The endogenous dynamics of markets: price impact, feedback loops and instabilities

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The Sacred Lore of Efficient Markets

• Why and how do market prices move?

• Efficient market theory:
  ▶ Rational Agents and Market in “Equilibrium”
  ▶ Prices reflect faithfully the Fundamental Value of assets and only move because of exogenous unpredictable news.

• Platonian markets that merely reveal fundamental values without influencing them
  ▶ or is it a mere tautology??
  ▶ If we had a way to check, we would not need markets!
The Sacred Lore of Efficient Markets

• Markets are fundamentally stable: any mispricing is arbitraged away by those who “know”

▷ but who exactly is supposed to know the price??

(An efficient market is such that prices are correct within a factor 2√ (F. Black))

• Crashes can only be exogenous, not induced by markets dynamics itself – oh really??

• Market stability is trivial and not even an interesting question (M. Friedman) – when feedback loops and instabilities are everywhere!
The Aftermath

• ...Yes, I’ve found a flaw [in the theory]. I don’t know how significant or permanent it is. But I’ve been very distressed by that fact.

The whole intellectual edifice collapsed!

_Alan Greenspan_, October 2008

• Macro models failed to predict the crisis and seemed incapable of explaining what was happening to the economy in a convincing manner. As a policy-maker during the crisis, I found the available models of limited help. In fact, I would go further: in the face of the crisis, we felt abandoned by conventional tools.

_Jean-Claude Trichet_, November 2010
Eyes Wide Shut

• I think that calls for a radical reworking of the field go too far. [...] The financial crisis did not discredit the usefulness of economic research and analysis by any means, still: The crisis should motivate economists to think further about their modeling of HUMAN BEHAVIOUR. Most economic researchers continue to work within the classical paradigm that assumes rational, self-interested behavior and the maximization of expected utility,

and: Another issue brought to the fore by the crisis is the need to better understand the determinants of LIQUIDITY in financial markets. The notion that financial assets can always be sold at prices close to their fundamental values is built into most economic analysis...

– Ben Bernanke, Princeton, September 2010
Indeed, Pr. Bernanke...(Human behaviour)

- Let’s face it: we are lost in the dark – swamped by noisy/superabundant information and radical uncertainty. We make errors, are subject to biases*, have regrets.

- We rely on heuristic rules to make suboptimal decisions
  - We are strongly influenced by the behaviour of others (who might have more information) – panic feeds panic
  - We are strongly influenced by past patterns (that might repeat) – trends feed trends
  - We are strongly risk adverse and very short-sighted – under-reactions and over-reactions

*see: D. Kahneman, *Thinking fast and slow*
Indeed, Pr. Bernanke...(Human behaviour)

- Theories that treat these effects consistently are still at an early stage
  
  ▶ see e.g. JPB, *Crises and collective socio-economic phenomena: cartoon models and challenges*, arXiv:1209.0453

  for a very recent review
Indeed, Pr. Bernanke...(Liquidity)

- **Liquidity and impact of trades**
  - **Empirical fact:** Trading, even with relatively small volumes in usual market conditions, moves prices in a measurable way – see below
  - This is called **PRICE IMPACT**

- **Impact transforms trades into price changes:** this is a key ingredient to understand *market dynamics and stability*

- **Impact also contributes to costs** and limits the size of trading strategies
Indeed, Pr. Bernanke...(Liquidity)

- **Efficient market story:** Informed agents successfully forecast short term price movements and trade accordingly. This results in correlations between trades and price changes, but uninformed trades should have no price impact – prices must stick to “Fundamental Values.”

- **An empirically rooted story:** since there is no easy way to distinguish “informed” from “non informed” traders, all trades do statistically impact prices (√)

  ▶ Agents believe/fear that trades might contain useful information they don’t have

  ▶ Even silly trades do impact market prices: a mechanism for feedback loops and avalanches
Endogenous crashes: Impact-induced instabilities

- Impact-induced feedback loops that can and do lead to crises
  - to name a few:
    - **Pattern following**: trends feed trends
    - **Crowd following**: panic feeds panic
    - **The risk aversion/liquidity** feedback loop and flash crash(es)
    - **Model induced feedback loops**: e.g. the BS feedback loop in 1987, the CDO feedback loop in 2008,...
    - **Regulation induced feedback loops**: mark to market, Value at Risk, margin calls,...
Some questions with empirical answers

- Financial markets offer Terabytes of information (daily) to try to investigate why and how prices move, and offer an ideal test bed for some fundamental questions in economics/finance:

  - A) Exogenous vs. Endogenous dynamics
    Are news really the main determinant of volatility?

  - B) How do trades impact prices?
    How sensitive is the market to trades?
A) Exogenous or endogenous dynamics?

- Yes, some news make prices jump, sometimes a lot, but jump freq. is much larger than news freq.

- On stocks, only $\sim 5\%$ of $4 - \sigma$ jumps can be attributed to news, most jumps appear to be endogenous.

- Similar conclusions on daily data in seminal papers (Cutler, Poterba, Summers; Shiller; Fair).

- NB: Private information should not induce jumps! (Kyle)

- Return distributions and ‘aftershocks’ (volatility relaxation) are markedly distinct.
Jump frequencies

Power-law distribution of news jumps and no-news jumps. With A. Joulin, D. Grunberg, A. Lefevre
Two jump types: Aftershocks

Volatility relaxation after news \((t^{-1}, \text{left})\) and endogenous jumps \((t^{-1/2}, \text{right})\). With A. Joulin, D. Grunberg, A. Lefevre
Power-law tails

Distribution of daily volatility moves on option markets or any other traded stuff: $\approx$ inverse cubic law
Multiscale intermittency

Excess volatility, with long range memory
– looks a lot like endogenous noise in complex systems
(Right: number of 1% jumps/min on S&P stocks)
Intermittency: Barkhausen noise, Turbulence

Slow, regular and featureless exogenous drive → Intermittent endogenous dynamics
A) Exogenous or endogenous dynamics?

- Excess volatility, with long range memory – looks like endogenous intermittent noise in complex systems (turbulence, Barkhausen noise, earthquakes, etc.)

- To a large extent: Universal observations in time, space & assets
  ▶ details may evolve, but main features remain

- These observations and analogies strongly suggest that endogenous dynamics is the solution to the excess volatility puzzle – NOT DUE TO FUNDAMENTALS
  ▶ Calibration of models indeed suggest that \( \approx 80\% \) of volatility is due to self-reflexive feedback of activity onto itself!
B) How do trades impact prices?

- **The fundamental paradox of liquid markets**: very small instantaneous liquidity but rather large daily volume
  
  ▶ Total *liquidity immediately accessible* on large US stocks: \( \sim 10^{-6} \) of market cap.
  
  ▶ Total daily traded volume: 5,000 times larger!
  
  ▶ Trades must be executed incrementally → “metaorders”

- **The (average) impact of a metaorder of size** \( Q \) **is singular**
  
  \[
  I(Q) \sim \sigma \sqrt{\frac{Q}{V}}
  \]

The square-root impact law

From ca. 500,000 CFM trades on futures markets
B) How do trades impact prices?

- A non trivial impact law:
  - Impact is concave (not additive): \(1 + 1 = 1.4142 < 2\)
  - Anomalously large impact of small trades: 1% of ADV pushes the price by 10% of its vol
  - Important: impact is usually small compared to volatility itself

- Why is impact so large (singular) and liquidity so small?
B) How do trades impact prices?

- Why is impact so large (singular) and liquidity so small?

- **A statistical theory of liquidity:**
  - Even with “zero-intelligence” agents: provided the price makes a random walk, and for generic order flow, the probability to have unexecuted orders close to the current price is linearly small
  - **Analytical result**
    \[
    \frac{\partial \rho}{\partial t} = \sigma^2 \frac{\partial^2 \rho}{\partial u^2} + \lambda(u) - \nu(u)\rho
    \]
    
    \(u\) : distance from current price
  - **Agent-based numerical simulations**
A linear liquidity profile

A generic result
B) How do trades impact prices?

- Why is impact so large (singular) and liquidity so small?

- **A statistical theory of liquidity:**
  - The probability to have unexecuted orders close to the current price is **linearly small**
  - Consequence: square-root impact!

\[
Q = \int_p^{p+I} \alpha u \, du = \frac{\alpha}{2} I^2 \rightarrow I \propto \sqrt{Q}
\]
B) How do trades impact prices?

- **Intrinsic Market Fragility!**
  - Markets are NOT obviously stable, Pr. Friedman

- Liquidity around current price is vanishingly small (eaten by the diffusive motion of prices): Market makers are needed!
  - **Liquidity fluctuations** are bound to play a crucial role: Micro-crisis and jumps in prices without news (cf. above)
  - Regulation must engineer stabilizing feedback loops
    - favoring liquidity when it is most needed (cf. debate about HFT)

- **Liquidity discount** to marked-to-market pricing: \( \sigma \sqrt{\frac{Q}{V}} \).
Conclusion – Endogenous crises?

- Financial markets, the economy, many other social phenomena exhibit crises, ruptures, sudden discontinuities that resemble far-from-equilibrium phenomena in complex systems

  ▶ Accumulating empirical evidence for positive feedback loops, self-reflexivity and endogenous crises

  → Most price jumps appear unrelated to any news at all

  → Market statistics share features with slowly driven, heterogeneous interacting systems with many equilibria

  ▶ Markets are critical (they operate in a regime of vanishing liquidity), making them particularly fragile
Conclusion – Endogenous crises?

- A major scientific program: infer “macro behaviour from micro-motives” (Schelling)

  ▶ Ideas & methods from statistical physics (multiple equilibria, collective behaviour, hysteresis, avalanches, etc.) are promising and provide interesting insights...

  ▶ ...but still a long way to go before old dogmas are abandoned....


  ▶ “CRISIS”: Complexity Research Initiative for Systemic Instabilities, led by D. Farmer and D. Delli Gatti
References

- This talk is based on the following papers:


References

