"In the short run, the market is like a voting machine, tallying up which firms are popular and unpopular. But in the long run, the market is like a weighing machine, assessing the substance [intrinsic value] of a company."
– Benjamin Graham (father of value investing)
THE GREAT RECESSION
(2008-2009)

billions US $

direct subprime loss

World GDP loss

Stock markets losses
and
the illusion of the perpetual money machine (1980–2008)

Index of over-valuation

PCA first component on a data set containing, emerging markets equity indices, freight indices, soft commodities, base and precious metals, energy, currencies...

The “perpetual money machine” broke.

Real-estate in the USA

Chart 1: HOME PRICES – STILL DEFLATING AFTER ALL THESE YEARS

United States

S&P/Case-Shiller Home Price Index: Composite 20
(Jan 2000 = 100, seasonally adjusted)

Source: Haver Analytics, Gluskin Sheff

The Great Experiment

• In response to the Great Financial Crisis, central banks are experimenting with non-conventional “Code Red” policies like quantitative easing, zero interest rates, large-scale asset purchases and currency debasement. These policies will lead towards inflation in the long run.

• Central bankers want everyone to keep borrowing and spending by creating negative real interest rates on cash. Inflation in most countries is higher than interest rates, so cash is trash. Their policies are designed to encourage borrowing and speculation.

• Politicians and central bankers want to encourage exports, so they are trying to devalue their currencies and make goods and services cheaper for foreigners. Unfortunately, not everyone can devalue their currency at the same time. Currency wars have happened before in the 1930 and 1970s. They rarely end well for anyone, but governments pursue currency wars anyway.
Easy Money will lead to more Bubbles

Financial bubbles are a (big) part of financial market lives and are likely to be even more relevant in the future!

The present and future financial opportunities and risks can only be understood from the attempt of policy makers to fight the consequences of past bubbles!
What is a bubble?

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

Ex: Refet S. Gürkaynak, *Econometric Tests of Asset Price Bubbles: Taking Stock.* Can asset price bubbles be detected? This survey of econometric tests of asset price bubbles shows that, despite recent advances, econometric detection of asset price bubbles cannot be achieved with a satisfactory degree of certainty. For each paper that finds evidence of bubbles, there is another one that fits the data equally well without allowing for a bubble. We are still unable to distinguish bubbles from time-varying or regime-switching fundamentals, while many small sample econometrics problems of bubble tests remain unresolved.

**Professional Literature:** we do not know... only after the crash


“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 is a bubble?

-exponentially “exploding” prices?

-exploding volatility?
What is a bubble?

- Positive feedback of price on volatility?

(Jarrow and Protter)

\[ \text{Implied vol before and after the crash of Oct. 19, 1987} \]

\[ \Rightarrow \text{NO ! Volatility is not a predictor} \]
What is a bubble?

Positive feedbacks

standard law of supply and demand

price

supply

demand

quantity

price

supply

demand

quantity

Positive feedbacks
Mechanisms for positive feedbacks in the stock market

• **Technical and rational mechanisms**
  1. Option hedging
  2. Insurance portfolio strategies
  3. Market makers bid-ask spread in response to past volatility
  4. Learning of business networks, human capital
  5. Procyclical financing of firms by banks (boom vs contracting times)
  6. Trend following investment strategies
  7. Algorithmic trading
  8. Asymmetric information on hedging strategies
  9. Stop-loss orders
  10. Portfolio execution optimization and order splitting
  11. Deregulation (Grimm act repelling the Glass-Steagall act)

• **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)
  3. “Social Proof” mechanism
Positive feedbacks until 2008...

- Financial innovations
  - Real-estate loans and MBS as fraction of bank assets
  - Securitization of finance
  - Leverage
  - Under-estimating aggregate risks

- Outsourcing of risks
  - Deregulation and lack of oversight
  - Bad quantitative risk models in banks (Basel II)
  - Rating agency failures
  - Lowering of lending standards
  - Managers greed and poor corporate governance problem

- Facilitating factors
  - Loans to poor’s
  - Freddy Mac and Fanny Mae...
  - Growth of over-capacity
  - Moral hazards
Synchronization is a disaster for financial markets: a synchronisation of sell orders leads to a crash; a synchronization of buy orders leads to a rally or a bubble regime.
Universal bubble scenario => ENDOGENEITY
and POSITIVE FEEDBACK

Financial bubbles, which we have been observing for over 400 years:

Tulip mania  
South Sea bubble  
IT bubble  
Housing bubble
Growth Processes

- exponential growth
- finite-time singularity
- power-law

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

\[
\delta = 0 \quad p(t) \sim e^t
\]

\[
\delta > 0 \quad p(t) \sim \frac{1}{(t_c - t)^{1/\delta}}
\]

\[
\delta < 0 \quad p(t) \sim t^{1/|\delta|}
\]
Super-exponential growth (positive feedbacks)

Diagram 1.5. Correlation between World Population Size and World Population Annual Growth Rate, 1650–1970

Korotayev, Malkov Khaltourina (2006)
Multivariate endogeneous growth models and FTS

Case $\theta + \beta > 1 : \text{FTS}$

\[
\frac{dA}{dt} = b A^{\theta} K^{\beta},
\]

\[
\frac{dK}{dt} = a A^{1-\alpha} K^{\alpha}.
\]

$\alpha = 0.6; \beta = 0.9; \theta = 0.9$
Finite-time Singularity

- Singularity theorems of Penrose and Hawking in General Relativity
- Formation of black holes (general relativity coupled to a mass field)
- Planet formation in solar system by run-away accretion of planetesimals
- Tokamak physics of plasma turbulence (Zakharov equation of beam-driven turbulence)
- Front genesis in meteorology
- Turbulence and Euler equation for inviscid fluids
- Rupture and failure of materials and engineering structures
- Earthquakes (Ruina-Dieterich state-and-velocity weakening solid friction)
- Micro-organisms chemotaxis aggregating to form fruiting bodies
- Surface instabilities to form spikes (Mullins-Sekerka instability)
- Jets from singular surfaces
- Fluid droplet snap-off
- Euler’s disk (rotating settling coin)
Famous historical bubbles

Source: Elliott Wave International; data source for South Seas, Global Financial Data
Positive feedbacks and origin of bubbles

Prices in the learning-to-forecast market experiments (Hommes et al., 2008).
Five out of six markets exhibit long lasting bubbles with asset prices increasing to more than 15 times fundamental value.

\[
\log \left( \frac{\bar{p}_t}{\bar{p}_{t-1}} \right) = a_2 + b_2 \bar{p}_{t-1}.
\]

Next period returns \( r(t+1) \) versus current returns \( r(t) \) for group 2. Points on the diagonal correspond to constant growth rate \( r(t+1) = r(t) \), points above the diagonal \( r(t+1) > r(t) \) correspond to accelerating growth. Returns are defined as discrete returns:

\[
r(t+1) = \left[ \frac{p(t+1)}{p(t)} \right] - 1.
\]

\[ r_t = \mu + \gamma(s_t)P_{t-1} + \sigma_{t,P} \varepsilon_t \]
\[ \sigma_{t,P}^2 = \omega + \alpha_P r_{t-1}^2 + \beta_P \sigma_{t-1,P}^2 \]

\begin{tabular}{|c|c|c|c|}
\hline
 & mean eq. & & variance eq. \\
\hline
 & & & \\
S&P 1968-2000 & $2.50 \cdot 10^{-2}$ & $6.30 \cdot 10^{-5}$ & \\
& (1.98) & (2.01) & \\
S&P 1977-1987 & $-4.91 \cdot 10^{-2}$ & $5.87 \cdot 10^{-4}$ & \\
& (-1.13) & (2.11) & \\
NASDAQ 1988-2000 & $0.029$ & $6.18 \cdot 10^{-5}$ & \\
& (1.19) & (3.16) & \\
DAX 1994-1998 & $-0.142$ & $8.62 \cdot 10^{-5}$ & \\
& (-1.52) & (2.67) & \\
STOXX 1994-1998 & $-0.127$ & $1.20 \cdot 10^{-4}$ & \\
& (-1.68) & (2.89) & \\
NIKKEI 1973-1990 & $0.028$ & $3.79 \cdot 10^{-6}$ & \\
& (1.80) & (3.48) & \\
\hline
\end{tabular}

standard one-sided t-test

\[ H_0 : \gamma \leq 0 \quad \text{against} \quad H_1 : \gamma > 0 \]
\[ r_t = \mu + \gamma \cdot \log(P_{t-1}) + \epsilon_t, \text{ with } \epsilon_t \sim N(0, h_t), \]
\[ h_t = \alpha_0 + \alpha_1 \cdot \epsilon^2_{t-1} + \beta_1 \cdot h_{t-1}, \quad t = 1, \ldots, T. \]

standard one-sided t-test \( H_0 : \gamma \leq 0 \) against \( H_1 : \gamma > 0 \)
Synthetic tests with simulated FTS-GARCH time series (false negative test)
NASDAQ Composite 1971-2001: estimated gamma (upper panel) and corresponding t-statistic (lower panel) in a FTS GARCH model
NIKKEI 1976-1992: estimated gamma (upper panel) and corresponding t-statistic (lower panel) in a FTS GARCH model.
DAX 1991-2000: estimated gamma (upper panel) and corresponding t-statistic (lower panel) in a FTS GARCH model ($y_t = \log(P_t)$)
Rational Expectation Bubbles and Crashes (Blanchard-Watson)

Martingale hypothesis ("no free lunch"): 
\[ \text{for all } t' > t \quad \mathbb{E}_t[p(t')] = p(t) \]

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)
Bubble with stochastic finite-time singularity due to positive feedbacks

\[ \frac{d B(t)}{B(t)} = \mu dt + \sigma dW_t - \kappa dt \]

\[
\begin{align*}
\mu(B)B &= \frac{m}{2B} [B\sigma(B)]^2 + \mu_0 \frac{[B(t)/B_0]^m}{m} \\
\sigma(B)B &= \sigma_0 \frac{[B(t)/B_0]^m}{m},
\end{align*}
\]

\[
\frac{dB}{dt} = (a\mu_0 + b\eta) B^m - \kappa Bdj \quad \kappa(t) = \frac{\mu(B(t))}{\langle \kappa \rangle}
\]

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

Stochastic finite-time singularity
The price drives the crash hazard rate.

D. Sornette and J.V. Andersen
A Nonlinear Super-Exponential Rational Model of Speculative Financial Bubbles,
\[ B(t) = \alpha^{\frac{1}{\alpha}} \frac{1}{(\mu_0[t_c - t] - (\sigma_0/B_0^m)W(t))^{\alpha}} \text{ where } \alpha \equiv 1/m - 1 \]

Contains two ingredients:

1. **growth faster than exponential**
2. **growth of volatility**

\[ \lim_{1/\alpha \to 0} (m \to 1) \]

\[ B_{BS}(t) = \exp(\mu_0 t + \sigma_0 W(t)) \quad \text{Standard Geometric random walk} \]

**Wilks’ test of embedded hypotheses**

Test of the existence of both ingredients

Example of a “fearful” super-exponential bubble

S&P 500 index from 1/7 1985 to 31/8 1987

Percentage of 100 searches $P_{SB} = 0.70$, $P_{BS} = 0.28$

<table>
<thead>
<tr>
<th>Parameters of the curves in the figure</th>
<th>$F$</th>
<th>$r$</th>
<th>$\sigma$</th>
<th>$\mu$</th>
<th>$\alpha$</th>
<th>$T_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB</td>
<td>110.64</td>
<td>$2.0 \times 10^{-5}$</td>
<td>$4.59 \times 10^{-5}$</td>
<td>$7.36 \times 10^{-4}$</td>
<td>3.0</td>
<td>3390.54</td>
</tr>
<tr>
<td>BS</td>
<td>185.06</td>
<td>$2.0 \times 10^{-4}$</td>
<td>$7.81 \times 10^{-5}$</td>
<td>$9.65 \times 10^{-4}$</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

$T = 183.71$ Prob.(SB) $> 0.9999$
The market is never following the average growth; it is either super-exponentially accelerating or crashing.

Patterns of price trajectory during 0.5-1 year before each peak: Log-periodic power law.
Real-estate in the USA

Chart 1: HOME PRICES — STILL DEFLATING AFTER ALL THESE YEARS

United States

S&P/Case-Shiller Home Price Index: Composite 20
(Jan 2000 = 100, seasonally adjusted)

Source: Haver Analytics, Gluskin Sheff

W.-X. Zhou and D. Sornette, Is There a Real-Estate Bubble in the US?
Real U.S. House Prices between 1974 and 2014. Levels are shown in black and should be read on the left axis. Yearly growth rates are shown in blue and should be read on the right axis. Three peaks in the growth rate coincide with a correction in the levels. When the growth itself grows, the process becomes unstable and a correction follows (Source: Federal Reserve Bank of Dallas international house price dataset, http://www.dallasfed.org/institute/houseprice/)
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?)
  => Discrete hierarchy of group sizes

- Interplay between nonlinear positive and negative feedbacks and inertia

- Technical analysis: Impulse-retracting market wave analysis
  Elliot waves.... => self-fulfilling structures
The Fedwire interbank payment network.

a, This ‘furball’ depiction takes in thousands of banks and tens of thousands of links representing US$1.2 trillion in daily transactions.

b, The core of the network, with 66 banks accounting for 75% of the daily value of transfers, and with 25 of the banks being completely connected. Every participating bank, and every transaction, in the full network is known (akin to an ecologist knowing all species in an ecosystem, and all flows of energy and nutrients). So the behavior of the system can be analysed in great detail, on different timescales and, for example, in response to events such as 9/11.

network topology of the interbank payments transferred between commercial banks over the Fedwire® Funds Service

Rational expectation bubble models with social interactions

Key idea: return-risk relationship also holds during bubbles via the no-arbitrage (or close to no-arbitrage) condition.

Two classes of models:

1) Risk is first ($h(t)$: crash hazard rate controlled by herding noise traders) and returns have to come to remunerate against the risk

2) Return $\mu(t)$ is first (rate of returns controlled by positive feedbacks from bubble price) and risk (crash hazard rate) follows.

## Log-Periodic Power Law model and Extensions

**From the perspective of economics and econometrics:**

- Rational expectation bubble model in the presence of an (unknown) fundamental value
- Rational expectation bubble model in the presence of mean-reverting self-consistent residuals

**From the perspective of complex systems:**

- Rational expectation models of negative bubbles and anti-bubbles
- Rational expectation bubble model with beta-function-type solution of the RG (RG: renormalization group)
- Rational expectation bubble model with higher order solutions of the RG
The **Log-Periodic Power Law** is a combination of

**Classical methods of economics:**

**Complex systems approach:**
- The crash is a tipping point (critical point), around which the system exhibits self-similar properties:
  \[ f(K) = g(K) + \mu^{-1} f[R(K)] \]

Diffusive dynamics of log-price in the presence of discontinuous jump \( j \):
\[
\frac{dp}{p} = \mu(t) dt + \sigma(t) dW - \kappa dj
\]

Under the no-arbitrage condition
\[ E_t[dp] = 0 \]
the excess returns are proportional to the hazard rate:
\[ \mu(t) = \kappa h(t) \]

Where the log-periodic oscillations for hazard rate are the first order approximation of the RG solution.

\[
E[\ln p(t)] = A + B|t_c - t|^m + C|t_c - t|^m \cos[\omega \ln |t_c - t| - \phi]
\]
Positive feedback
\[ \frac{dp}{dt} = cp^d \quad \text{with } d > 1 \]
e.g. as a result of herding in dynamics of "noise traders"

Faster-than exponential growth
\[ p(t) \sim (t_c - t)^{-m} \]

Discrete scale invariance
\[ p(\lambda_n t) \sim \lambda_n^\alpha p(t), \quad n \in \mathbb{N} \]
as a result of RG solution around the tipping point (end of bubble)

Log-periodic oscillations
\[ p(t) \sim \cos[\omega \ln(t_c - t) + \phi] \]

Martingale hypothesis (no "free lunch")

Johansen-Ledoit-Sornette (JLS) model (Log-Periodic Power Law)
\[ E[\ln p(t)] = A + B|t_c - t|^m + C|t_c - t|^m \cos[\omega \ln |t_c - t| - \phi] \]
## Extensions of the Log-Periodic Power Law model

### Extensions from the perspective of economics and econometrics:

1. Rational expectation bubble model in the presence of an (unknown) fundamental value
2. Rational expectation bubble model in the presence of mean-reverting self-consistent residuals

### Extensions from the perspective of complex systems:

1. Rational expectation models of negative bubbles and anti-bubbles
2. Rational expectation bubble model with beta-function-type solution of the RG (RG: renormalization group)
3. Rational expectation bubble model with higher order solutions of the RG
Extensions of the Log-Periodic Power Law model

From the perspective of economics and econometrics:

- addresses the problem of the joint estimation of the fundamental and bubble components
- mechanism for bubble survival by lack of synchronization due to heterogenous beliefs on critical
- Rational expectation bubble model in the presence of mean-reverting self-consistent residuals

From the perspective of complex systems:

- Rational expectation models of negative bubbles and anti-bubbles
- Rational expectation bubble model with beta-function-type solution of the RG (RG: renormalization group)
- Rational expectation bubble model with higher order solutions of the RG
Construction of alarms

Prices converted in stochastic singular times for crash

\[ \tilde{T}_{c,i}(t) = t_i + \left( \frac{A - \ln p(t)}{B} \right)^{\frac{1}{1-\beta}}, \quad t = t_i - 899, \ldots, t_i. \]

\[ T_{c,i} = \frac{1}{750} \sum_{t=1}^{750} \tilde{T}_{c,i}(t) \quad \tilde{t}_{c,i}(t) = \tilde{T}_{c,i}(t) - T_{c,i} \]

Bubble diagnostic if

(i) \( 0 < \beta^* < 1 \) such that \( m > 2 \) (the signature of a positive feedback in the momentum price dynamics model) and

(ii) \(-25 \leq T_{c,i} - t_i \leq 50\), such that the estimated termination time of the bubble is close to the right side of the time window.

(iii) We further refine the filtering by considering three levels of significance quantified by the value of the exponent \( m \): level 1 (\( m > 2 \)), level 2 (\( m > 2.5 \)) and level 3 (\( m > 3 \)).

(iv) Dickey – Fuller unit – root test is rejected at \( 99.5\% \) significance level
<table>
<thead>
<tr>
<th>From the perspective of economics and econometrics:</th>
<th>From the perspective of complex systems:</th>
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</tbody>
</table>
A Consistent Model of ‘Explosive’ Financial Bubbles With Mean-Reversing Residuals

L. Lin, R. E. Ren and D. Sornette (2009)

http://papers.ssrn.com/abstract=1407574

\[
\frac{dI}{I} = \mu(t) dt + \sigma_Y dY + \sigma_W dW - \kappa dj
\]

\[
dY = -\alpha Y dt + dW.
\]
Rational Expectation formulation

Volatility Confined LPPL = \textbf{deterministic component} + Ornstein-Uhlenbeck process

\[ \text{LPPL fitting} \]

- \textbf{First model: based on Rational Expectation (RE) condition}
  - Original price process:
    \[ \frac{dp}{p} = \mu(t)dt + \sigma_YdY + \sigma_w dW - k dj \]
    
    \[ dY = -\alpha Y dt + dW \]
  - Stochastic Discount Factor:
    \[ \frac{d\Lambda_t}{\Lambda_t} = -rdt - \rho_Y dY - \rho wdW \]
  - Under no-arbitrage condition:
    \[ \mu(t) = \text{LPPL component} + \alpha(\sigma_Y - \rho_Y)Y_t^\circ \]
    
    \[ r_{i+1} = \ln p_{t_{i+1}} - \ln p_{t_i} \sim N(\Delta H_{t_{i+1}, t_i} - \alpha(\ln p_t - H_t), \sigma^2(t_{i+1} - t_i)) \]
    
    \[ H_t = A - B(t_c - t_i)^\beta \left[ 1 + \frac{C}{\sqrt{1 + \left( \frac{\omega}{\beta} \right)^2}} \cos(\omega \ln(t_c - t_i) + \phi) \right] \]

There is also a Behavioral discount factor formulation.
Bayesian approach
S&P500 1987 and Hong-Kong 1997
(answersing to Chang and Feigenbaum, 2006)

- Bayesian Factor
  \[ B(\text{model}_1, \text{model}_2) = \frac{\text{Marginal Likelihood (model}_1)}{\text{Marginal Likelihood (model}_2)} \]
- Model_1: Volatility Confined LPPL
- Prior probability
- Model_2: Black–Scholes model

Calculation Results
\[ \mathcal{L}_{\text{LPPL}}(2.5\% - 97.5\%) = 3173.546 - 3176.983 \]
\[ \mathcal{L}_{\text{BS}}(2.5\% - 97.5\%) = 3169.808 - 3170.097 \]

- \( \mu \sim N(0.0003, (0.01)^2) \)
- \( \tau \sim \Gamma(1.0, 10^5) \)
- \( \alpha \sim \Gamma(1.0, 0.05) \)
- \( A \sim N(6, 0.05) \)
- \( B \sim \Gamma(1, 0.01) \)
- \( C \sim U(0, 1) \)
- \( \beta \sim B(40, 30) \)
- \( \omega \sim \Gamma(16, 0.4) \)
- \( \phi \sim U(0, 2\pi) \)
- \( t_c - t_N \sim \Gamma(1, 30) \)

LPPL outperform BS here
Extensions of the Log-Periodic Power Law model

From the perspective of complex systems:

- Rational expectation models of negative bubbles and anti-bubbles
- Rational expectation bubble model with beta-function-type solution of the RG (RG: renormalization group)
- Rational expectation bubble model with higher order solutions of the RG
Extensions of the **Log-Periodic Power Law** model

From the perspective of complex systems:

- Rational expectation models of negative bubbles and anti-bubbles
Time

Price

Positive bubble
(the pressure builds up, generally in multiple stages)

Positive anti-bubble
(the pressure is progressively released, generally in multiple stages)

$\frac{\text{Price}}{\text{Time}} = \frac{\text{Pressure}}{\text{Build Time}}$

$\frac{\text{Price}}{\text{Time}} = \frac{\text{Negative Pressure}}{\text{Release Time}}$

Negative bubble
(pressure towards panic = herding in bearish phase)

Negative anti-bubble
(negative pressure released, progressively)
From the perspective of complex systems:

- Rational expectation models of negative bubbles and anti-bubbles
- Generalized Weierstrass functions
  (RG: renormalization group)
- Rational expectation bubble model with higher order solutions of the RG
Extensioons of the Log-Periodic Power Law model

From the perspective of complex systems:

Methodology for diagnosing bubbles

- Positive feedbacks of higher return anticipation
  - Super exponential price
  - Power law “Finite-time singularity”

- Positive feedback of negative spirals of crash expectation
  - Accelerating large-scale financial volatility
  - Log-periodic discrete scale-invariant patterns

The Log-Periodic Power Law (LPPL) model

\[
\ln(P) = A + B \left( t_c - t \right)^m + C \left( t_c - t \right)^m \cos \left( \omega \ln \left[ t_c - t \right] - \phi \right)
\]

A. Johansen, D. Sornette and O. Ledoit

Predictability of the 2007-XXXX crisis: 30 year History of bubbles and of Endogeneity

- Real-estate bubbles (2003-2006)
- MBS, CDOs bubble (2004-2007)
- Stock market bubble (2004-2007)
- Commodities and Oil bubbles (2006-2008)
- Debt bubbles


THE CRASH OF OCTOBER 1987

7 years

6 months
THE NASDAQ CRASH OF APRIL 2000

Super-exponential growth

Log(Nasdaq Composite) vs Date

97.5  98  98.5  99  99.5  00
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.
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.

The fingerprint of a positive (in green) and a negative bubble (in red) can be seen in the S&P500 before and during the credit crisis. Notice the distinct pattern combining oscillations with a faster-than-exponential rise (or drop for a negative bubble) in the price. For both bubbles, the LPPL model is fitted to the data in the window between $t_1$ and $t_2$. The critical time $t_c$ is given as a result of the model, it is the most probable time for a change in regime. This may be a crash after a positive bubble or a rally following a negative bubble.
Typical result of the calibration of the simple LPPL model to the oil price in US$ in shrinking windows with starting dates $t_{\text{start}}$ moving up towards the common last date $t_{\text{last}} = \text{May 27, 2008}$.

Total liabilities of the U.S. financial and non-financial sectors divided by the GDP

The data are taken from the Flow of Funds accounts of the U.S. (http://www.federalreserve.gov/releases/z1/), the non-financial sector includes the federal government, government sponsored entities, household and non-profit and non-financial business. The smooth curves show the fits of the models.

This picture demonstrates that debt levels are on unsustainable tracks that, according to our bubble models, are expected to reach a critical point towards the end of the present decade.

The efficiency of U.S. Non Financial debt. The dots tell you how many USD of GDP are generated for each USD of U.S. Non Financial debt. The black double line gives an LPPL model fit and the grey line gives the DS LPPL Trust index. When this index exceeds the 5% level, the process is not sustainable and there is a substantial risk for a critical transition of the system.
MISLEADING METRICS: THE GREAT MODERATION

Change of regime around 1980

Total U.S. Debt as a % of GDP


Sources: Lane and Milesi-Ferretti, 2007; Reinhart and Rogoff, 2009; Reinhart, Reinhart, and Rogoff, 2012, and sources cited therein; World Bank Quarterly External Debt Statistics, various years; World Bank Global Development Finance, various years.
The illusionary “PERPETUAL MONEY MACHINE”

Rate of profit and rate of accumulation: The United States + European Union + Japan
* Rate of accumulation = rate of growth rate of the net volume of capital * Rate of profit = profit/capital (base: 100 in 2000)
Sources and data of the graphs: http://hussonet.free.fr/toxicap.xls

The gap widens between the share of wages and the share of consumption (gray zones), so as to compensate for the difference between profit and accumulation. FINANCE allows increasing debt and virtual wealth growth... which can only be transitory (even if very long).

United States Share of wages and of private consumption in Gross Domestic Product (GDP)
Source of data and graphics: http://hussonet.free.fr/toxicap.xls
The Financial Crisis Observatory (FCO) is a scientific platform aimed at testing and quantifying rigorously, in a systematic way and on a large scale, the hypothesis that financial markets exhibit a degree of inefficiency and a potential for predictability, especially during regimes when bubbles develop.

Current analysis and forecasts

**CDS** (19 February 2009)
Our analysis has been performed on data kindly provided by Amjed Younis of Fortis on 19 February 2009. It consists of 3 data sets: credit default swaps (CDS); German bond futures prices; and spread evolution of several key euro zone sovereigns. The date range of the data is between 4 January 2006 and 18 February 2009. Our log-periodic power law (LPPL) analysis shows that credit default swaps appear bubbly, with a projected crash window of March-May, depending on the index used. German bond futures and European sovereign spreads do not appear bubbly. (See report for more information.)

**OIL** (27 May 2008)
Oil prices exhibited a record rise followed by a spectacular crash in 2008. The peak of $145.29 per barrel was set on 3 July 2008 and a recent low of $40.81 was recorded on 5 December, a level close to the bottom of the prior cycle in 2005. The analysis showed that the prior cycle followed a log-periodic power law.
The Financial Crisis Observatory

- **Hypothesis H1**: financial (and other) bubbles can be diagnosed in real-time before they end.

- **Hypothesis H2**: The termination of financial (and other) bubbles can be bracketed using probabilistic forecasts, with a reliability better than chance (which remains to be quantified).

The Financial Bubble Experiment
advanced diagnostics and forecasts of bubble terminations

- **Time@Risk**: Development of dynamical risk management methods
Financial Crisis Observatory

Overview

World Markets
- FTSE 100 (Pound/Pence)
- MDAX FRANKFURT (Euro)
- S&P 500 COMPOSITE (Dollar)
- SHANGHAI SE A SHARE (Yuan Renminbi)
- NIKKEI 225 STOCK AVERAGE (Yen)
- S&P BSE (100) NATIONAL (Rupee)

Commodities
- Gold Bullion LBMA Troy Ounce (Dollar)
- Crude Oil Brent Cur. Month FOB U.S./BBL (Dollar)
- Natural Gas Henry Hub U.S./MMBTU (Dollar)
- Corn No.2 Yellow Cents/Bushel (Cent)

US Sectors
- US-D6 Financials (Dollar)
- US-D6 Industrials (Dollar)
- US-D6 Oil & Gas (Dollar)
- US-D6 Technology (Dollar)
- US-D6 Utilities (Dollar)

US Large Cap
- BANK OF AMERICA (Dollar)
- GENERAL ELECTRIC (Dollar)
- JP MORGAN CHASE & CO. (Dollar)
- MICROSOFT (Dollar)
- WAL MART STORES (Dollar)
- APPLE (Dollar)
Proshares Ultra Silver | AGQ | t2 = 2011-04-25

price(t2) = 344.75
05/95: 2011-04-21 - 2011-05-23
median tc: 2011-05-02
ex-post tc = 2011-04-28
A crash has 50% chance of happening within the red band

Fits to the prices are shown and their extrapolation into the future

The alarm measures the strength of the signal

Date: 2011-12-26
Advanced real-estate bubble detection
with Dorsa Sanadgol and Diego Ardila
Advanced real-estate bubble detection

Left columns: 0<Tuning<1, Middle Columns: Tuning>1, Right columns: Real data, Tuning>1

Spain

Finland

France
### Advanced real-estate bubble detection

<table>
<thead>
<tr>
<th>Country</th>
<th>Graph 1</th>
<th>Graph 2</th>
<th>Graph 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
</tr>
<tr>
<td>Ireland</td>
<td><img src="image4.png" alt="Graph" /></td>
<td><img src="image5.png" alt="Graph" /></td>
<td><img src="image6.png" alt="Graph" /></td>
</tr>
<tr>
<td>Italy</td>
<td><img src="image7.png" alt="Graph" /></td>
<td><img src="image8.png" alt="Graph" /></td>
<td><img src="image9.png" alt="Graph" /></td>
</tr>
</tbody>
</table>
Advanced real-estate bubble detection

Left columns: 0<Tuning<1, Middle Columns: Tuning>1, Right columns: Real data, Tuning>1

Japan

South Korea

Luxembourg
Advanced real-estate bubble detection

Netherlands

Norway

New Zealand
### Advanced real-estate bubble detection

<table>
<thead>
<tr>
<th></th>
<th>Left columns: 0&lt;Tuning&lt;1</th>
<th>Middle Columns: Tuning&gt;1</th>
<th>Right columns: Real data, Tuning&gt;1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sweden</td>
<td>Swedish</td>
<td>Sweden</td>
</tr>
<tr>
<td></td>
<td>US</td>
<td>US</td>
<td>US</td>
</tr>
<tr>
<td></td>
<td>South Africa</td>
<td>South Africa</td>
<td>South Africa</td>
</tr>
</tbody>
</table>

The graphs illustrate the real-estate bubble detection for Sweden, the US, and South Africa. The left columns show the detection with tuning values between 0 and 1, middle columns with tuning values greater than 1, and the right columns with real data and tuning values greater than 1.
Overview of the different asset classes and indices

FCO Cockpit
(end of January 2014 calculations, ETHZ FCO)

- The **DS LPPL Confidence™** indicator measures the sensitivity of the observed bubble pattern to the chosen starting time. If the value is close to zero, it means that the pattern was found only in a few of the data windows that were analyzed; if the value is close to one, it means that the pattern is practically insensitive to the choice of the data window. A very low value of this indicator means that the signal is not robust and only pops up in one or two specific data windows, in that case, there is a risk of over-fitting or data snooping and the result should be interpreted with care;

- The **DS LPPL Trust™** indicator measures how closely the pattern matches the theoretical LPPL model, zero being a bad and one being a perfect match.
Overview of the different asset classes and indices monitored in the FCO Cockpit
(end of January 2014 calculations, ETHZ FCO)

436 systemic financial assets or indices in fixed income, equities, commodities and currencies

<table>
<thead>
<tr>
<th></th>
<th># Assets</th>
<th># Bubbles</th>
<th>% Bubbles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Income Indices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td>34</td>
<td>5</td>
<td>15%</td>
</tr>
<tr>
<td>Corporate</td>
<td>82</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>Equities Indices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>78</td>
<td>16</td>
<td>21%</td>
</tr>
<tr>
<td>US-Sector</td>
<td>64</td>
<td>32</td>
<td>50%</td>
</tr>
<tr>
<td>EUR-Sector</td>
<td>32</td>
<td>4</td>
<td>13%</td>
</tr>
<tr>
<td>Special</td>
<td>12</td>
<td>5</td>
<td>42%</td>
</tr>
<tr>
<td>Commodities</td>
<td>38</td>
<td>1</td>
<td>3%</td>
</tr>
<tr>
<td>Currencies</td>
<td>96</td>
<td>21</td>
<td>22%</td>
</tr>
<tr>
<td>Total</td>
<td>436</td>
<td>82</td>
<td>19%</td>
</tr>
</tbody>
</table>
Clear bubble signals in Spanish, Irish and Italian government bonds and in European financial subordinated bonds

recovery in the form of bubble exuberance

<table>
<thead>
<tr>
<th>Fixed Income Country Indices</th>
<th>Yearly Return</th>
<th>DS LPPL Trust</th>
<th>DS LPPL Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>iBoxx EUR Spain Index</td>
<td>12.5%</td>
<td>12.4%</td>
<td>18.3%</td>
</tr>
<tr>
<td>iBoxx EUR Ireland Index</td>
<td>12.4%</td>
<td>7.8%</td>
<td>11.1%</td>
</tr>
<tr>
<td>iBoxx EUR Italy Index</td>
<td>7.1%</td>
<td>5.2%</td>
<td>12.6%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fixed Income Sector Indices</th>
<th>Yearly Return</th>
<th>DS LPPL Trust</th>
<th>DS LPPL Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>iBoxx EUR Insurance Subordinated Index</td>
<td>10.8%</td>
<td>8.0%</td>
<td>13.6%</td>
</tr>
<tr>
<td>iBoxx EUR Insurance Index</td>
<td>7.3%</td>
<td>6.7%</td>
<td>8.7%</td>
</tr>
<tr>
<td>iBoxx EUR Financial Services Subordinated Index</td>
<td>10.2%</td>
<td>5.1%</td>
<td>9.5%</td>
</tr>
</tbody>
</table>
Energy products down -2%, agricultural products -12%, industrial metals -14% and precious metals down a whopping -29%.

Weak negative signal bubbles

This is in great dissonance with the equities bull market that we are riding now.

<table>
<thead>
<tr>
<th>Commodities</th>
<th>Yearly Return</th>
<th>DS LPPL Trust</th>
<th>DS LPPL Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat ER Index</td>
<td>-32%</td>
<td>4%</td>
<td>24%</td>
</tr>
<tr>
<td>Aluminum ER Index</td>
<td>-22%</td>
<td>4%</td>
<td>10%</td>
</tr>
<tr>
<td>Softs ER Index</td>
<td>-14%</td>
<td>2%</td>
<td>3%</td>
</tr>
<tr>
<td>Gold ER Index</td>
<td>-27%</td>
<td>2%</td>
<td>5%</td>
</tr>
</tbody>
</table>
Gold Bullion (Zurich) kg (995) CHF
Significant weakening of some emerging markets currencies

Negative bubble for the Argentine Peso, the Turkish Lira and the Indonesian Rupiah

Clear indication of an overreaction in this market.

<table>
<thead>
<tr>
<th>FX</th>
<th>Yearly Return</th>
<th>DS LPPL Trust</th>
<th>DS LPPL Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentine Peso/Euro</td>
<td>-29%</td>
<td>52%</td>
<td>54%</td>
</tr>
<tr>
<td>Argentine Peso/Swiss Franc</td>
<td>-29%</td>
<td>41%</td>
<td>45%</td>
</tr>
<tr>
<td>Argentine Peso/US Dollar</td>
<td>-39%</td>
<td>64%</td>
<td>76%</td>
</tr>
<tr>
<td>Indonesian Rupiah/Euro</td>
<td>-22%</td>
<td>6%</td>
<td>7%</td>
</tr>
<tr>
<td>Indonesian Rupiah/Swiss Franc</td>
<td>-22%</td>
<td>9%</td>
<td>8%</td>
</tr>
<tr>
<td>Indonesian Rupiah/US Dollar</td>
<td>-26%</td>
<td>8%</td>
<td>9%</td>
</tr>
<tr>
<td>Turkish Lira/Euro</td>
<td>-23%</td>
<td>18%</td>
<td>38%</td>
</tr>
<tr>
<td>Turkish Lira/Swiss Franc</td>
<td>-23%</td>
<td>17%</td>
<td>36%</td>
</tr>
<tr>
<td>Turkish Lira/US Dollar</td>
<td>-27%</td>
<td>9%</td>
<td>34%</td>
</tr>
</tbody>
</table>
Turkish lira vs ChF

- Prices
- DS LPPL Confidence

Financial Crisis Observatory

Entrepreneurial Risks

MTEC

ETH Eidgenössische Technische Hochschule Zürich

Swiss Federal Institute of Technology Zurich
**Worrying exuberance in equity markets**

*1 out 3 markets are diagnosed in bubble regime*

<table>
<thead>
<tr>
<th>Equities Country Indices</th>
<th>Yearly Return</th>
<th>DS LPPL Trust</th>
<th>DS LPPL Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASDAQ Composite Index</td>
<td>34%</td>
<td>25%</td>
<td>34%</td>
</tr>
<tr>
<td>Dubai Financial Market General Index</td>
<td>107%</td>
<td>20%</td>
<td>56%</td>
</tr>
<tr>
<td>ISEQ Overall Price Index</td>
<td>39%</td>
<td>15%</td>
<td>30%</td>
</tr>
<tr>
<td>Deutsche Boerse DAX Index</td>
<td>26%</td>
<td>14%</td>
<td>24%</td>
</tr>
<tr>
<td>EGX 30 Index</td>
<td>27%</td>
<td>14%</td>
<td>34%</td>
</tr>
<tr>
<td>Oslo Stock Exchange Equity Index</td>
<td>21%</td>
<td>12%</td>
<td>20%</td>
</tr>
<tr>
<td>OMX Copenhagen 20 Index</td>
<td>22%</td>
<td>12%</td>
<td>34%</td>
</tr>
<tr>
<td>Qatar Exchange General Index</td>
<td>30%</td>
<td>11%</td>
<td>31%</td>
</tr>
<tr>
<td>Dow Jones Composite Index</td>
<td>20%</td>
<td>9%</td>
<td>25%</td>
</tr>
<tr>
<td>Abu Dhabi index</td>
<td>66%</td>
<td>5%</td>
<td>20%</td>
</tr>
</tbody>
</table>

BRICS disappointed in the past year with the Brazilian Bovespa down -21%, the Russian RTS Index -12%, the Indian BSE +7% and the Shanghai Composite -11%.

This is to be compared with a Dow Jones index +20% and Eurostoxx +19%.
strong bubble warnings are flashing in internet retail equities (where Amazon is part of), life sciences, consumer finance, auto components, aerospace and defense, health care…

<table>
<thead>
<tr>
<th>Equities Sector Indices</th>
<th>Return</th>
<th>Trust</th>
<th>DS LPPL Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>S&amp;P 500 Internet Catalog Retail (Ind)</td>
<td>63%</td>
<td>40%</td>
<td>16%</td>
</tr>
<tr>
<td>S&amp;P 500 - Life Sciences Tools &amp; Services (Ind)</td>
<td>42%</td>
<td>36%</td>
<td>61%</td>
</tr>
<tr>
<td>S&amp;P 500 Industrial Conglomerate (Ind)</td>
<td>24%</td>
<td>21%</td>
<td>18%</td>
</tr>
<tr>
<td>S&amp;P 500 Auto Components (Industry)</td>
<td>63%</td>
<td>21%</td>
<td>18%</td>
</tr>
<tr>
<td>S&amp;P 500 Aerospace &amp; Defense (Industry)</td>
<td>49%</td>
<td>19%</td>
<td>18%</td>
</tr>
<tr>
<td>S&amp;P 500 Internet Software &amp; Services (Ind)</td>
<td>53%</td>
<td>17%</td>
<td>25%</td>
</tr>
<tr>
<td>S&amp;P 500 Consumer Finance (Industry)</td>
<td>43%</td>
<td>17%</td>
<td>41%</td>
</tr>
<tr>
<td>S&amp;P 500 Health Care Practional Services (Ind)</td>
<td>37%</td>
<td>16%</td>
<td>39%</td>
</tr>
<tr>
<td>S&amp;P 500 Office Electronics (Industry)</td>
<td>61%</td>
<td>15%</td>
<td>37%</td>
</tr>
<tr>
<td>S&amp;P 500 Chemicals</td>
<td>22%</td>
<td>15%</td>
<td>23%</td>
</tr>
<tr>
<td>S&amp;P 500 Electrical Equip (Industry)</td>
<td>28%</td>
<td>15%</td>
<td>14%</td>
</tr>
<tr>
<td>S&amp;P 500 Insurance (Industry)</td>
<td>32%</td>
<td>14%</td>
<td>15%</td>
</tr>
<tr>
<td>S&amp;P 500 Media (Industry)</td>
<td>35%</td>
<td>14%</td>
<td>35%</td>
</tr>
<tr>
<td>S&amp;P 500 Capital Markets (Industry)</td>
<td>33%</td>
<td>13%</td>
<td>41%</td>
</tr>
<tr>
<td>S&amp;P 500 - E Equip, Instrmnt &amp; Comp (Ind)</td>
<td>41%</td>
<td>12%</td>
<td>28%</td>
</tr>
<tr>
<td>S&amp;P 500 Semicond &amp; Semicond Equip (Ind)</td>
<td>27%</td>
<td>11%</td>
<td>29%</td>
</tr>
<tr>
<td>S&amp;P 500 Containers &amp; Packaging (Ind)</td>
<td>28%</td>
<td>11%</td>
<td>41%</td>
</tr>
<tr>
<td>S&amp;P 500 Software (Industry)</td>
<td>26%</td>
<td>10%</td>
<td>11%</td>
</tr>
<tr>
<td>S&amp;P 500 Road &amp; Rail (Industry)</td>
<td>28%</td>
<td>10%</td>
<td>28%</td>
</tr>
<tr>
<td>S&amp;P 500 Health Care Equip &amp; Spls (Ind)</td>
<td>22%</td>
<td>8%</td>
<td>23%</td>
</tr>
<tr>
<td>S&amp;P 500 - Pharmaceuticals (Industry)</td>
<td>27%</td>
<td>8%</td>
<td>13%</td>
</tr>
<tr>
<td>S&amp;P 500 Construction &amp; Eng (Ind)</td>
<td>27%</td>
<td>8%</td>
<td>10%</td>
</tr>
<tr>
<td>S&amp;P 500 - Biotechnology (Industry)</td>
<td>77%</td>
<td>8%</td>
<td>7%</td>
</tr>
<tr>
<td>S&amp;P 500 IT Services (Industry)</td>
<td>20%</td>
<td>6%</td>
<td>30%</td>
</tr>
<tr>
<td>S&amp;P 500 Commercial Banks (Industry)</td>
<td>32%</td>
<td>6%</td>
<td>22%</td>
</tr>
<tr>
<td>S&amp;P 500 Gas Utilities (Industry)</td>
<td>35%</td>
<td>6%</td>
<td>9%</td>
</tr>
</tbody>
</table>
Bubble warnings in social network companies, venture capital and dividend paying stock

<table>
<thead>
<tr>
<th>Equities Special Indices</th>
<th>Yearly Return</th>
<th>DS LPPL Trust</th>
<th>DS LPPL Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomson Reuters Venture Capital Index</td>
<td>50%</td>
<td>23%</td>
<td>22%</td>
</tr>
<tr>
<td>Solactive Social Networks Index</td>
<td>93%</td>
<td>12%</td>
<td>32%</td>
</tr>
<tr>
<td>DOW JONES GERMANY SELECT DIVIDEND 20 INDEX</td>
<td>24%</td>
<td>9%</td>
<td>7%</td>
</tr>
</tbody>
</table>
Regime shifts and change of regimes are the “norm” rather than the exception and will be growing in the future.

Financial markets exhibit transitions between phases of growth, exuberance and crises.

Most crises are endogenous and are the consequence of procyclical positive feedbacks that burst.

Based on a solid monitoring infrastructure, a dynamical time@risk management based on scenarios is possible by recognizing the ubiquitous positive feedbacks and “pockets of predictability”.

Highlights
Further Reading


D. Sornette and G. Ouillon, editors of the special issue of Eur. Phys. J. Special Topics on "Discussion and debate: from black swans to dragon-kings - Is there life beyond power laws?", volume 25, Number 1, pp. 1-373 (2012). http://www.springerlink.com/content/d5x6386kw2055740/?MUD=MP