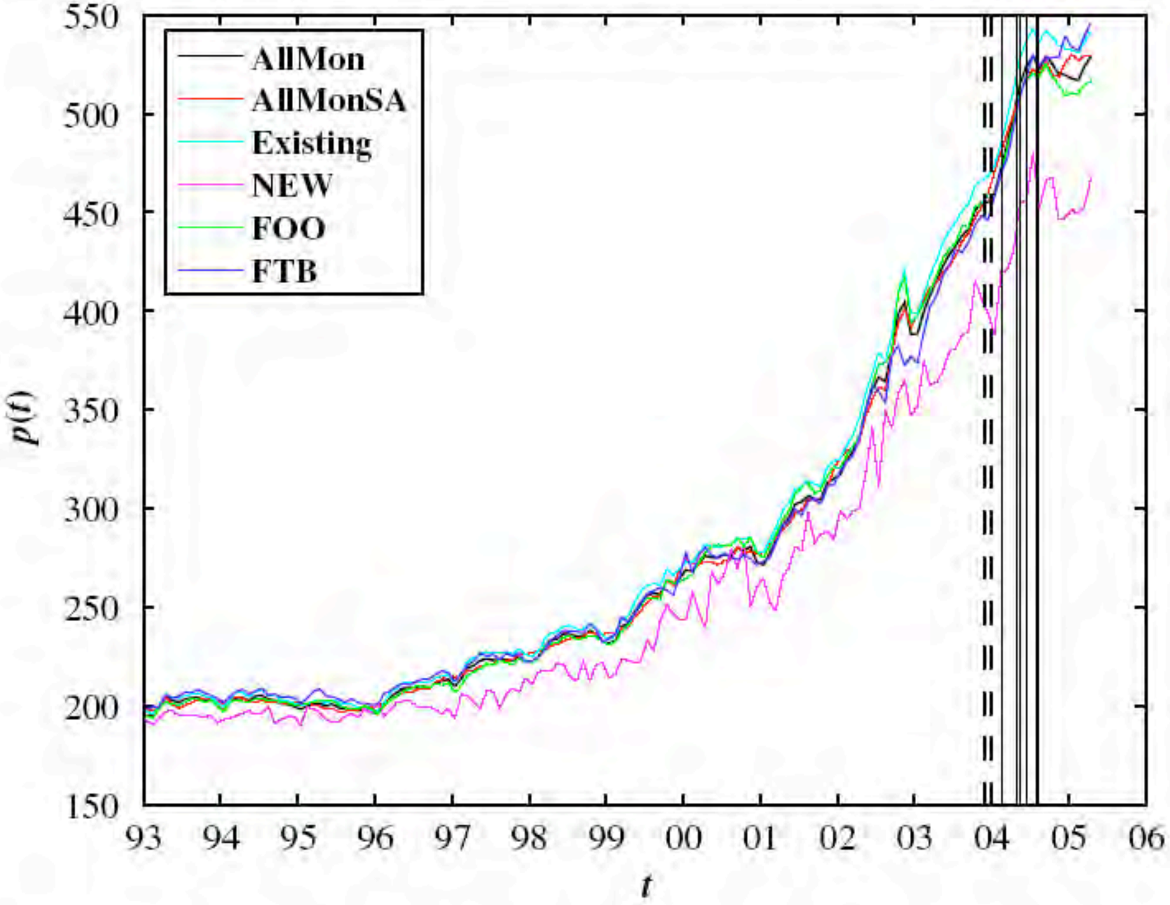


Fig. 1. (Color online) Plot of the UK Halifax house price indices from 1993 to April 2005 (the latest available quote at the time of writing). The two groups of vertical lines correspond to the two predicted turning points reported in Tables 2 and 3 of [1]: end of 2003 and mid-2004. The former (resp. later) was based on the use of formula (2) (resp. (3)). These predictions were performed in February 2003.

W.-X. Zhou, D. Sornette, 2000–2003 real estate bubble in the UK but not in the USA, Physica A 329 (2003) 249–263.

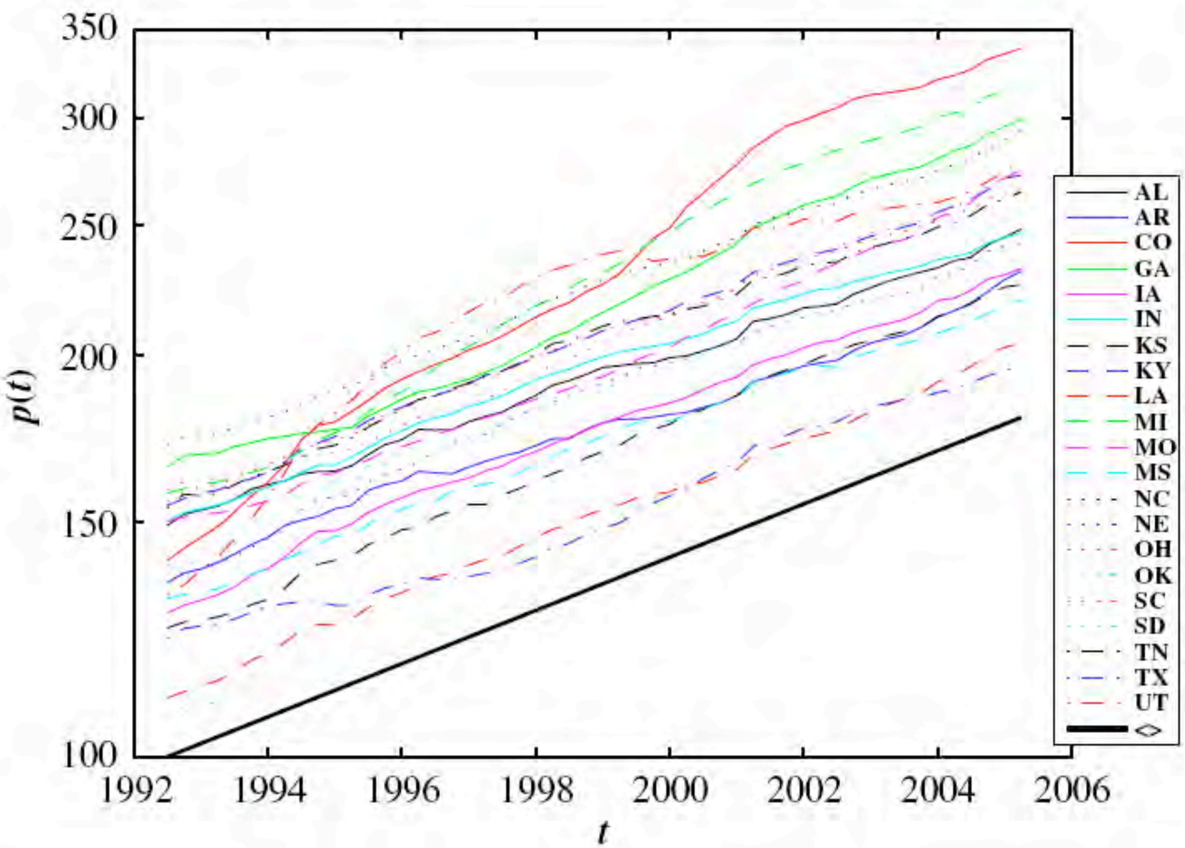


Fig. 3. (Color online) Quarterly HPI in the 21 states which have an approximately constant exponential growth, qualified by a linear trend in a linear-logarithmic scale. The thick straight line at the bottom of the figure indicates the average over all 21 states corresponding to an annual growth rate of 4.6% over the last 13 years. The corresponding states are given in the legend. Note that Colorado seems to be on a faster trend.

W.-X. Zhou, D. Sornette / Physica A 361 (2006) 297–308

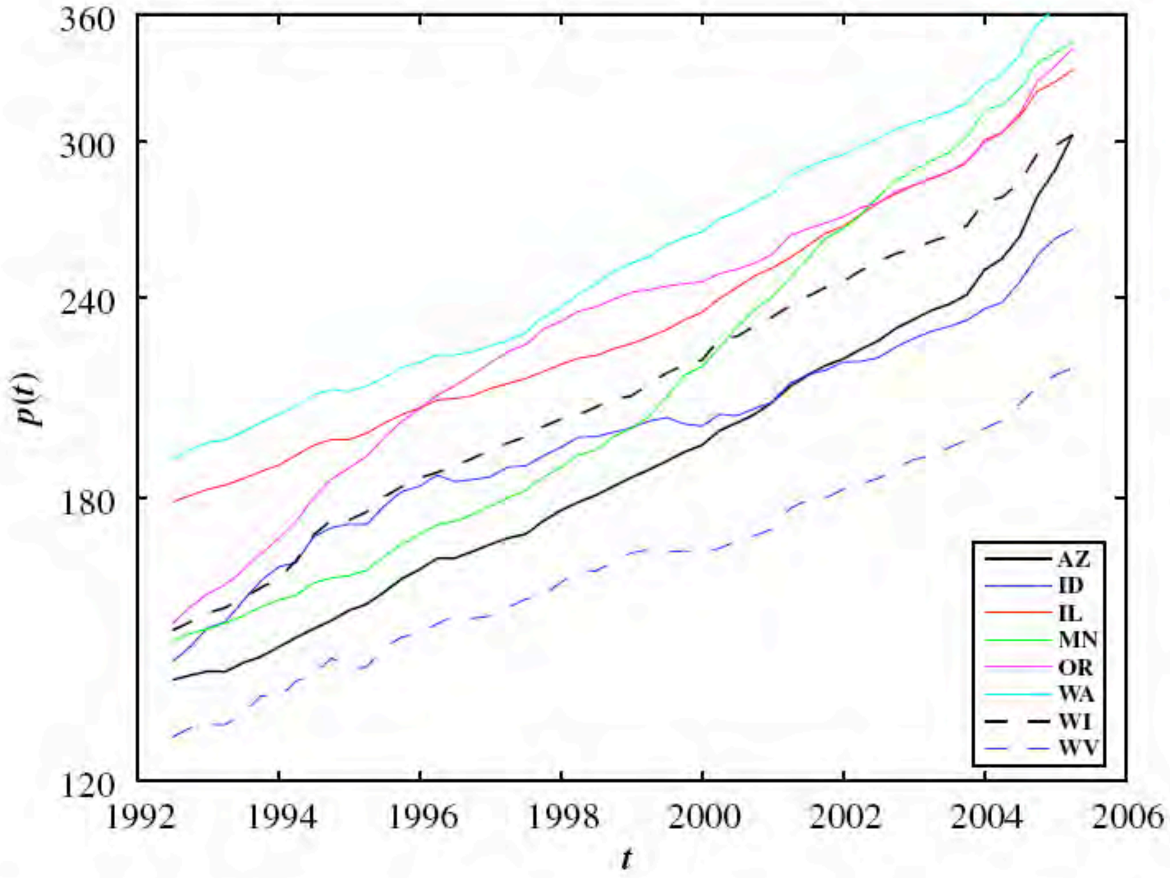


Fig. 4. (Color online) Quarterly HPI in the 8 states exhibiting a recent upward acceleration following an approximately constant exponential growth rate. The corresponding states are given in the legend.

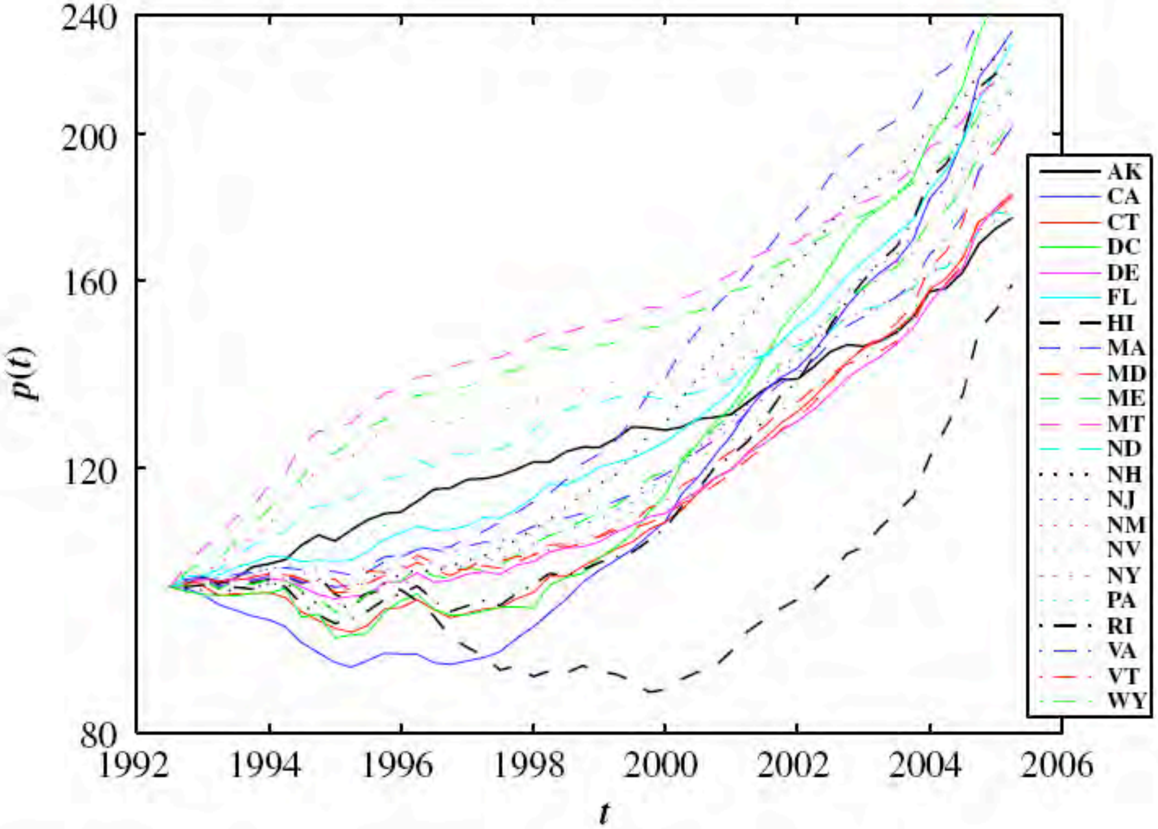
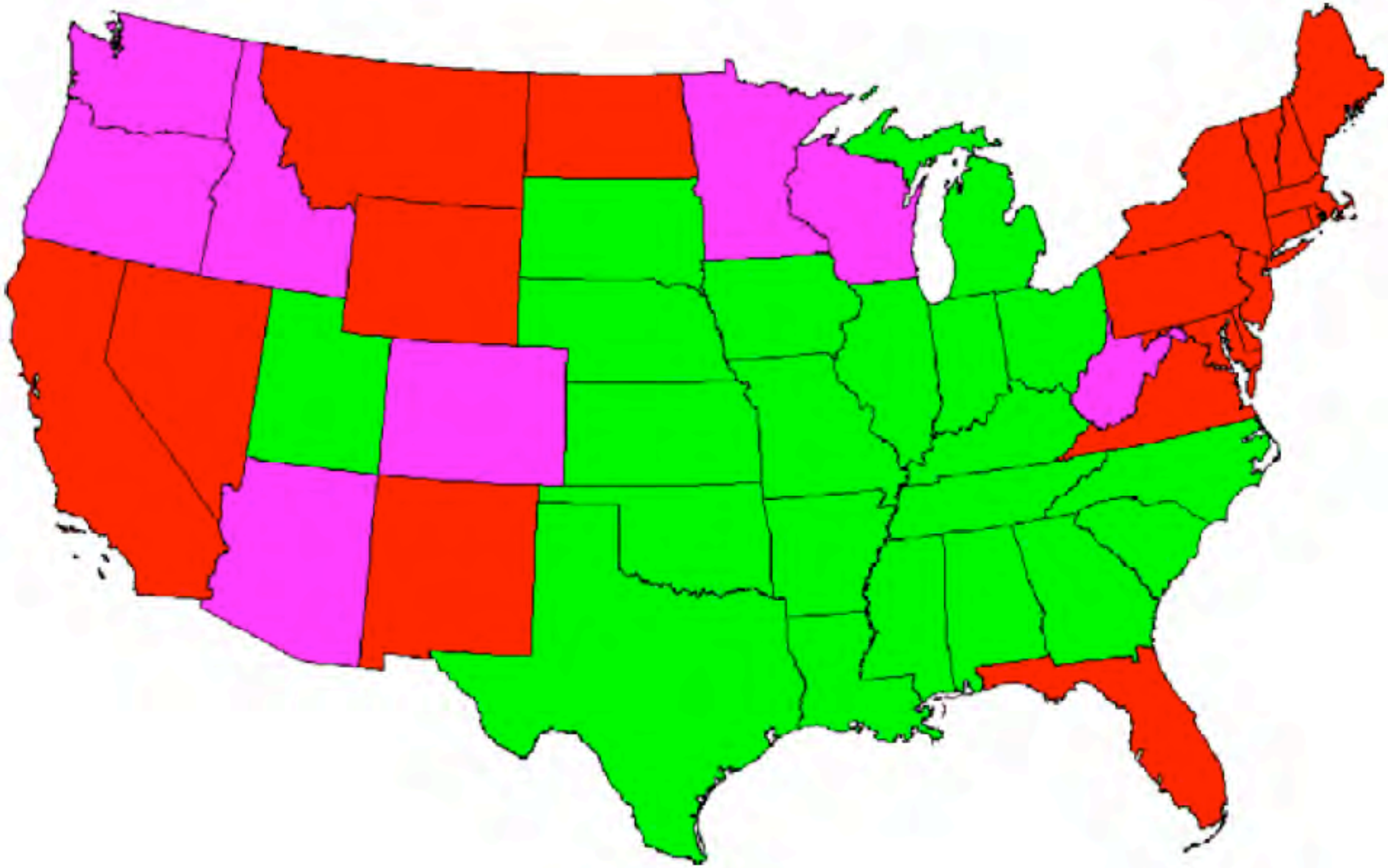


Fig. 5. (Color online) Quarterly average HPI in the 21 states and in the District of Columbia (DC) exhibiting a clear upward faster-than-exponential growth. For better representation, we have normalized the house price indices for the second quarter of 1992 to 100 in all 22 cases. The corresponding states are given in the legend.



W.-X. Zhou, D. Sornette / Physica A 361 (2006) 297–308

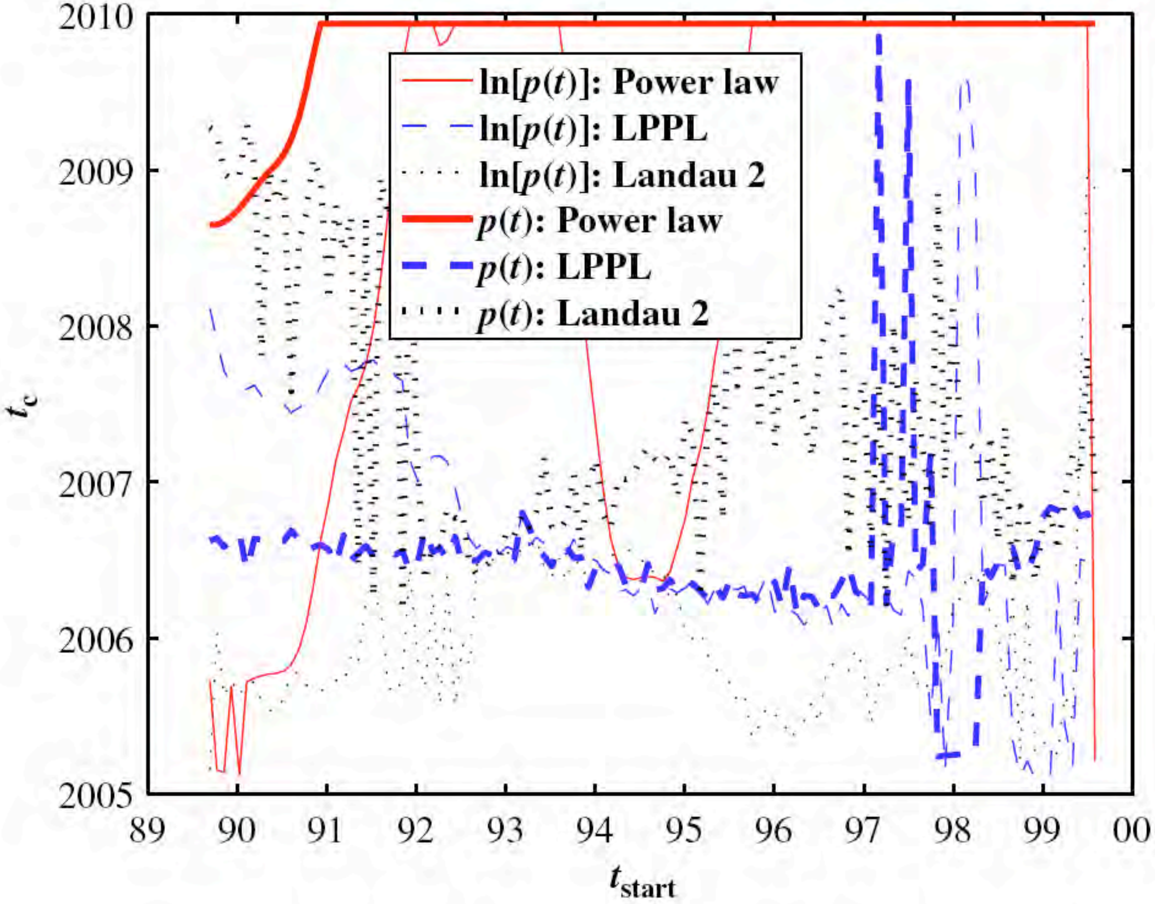


Fig. 9. (Color online) Predicted critical time t_c as a function of t_{start} obtained from the fits with the LPPL and the 2nd-order Landau LPPL models as in Fig. 8.

717 VERNON WY
BURLINGAME, CA 94010

(2005)

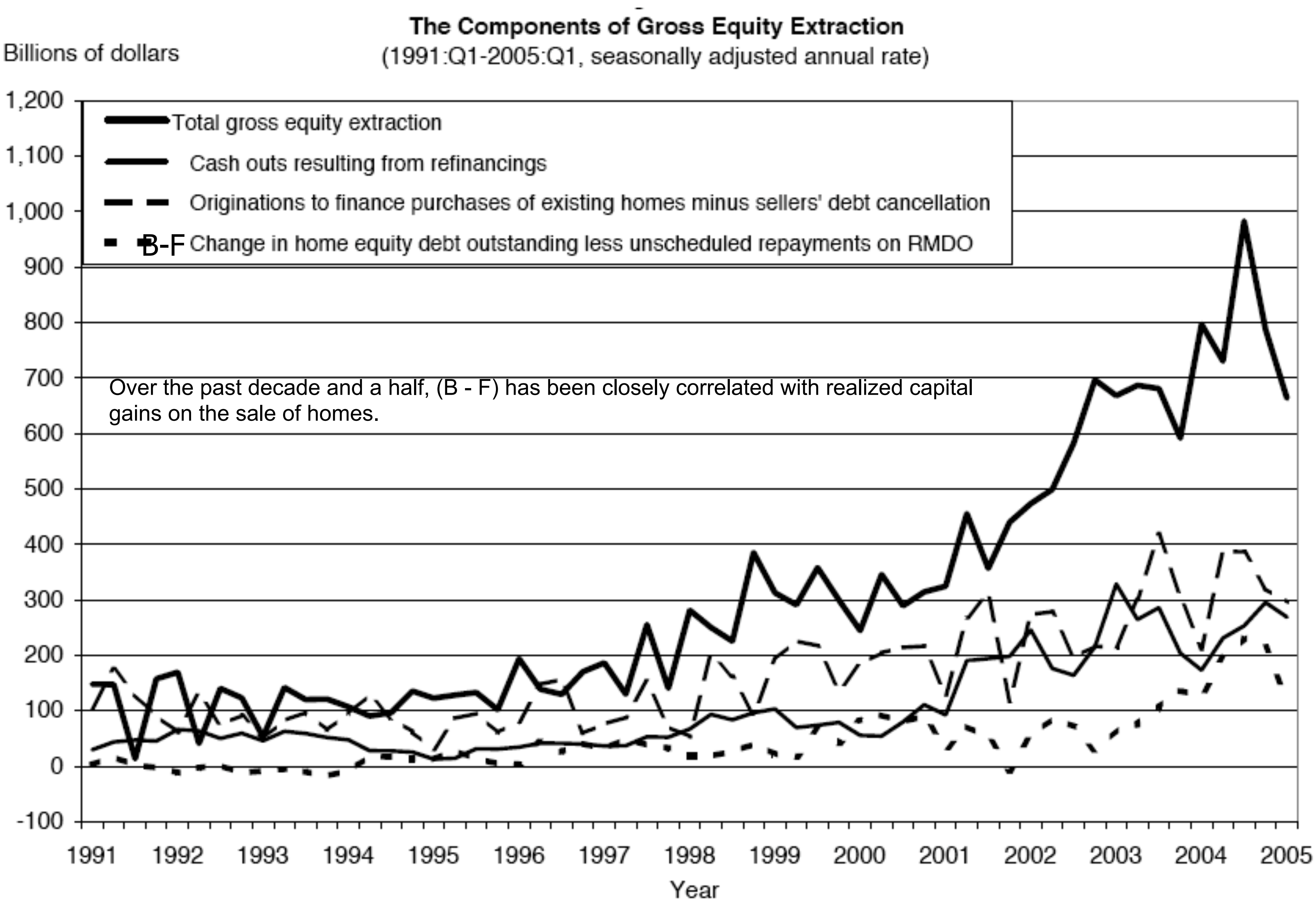
2 Bedrooms, **1** Bath(s)
1,310 Estimated Sq. Ft.

Listing #: 620130

$1,049,000

And this with the median household income in San Mateo County of ~$70,000. With 20% down, the mortgage for a "starter" $1M house would be 11-12 times the median income. Even if one were "buying up" to one of these houses, say, with equity of 50%, the mortgage/median income ratio would be 7:1!!!

From late '02 and early '03 to date--the bubbliest phase--the value of the property below is estimated to have more than DOUBLED, peaking at an estimated $1.16M in summer-fall '05, an annualized increase in value of ~14% from '96. However, before the one order of magnitude of exponential growth of the bubble commenced in late '02, the rate of growth of the value of this property was ~6.9%/yr. Were the value to regress to the pre-bubble trend, the estimated value would be $620,000-$820,000 over the course of the next 4 years or a 30% to 40-45% nominal decline and -11% to -18%/yr. in real terms (at the trend 2.7% CPI).



Alan Greenspan and James Kennedy (Nov. 2005)

LAS VEGAS

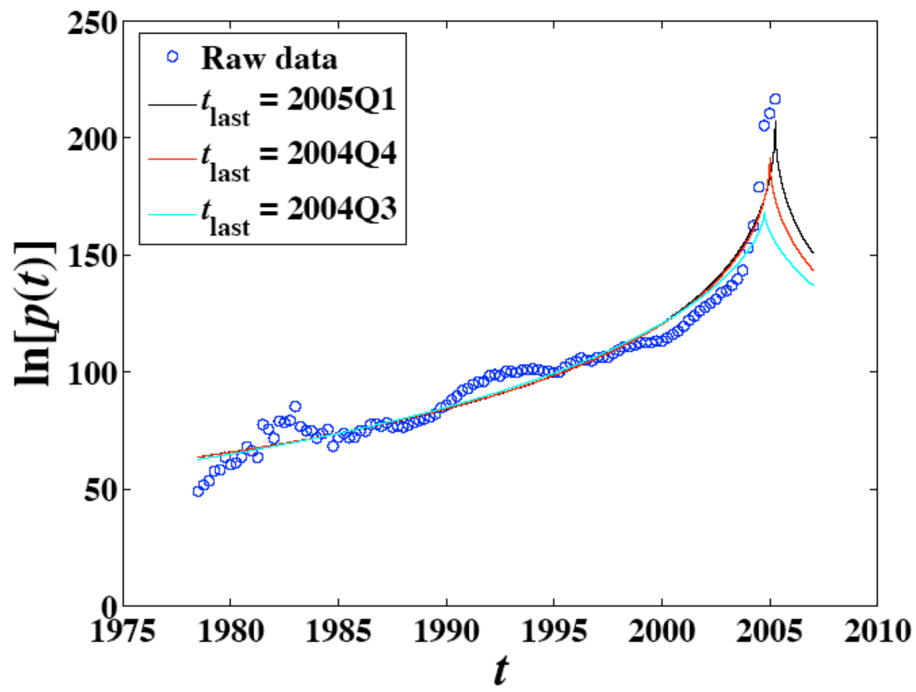
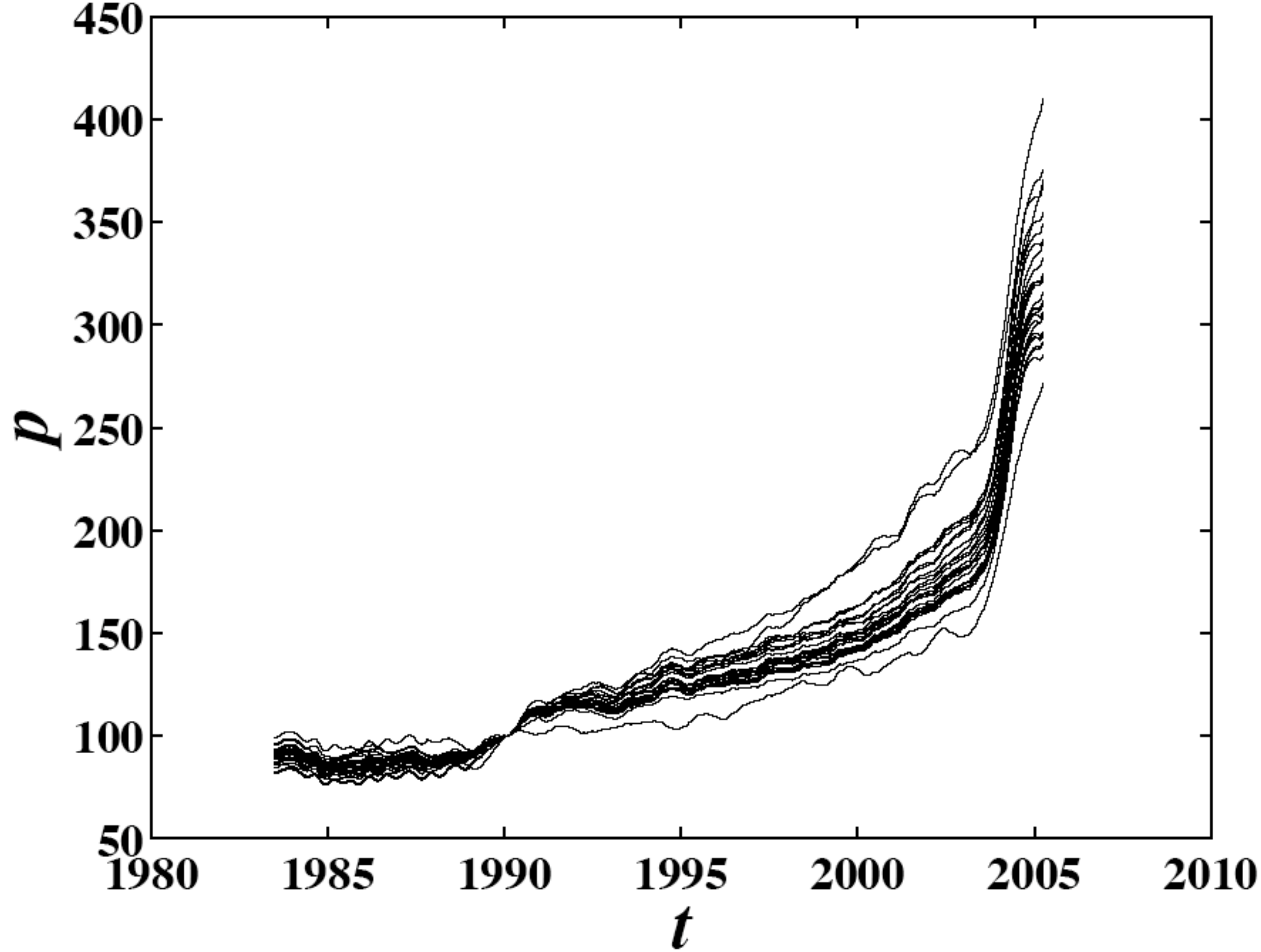


Figure 1: Three fits of the quarterly data of Las Vegas house price index from 1978Q2 to 2004Q3, to 2004Q4, and to 2005Q1, respectively, using the pure power model (9). The fit parameters for 2004Q3 are $t_c = 2004.75$ and $m = 0.63$ with the r.m.s. of the fit residuals being 0.0686. The fit parameters for 2004Q4 are $t_c = 2005.0$ and $m = 0.54$ with the r.m.s. of the fit residuals being 0.0709. The fit parameters for 2005Q1 are $t_c = 2005.25$ and $m = 0.48$ with the r.m.s. of the fit residuals being 0.0725.

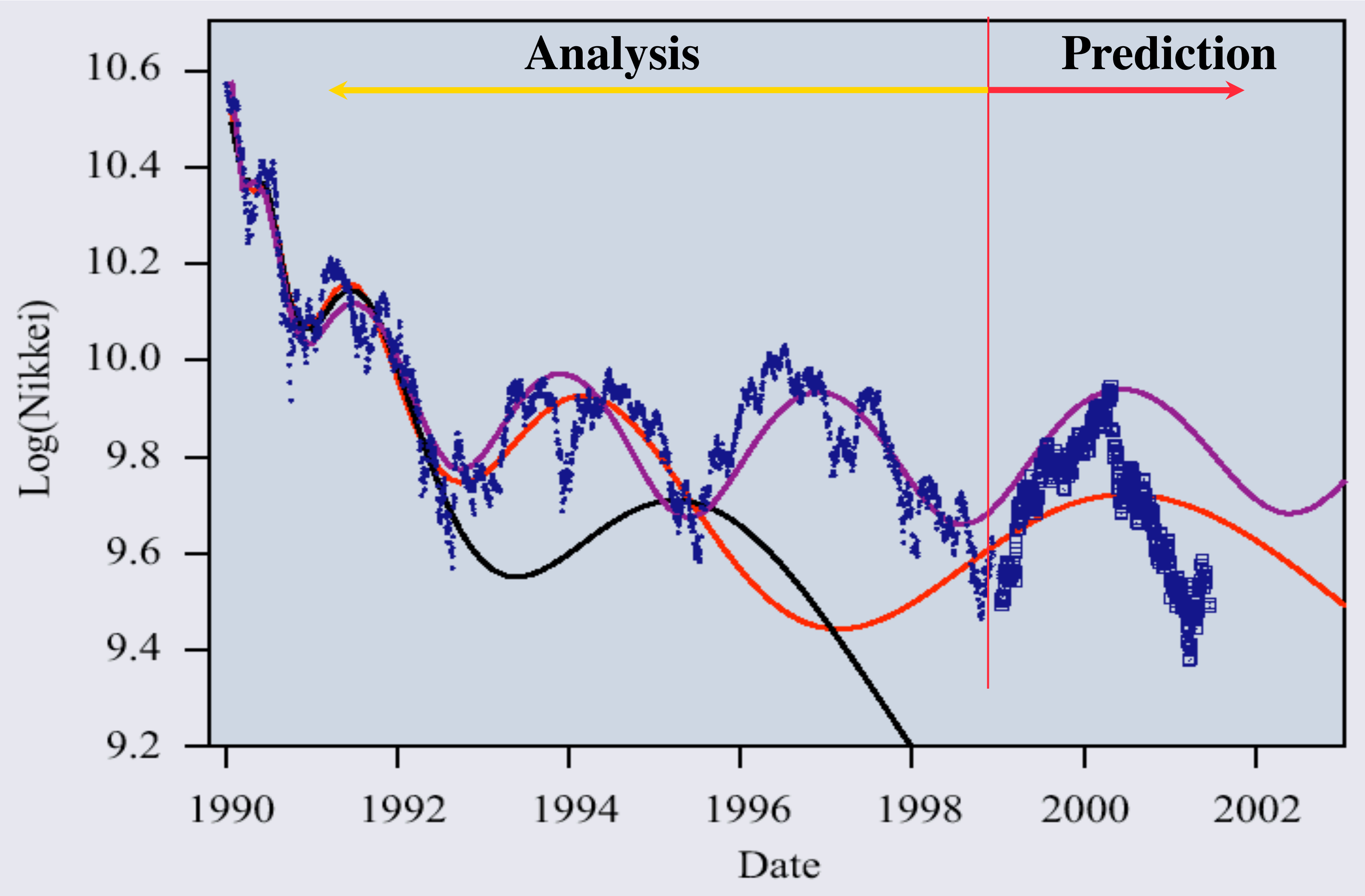
Regional Case-Shiller-Weiss Indices of Las Vegas



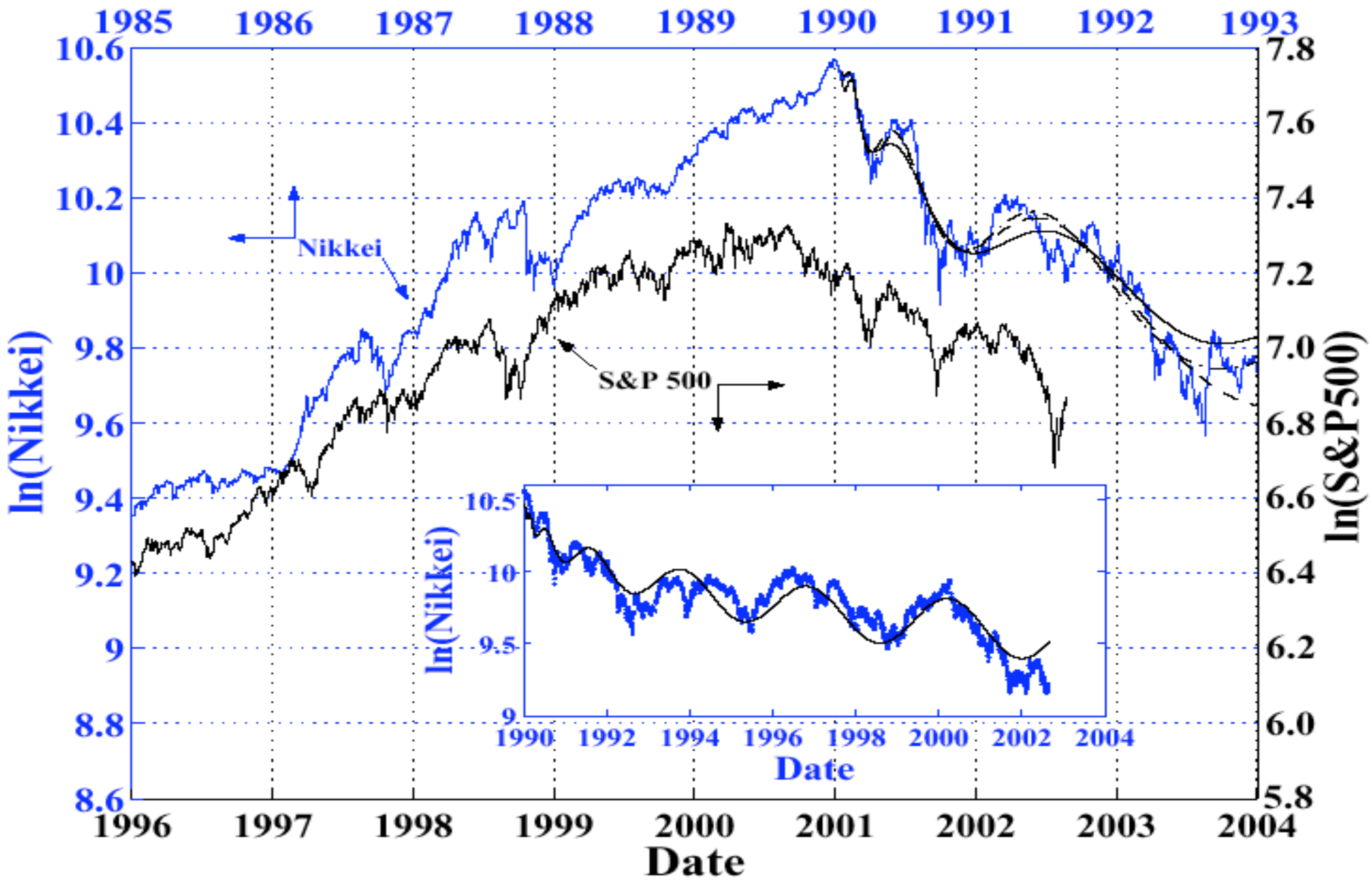
Time evolution of the Case-Shiller-Weiss (CSW) indices of 27 Las Vegas zip codes

ANTIBUBBLES

Japanese Index: model and prediction

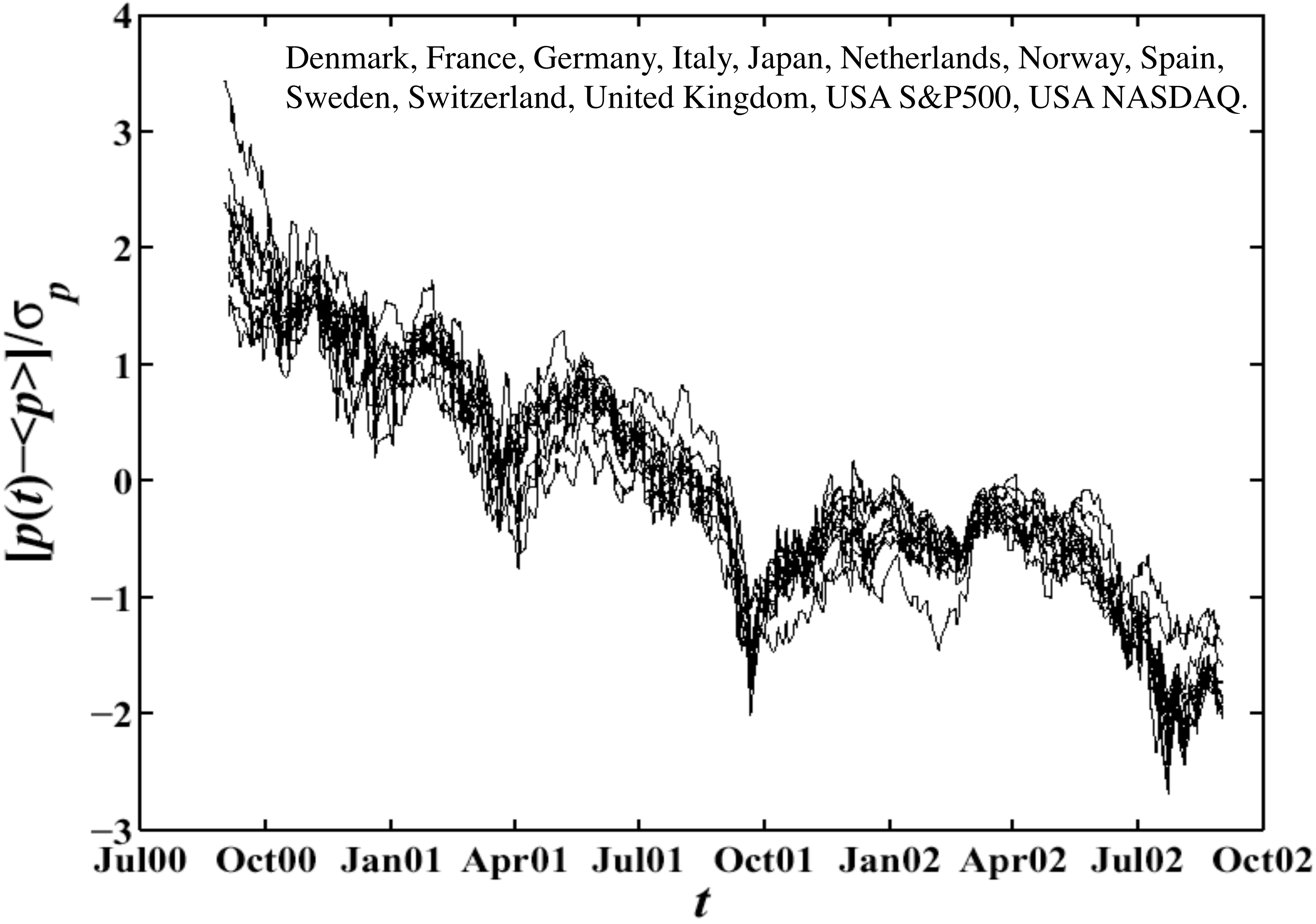


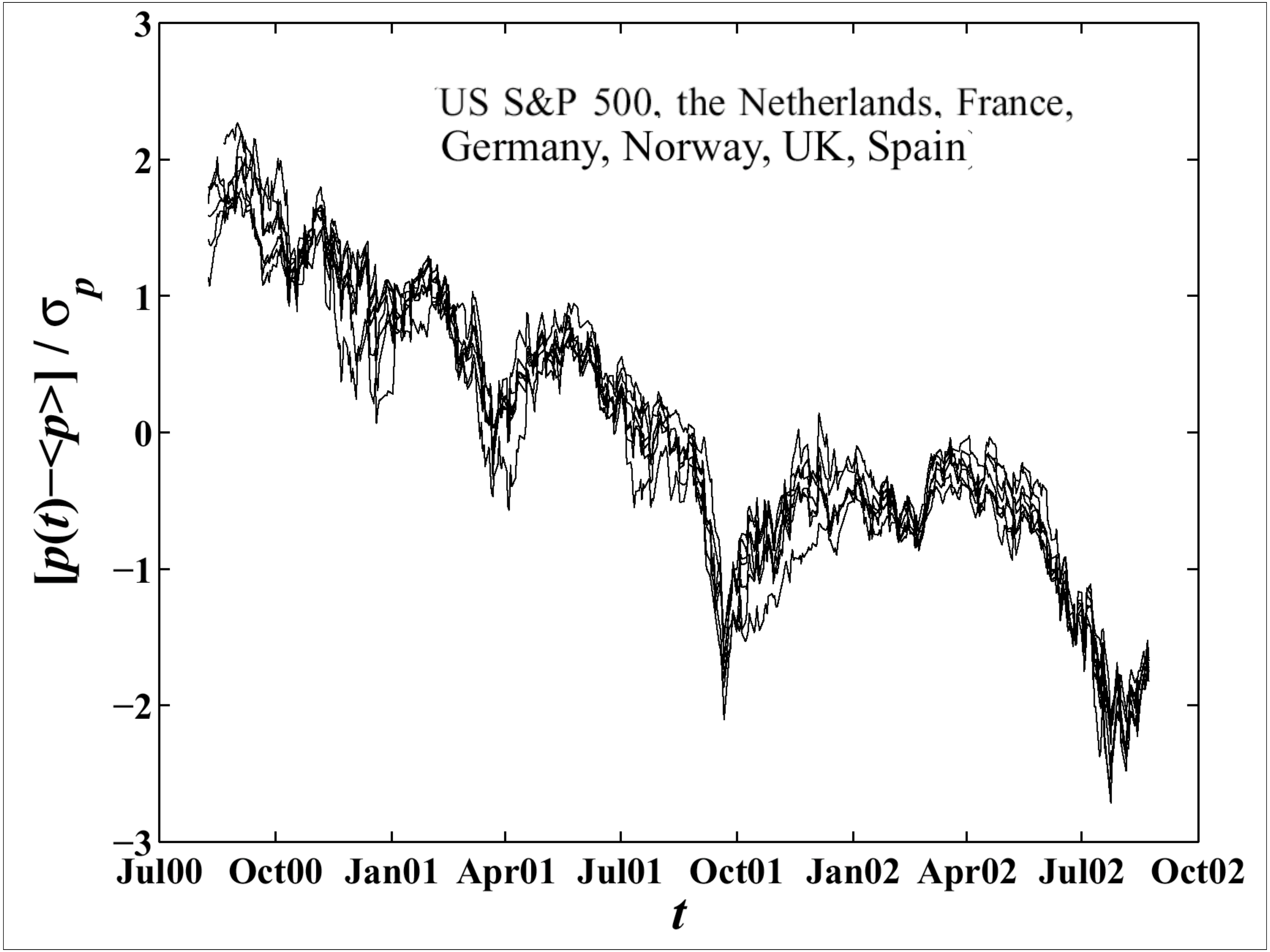
S&P vs Nikkei



1985 1986 1987 1988 1989 1990 1991 1992 1993
10.6 10.4 10.2 10 9.8 9.6 9.4 9.2 9 8.8 8.6
ln(Nikkei)
Nikkei
S&P 500
7.8 7.6 7.4 7.2 7.0 6.8 6.6 6.4 6.2 6.0 5.8
ln(S&P500)
1996 1997 1998 1999 2000 2001 2002 2003 2004
Date
10.5 10 9.5 9
ln(Nikkei)
1990 1992 1994 1996 1998 2000 2002 2004
Date

Inter-market Correlations





US S&P 500, the Netherlands, France,
Germany, Norway, UK, Spain
$[p(t) - \langle p \rangle] / \sigma_p$
3
2
1
0
−1
−2
−3
Jul00
Oct00
Jan01
Apr01
Jul01
Oct01
Jan02
Apr02
Jul02
Oct02
t

Does knowledge of all this change the future? Forecasts?

Learning from the Oct. 1987 Crash: implied volatility has changed dramatically, and in Bates' opinion permanently, since the 1987 crash.

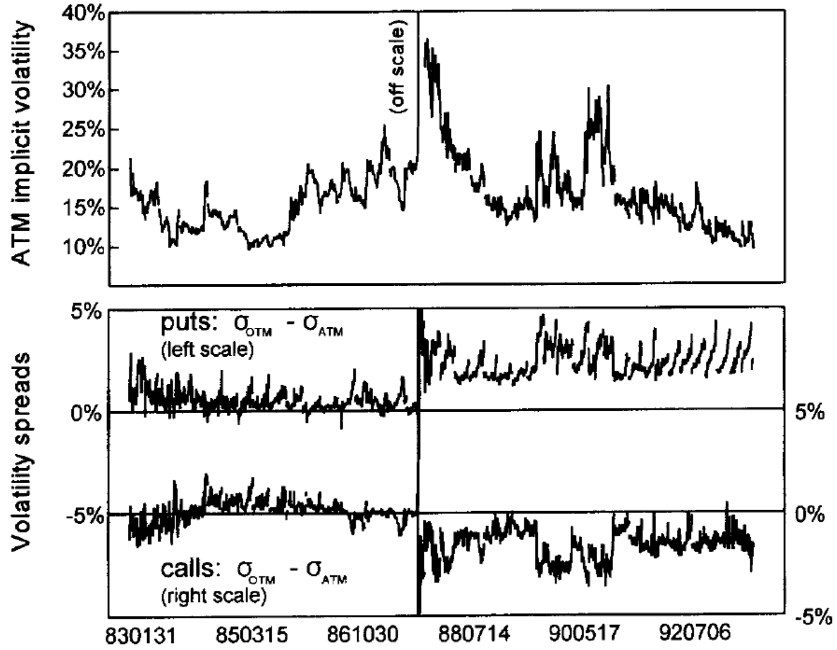


Fig. 2. Upper panel: implicit volatilities from at-the-money S&P 500 futures options, 1983–93. Lower panel: Volatility spreads for calls and puts.

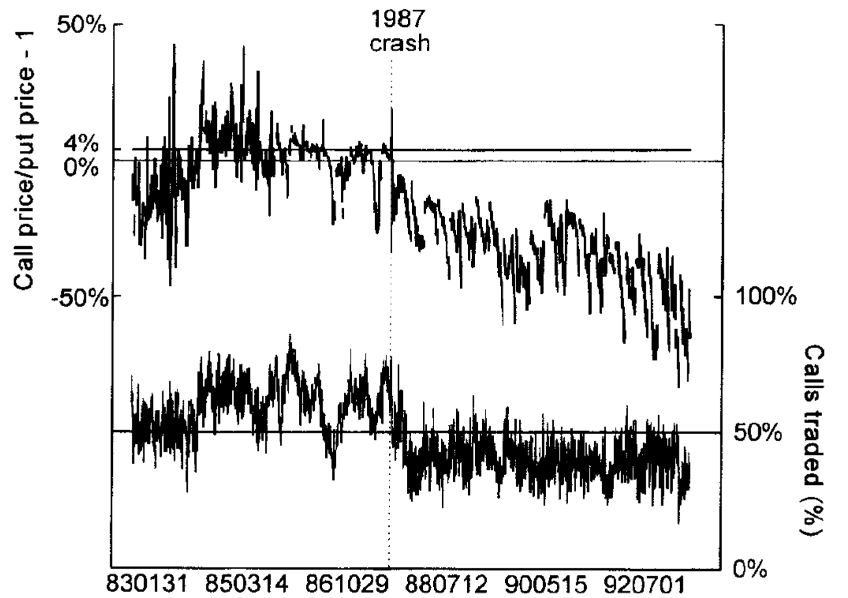


Fig. 3. 4% OTM skewness premium (upper line), and call transactions as a percentage of total reported call and put transactions (lower line).

Bates, D., 2000, Post-'87 crash fears in S&P500 futures options. Journal of Econometrics, 94, 181-238.

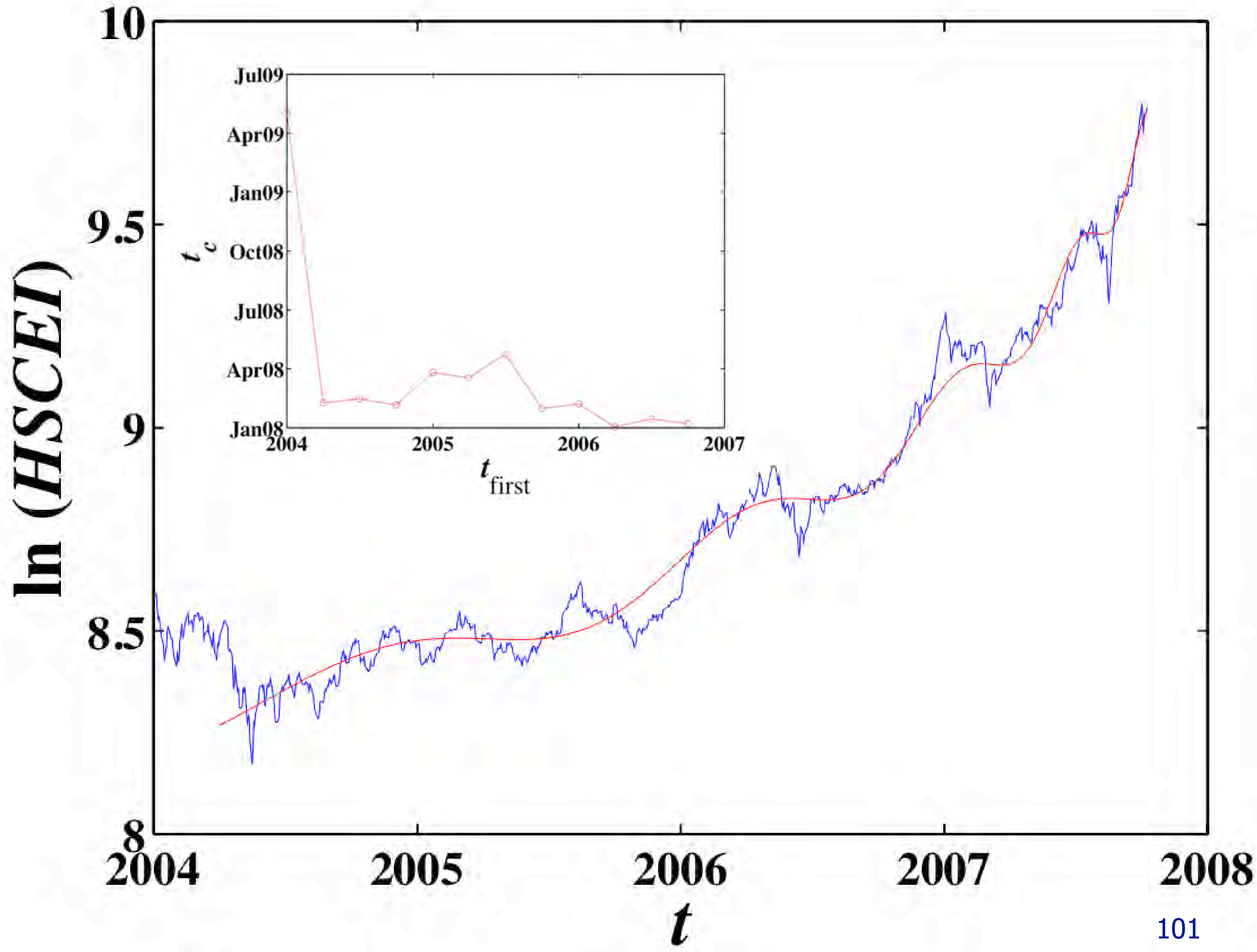
COLLECTIVE BEHAVIOR between AGENTS
(with negative and positive feedbacks)

Basle Committee on Banking Supervision: "In handling systemic issues, it will be necessary to address, on the one hand, risks to confidence in the financial system and contagion to otherwise sound institutions, and, on the other hand, the need to minimize the distortion of market signals and discipline."

A. Greenspan (Aug., 30, 2002):
"We, at the Federal Reserve…recognized that, despite our suspicions, it was very difficult to definitively identify a bubble until after the fact, that is, when its bursting confirmed its existence… Moreover, it was far from obvious that bubbles, even if identified early, could be preempted short of the Central Bank inducing a substantial contraction in economic activity, the very outcome we would be seeking to avoid."

Our conclusion is that the presence of the bubble and its approximate end was predictable.

Hang Seng China Entreprises Index (HSCEI)



14 factors to propel a market bubble

1. the capitalist explosion and the ownership society,
2. cultural and political changes favoring business success,
3. new information technology,
4. supportive monetary policy and the Greenspan put,
5. the baby boom and their perceived effects on the markets,
6. an expansion in media reporting of business news,
7. analysts' optimistic forecasts,
8. the expansion of defined contribution pension plans,
9. the growth of mutual funds,
10. the decline of inflation and the effects of money illusion,
11. the expansion of the volume of trade due to discount brokers,
12. day traders,
13. twenty-four-hour trading,
14. the rise of gambling opportunities.

Why bubbles are not arbitraged away?

1. limits to arbitrage caused by noise traders (DeLong et, 1990)
2. limits to arbitrage caused by synchronization risk (Abreu and Brunnermeier, 2002 and 2003)
3. short-sale constraints (many papers)
4. lack of close substitutes for hedging (many papers)
5. heterogenous beliefs (many papers)
6. lack of higher-order mutual knowledge (Allen, Morris and Postlewaite, 1993)
7. delegated investments (Allen and Gorton, 1993)
8. psychological biases (observed in many experiments)
9. positive feedback bubbles

Conclusion

- ❑ Regularities in bubbles and crashes
- ❑ Kings and black swans
- ❑ Positive and negative feedbacks
- ❑ RE bubble models and imitation/herding
- ❑ Empirical case studies
- ❑ Endogenous versus Exogenous
- ❑ Foreign capital flows, Fed's feedback and macroeconomic feedbacks (not shown here)
- ❑ Anti-bubbles and the recent 2000-05 phase (not shown here)
- ❑ Towards routine predictions

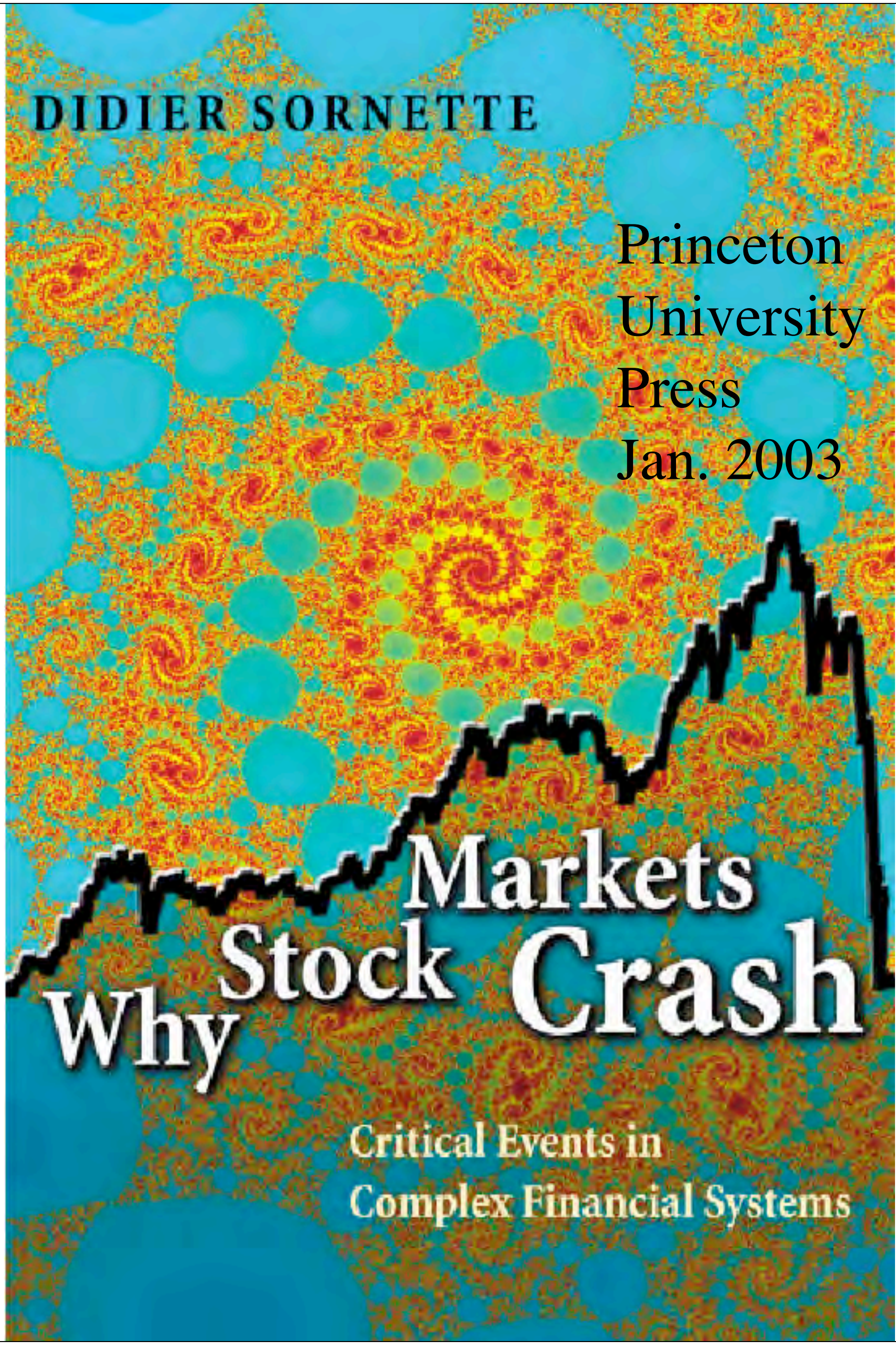
All papers and much more at http://www.ess.ucla.edu/faculty/sornette/

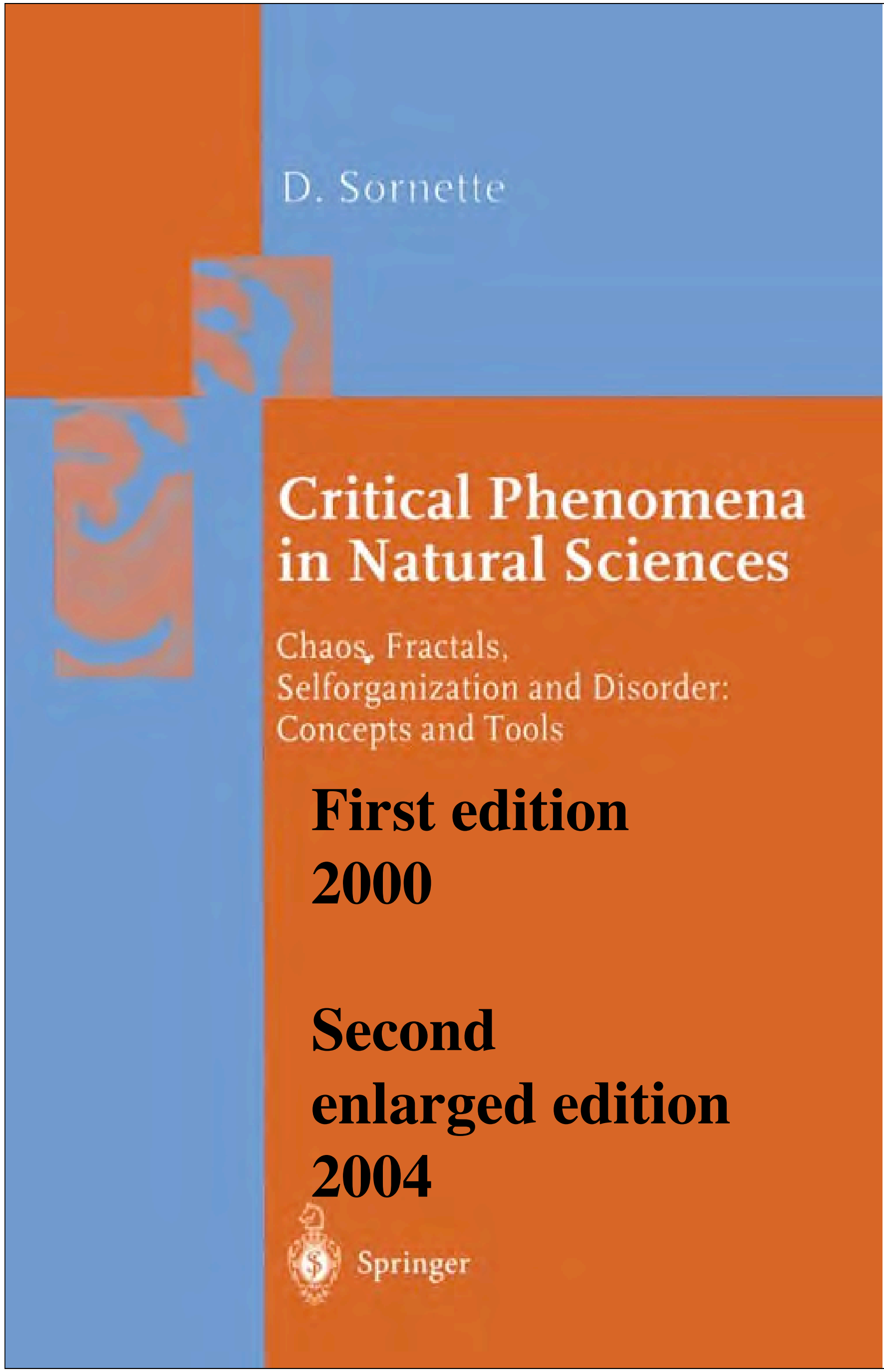
Main Messages

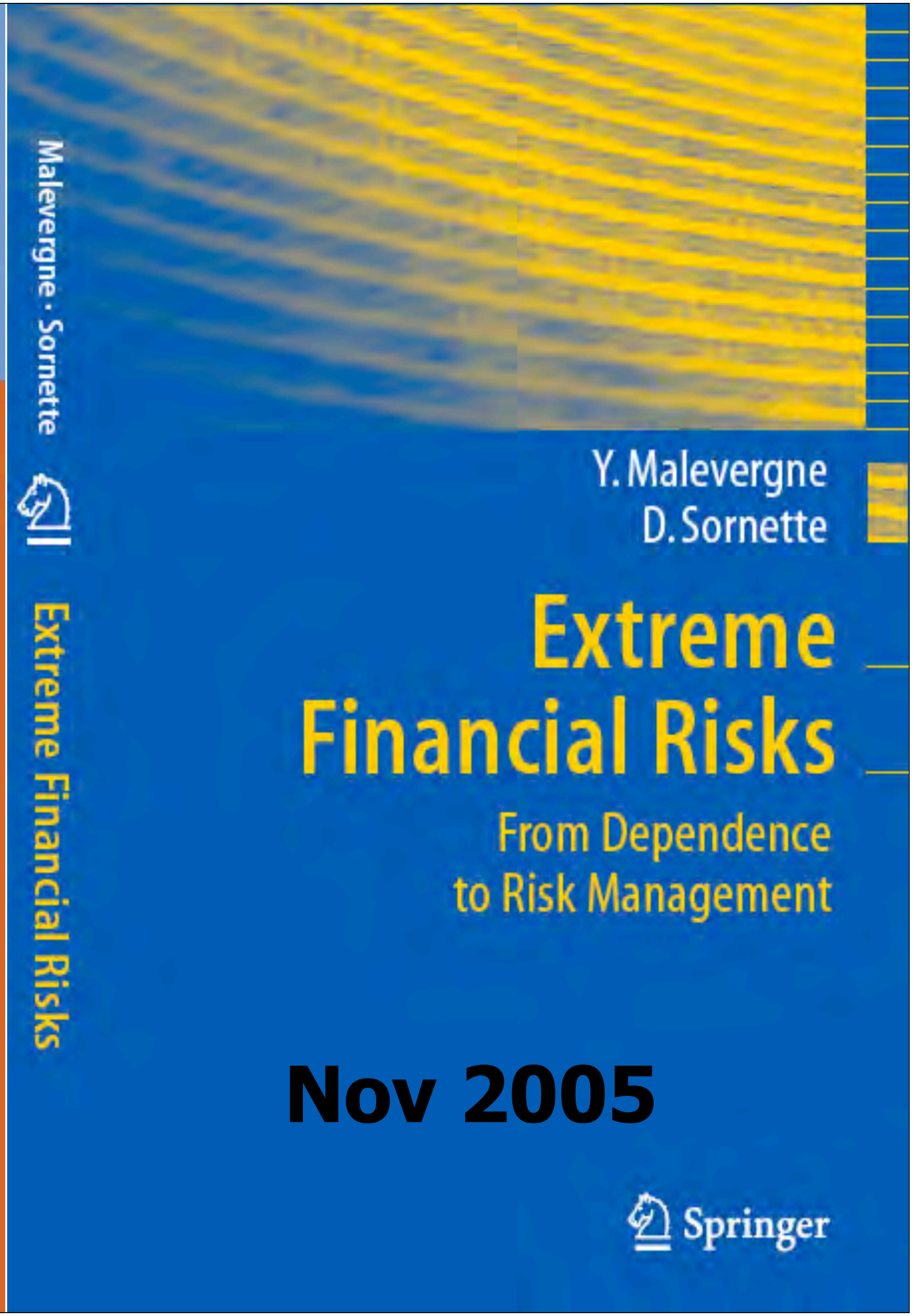
Investors, stock market regulators and macro-economic policy cannot ignore COLLECTIVE BEHAVIOR between AGENTS (with negative and positive feedbacks).

Imitation and herding behaviors lead to Positive and negative feedbacks AND vice-versa : the stock markets and the economy have never been more a CONFIDENCE "game".

Predictions and Preparation: complexity theory applied to such collective processes provides clues for precursors and suggests steps for precaution and preparation.


DIDIER SORNETTE
Princeton
University
Press
Jan. 2003
Why Stock Markets Crash
Critical Events in
Complex Financial Systems


D. Sornette
Critical Phenomena in Natural Sciences
Chaos, Fractals, Selforganization and Disorder: Concepts and Tools
First edition 2000
Second enlarged edition 2004
Springer


Malevergne · Sornette
Extreme Financial Risks
Y. Malevergne
D. Sornette
Extreme Financial Risks
From Dependence to Risk Management
Nov 2005
Springer