What have physicists accomplished in economics?

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What is the root cause of problems in economics?

An epistemology that does not employ the scientific method as it is used in other successful fields of science, in particular for accumulating and explaining empirical facts.

Descartes (1596-1650)

Newton (1642-1727)

Galileo (1564-1642)

Descartes' *Principia Philosophiae*

- Presents theories for origin and mechanism of the solar system, transmission of light, tides, power of magnets, fire in the heart, sensations of the mind, volcanos
- But full of statements that in hindsight look silly
  - Asserts blood vaporized in heart, recondensed in lungs
  - Claims the soul is located in Pineal gland
  - Assumes three types of matter, composed of corpuscles.

  Dazzling imagination and mathematics, but poor science.

  Reason for failure: Indifference to empirical test.

Difference between Galileo and Newton vs. Descartes illustrated by debate on action at a distance

Hypotheses non fingo

I have not as yet been able to discover the reason for these properties of gravity from phenomena, and I do not feign hypotheses. For whatever is not deduced from the phenomena must be called a hypothesis; and hypotheses, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phenomena, and afterwards rendered general by induction. (Issac Newton, 1712)

Contrast with “economic content”.

Epistemology of physics vs. financial economics

- Data should drive theory and select models. Weaker priors as to correct models.
- Social systems follow laws: primary goal is to identify and explain them.
- Mathematics is secondary.
  - Computer simulation is not shameful.
- Different view of the purpose of theory
  - Physics: Theories link facts
  - Econ: agents selfishly maximize preferences
- Functional forms are important

Different view on plausible assumptions

- Equilibrium: sometimes yes, sometimes no
  - alternatives to Nash, e.g. minority game
- Efficiency
  - informational efficiency good approximation at first order, but necessarily wrong at 2nd order; deviations drive key market phenomena
  - allocation efficiency is a poor approximation
- Rationality: Limited domain of validity.
- Structure vs. strategy: Institutional constraints more important than strategic reasoning.

Plausible assumptions

- Information: Traders are poorly informed, “fundamental price” difficult to know
- Most market dynamics are internally driven collective phenomena.

Largest S&P index moves 1946-87

(Cutler, Poterba, Summers 1989)

Rank	Date	%	NY Times explanation
1	Oct 19, 1987	-20.5	Worry over dollar decline and rate deficit Fear of US not supporting dollar
2	Oct 21, 1987	9.1	Interest rates continue to fall Deficit talks in Washington Bargain hunting
3	Oct 26, 1987	-8.3	Fear of budget deficits Margins calls Reaction to falling foreign stocks
4	Sep 3, 1946	-6.7	"No basic reason for the assault on prices"
5	May 28, 1962	-6.7	Kennedy forces rollback of steel price hike
6	Sep 26, 1955	-6.6	Eisenhower suffers heart attack
7	Jun 26, 1950	-5.4	Outbreak of Korean War
8	Oct 20, 1987	5.3	Investors looking for quality stocks
9	Sep 9, 1946	-5.2	Labor unrest in maritime and trucking
10	Oct 16, 1987	-5.2	Fear of trade deficit Fear of higher interest rates Tension with Iran
11	May 27, 1970	5.0	Rumors of change in economic policy "stock surge happened for no fundamental reasons"
12	Sep 11, 1986	-4.8	Foreign governments refuse to lower interest rates Crackdown on triple witching announced

Empirical regularities of markets

- Long memory
  - volatility, volume, order flow, liquidity
- Power law tails with characteristic exponents
  - price returns (3), volume (1.5), limit prices for order placement (1), Omori law (1)
- Market impact of metaorders under orderly execution follows universal square root law*
- Event timing follows Hawkes process
- Heavy tails in growth fluctuations
- Empirical studies of market ecology

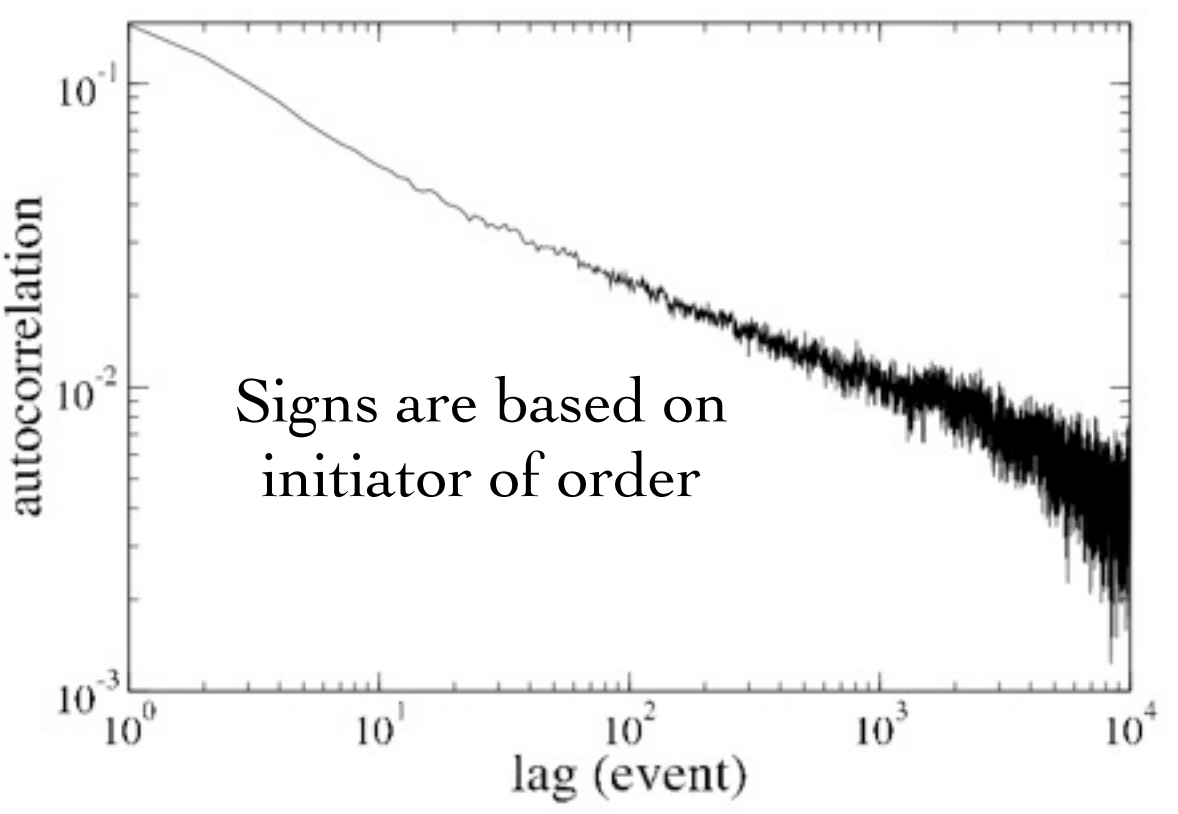
Theories

- Theory for equivalence of magnitude of spread, market impact and volatility.
- Explanations for power laws for returns
- Theory for long-memory and relation to heavy tails of metaorder size.
- Theories for market impact
- Equation of state for order flow vs. volatility

Autocorrelation of order flow (long memory of supply and demand)

- *Order flow* is the sequence of transaction signs.

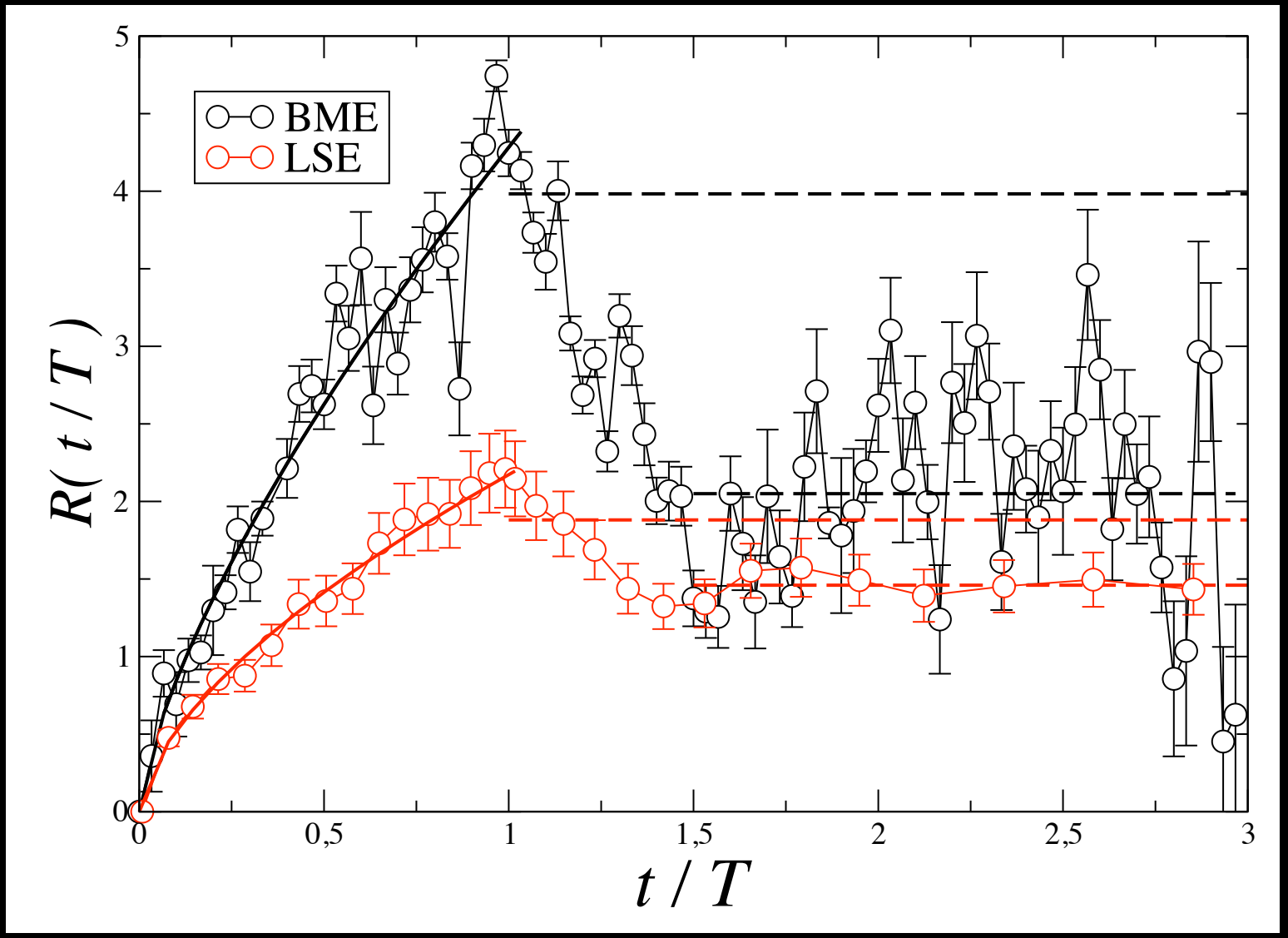
Autocorrelation of trade signs



Bouchaud, Gefen, Potters, and Wyart (2004)
Lillo and Farmer (2004)

Market impact

- Market impact is difference between price before trade starts and price at a later time. Here interested in large institutional trades executed in many pieces.


BME
LSE
R(t / T)
t / T
0
1
2
3
4
5
0
0,5
1
1,5
2
2,5
3

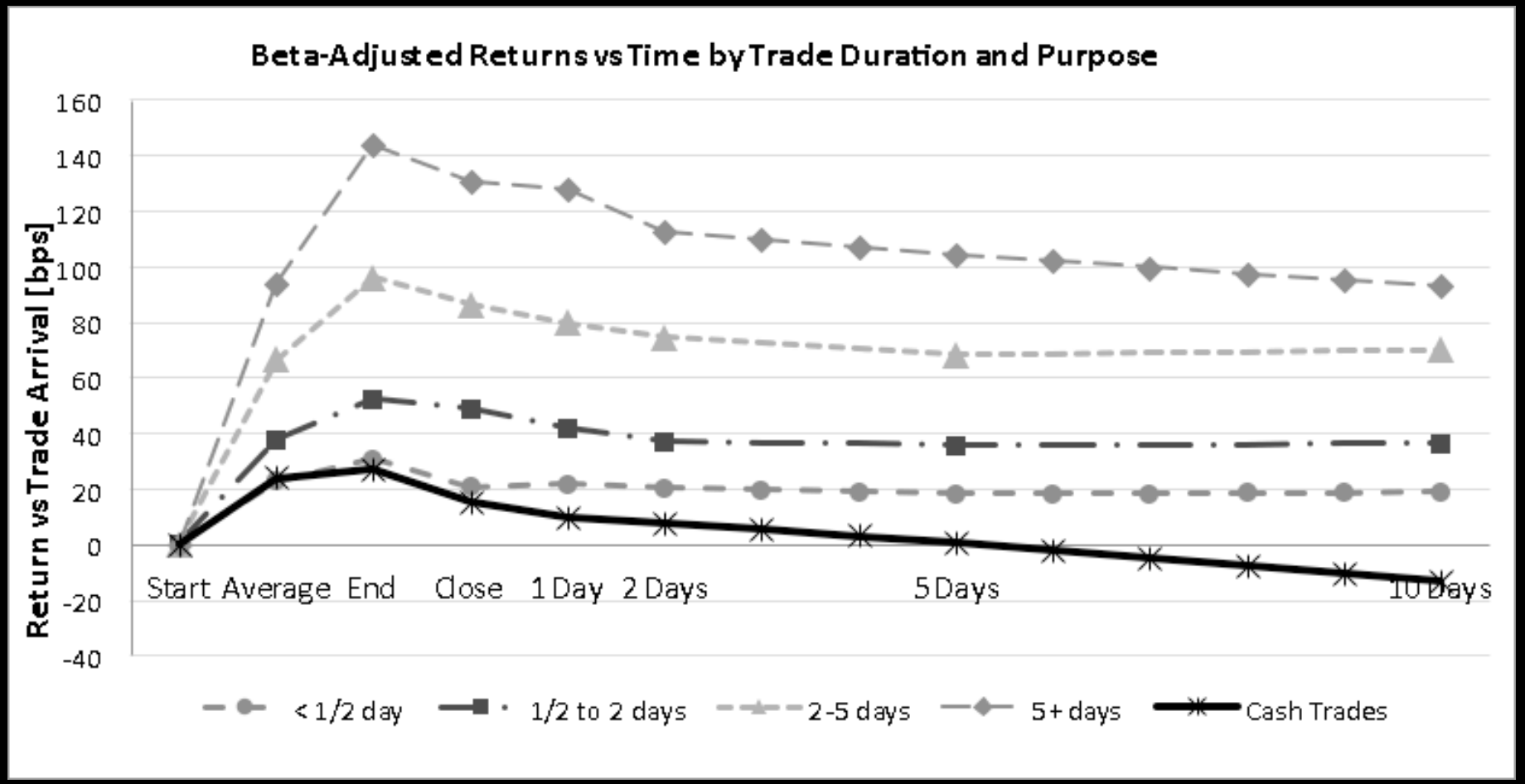
Theories for market impact

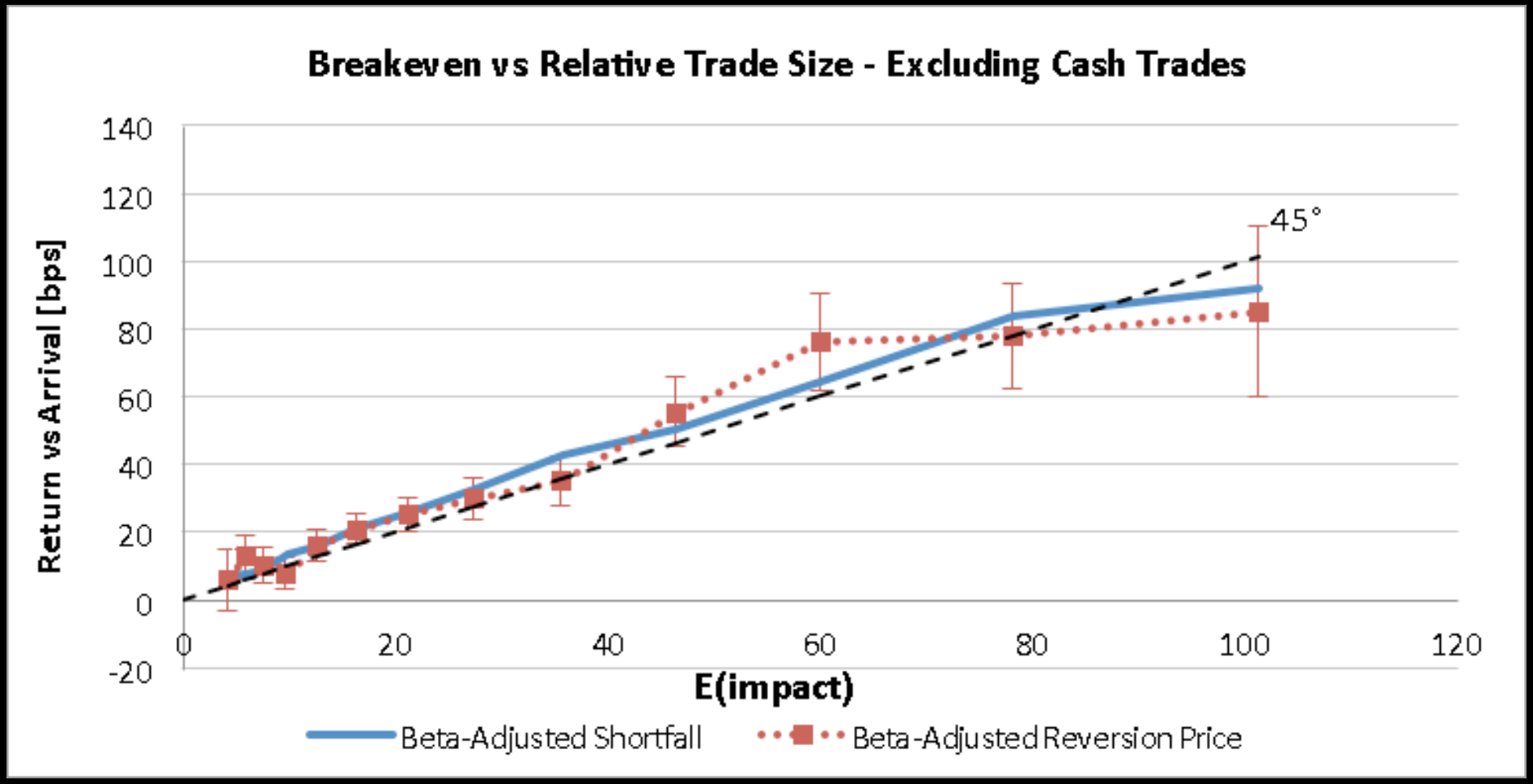
- Kyle (1985), Huberman and Stanzl (2004) Linear price impact
- Fair pricing: Nash equilibrium between metaorder size and liquidity provision. Predicts impact related to long-memory of order flow, reversion to 2/3 peak impact. (Farmer, Gerig, Lillo, Waelbroeck)
- Market impact constrained by price diffusion. Virtual limit order book must have linear depth profile. (Toth, Lemperiere, Deremble, Lataillade, Kockelkoren, Bouchaud)

Conjectured law for market impact

- Q = quantity to trade
- sigma = daily volatility
- V = daily volume
- Y = constant of order one

$$I(Q) = Y\sigma\sqrt{\frac{Q}{V}}$$


Beta-Adjusted Returns vs Time by Trade Duration and Purpose
Return vs Trade Arrival [bps]
160
140
120
100
80
60
40
20
0
-20
-40
Start Average End
Close
1 Day
2 Days
5 Days
10 Days
< 1/2 day
1/2 to 2 days
2-5 days
5+ days
Cash Trades


Breakeven vs Relative Trade Size - Excluding Cash Trades
Return vs Arrival [bps]
140
120
100
80
60
40
20
0
-20
0
20
40
60
80
100
120
45°
E(impact)
Beta-Adjusted Shortfall
Beta-Adjusted Reversion Price

Many economic phenomena are far from equilibrium

joint work with Tobias Galla, James Sanders

- Make up games at random.
- Players use reinforcement learning to learn strategy for playing game.
- Complicated games: Lots of moves, e.g. stock market
- Two parameters:

Γ = Competition parameter

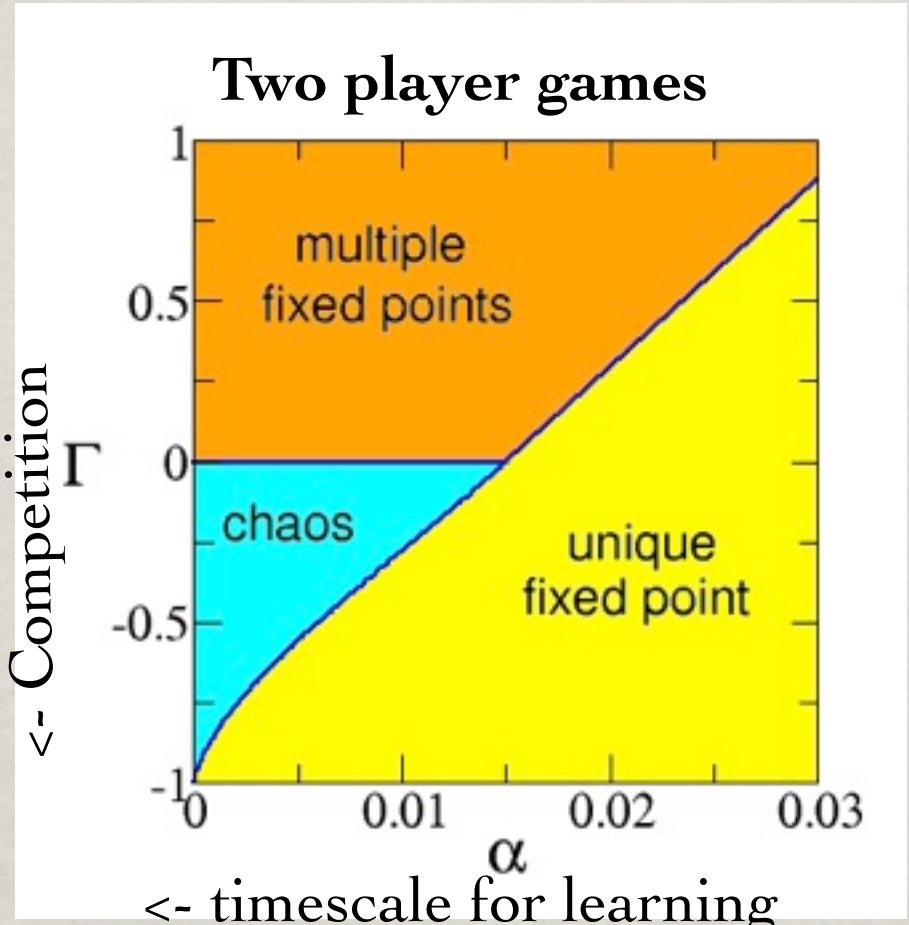
= correlation between payoffs of players

α = memory parameter

$\alpha = 0$: infinite memory

$\alpha > 0$: recent data gets more weight

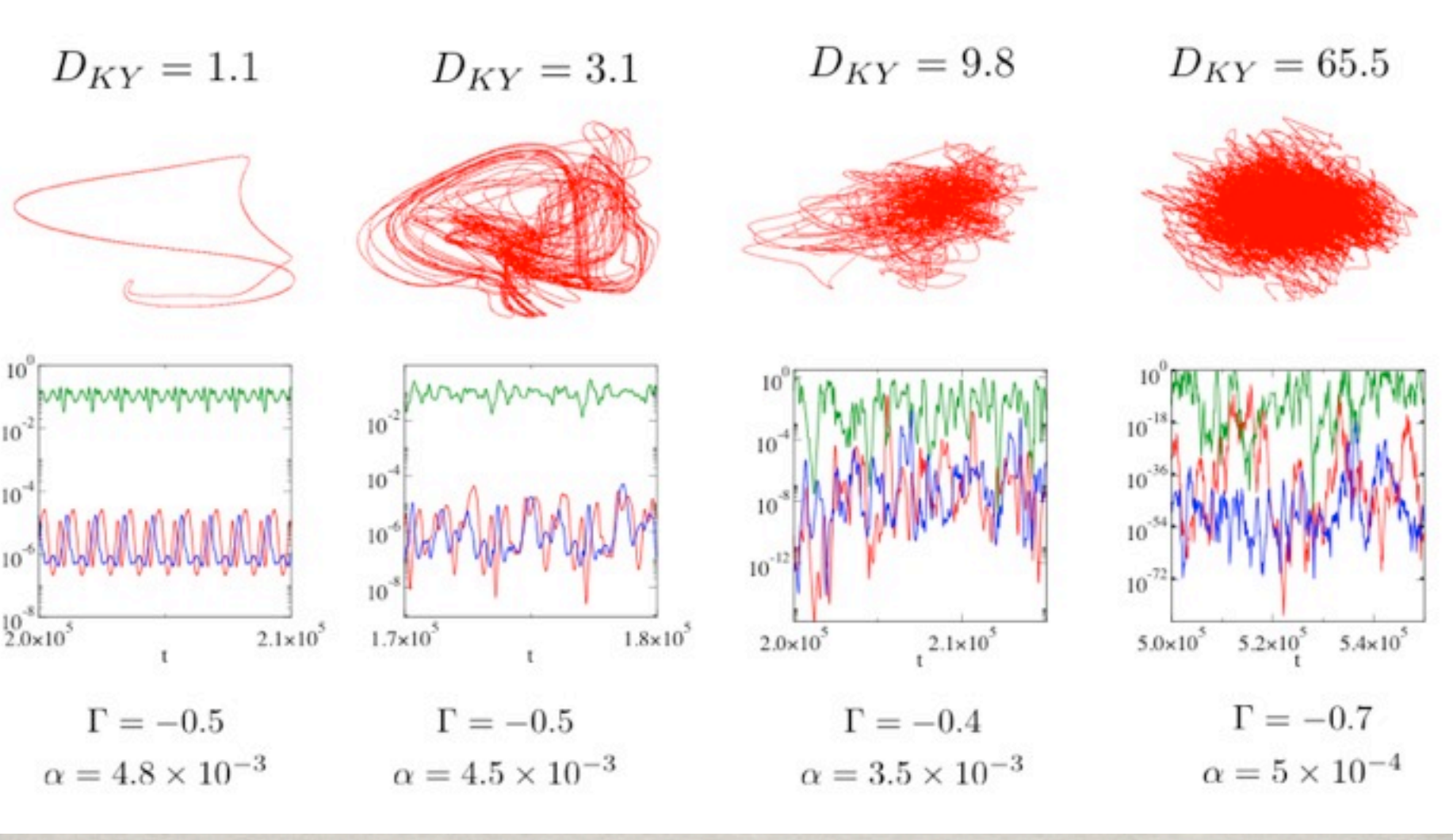
When is equilibrium useful?



For M player competitive games chaos takes over at large M

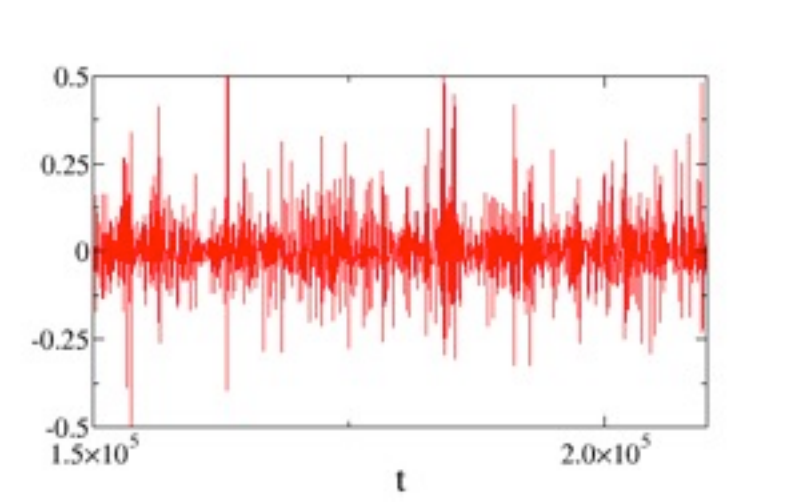
Punchline: Equilibrium methods fail for complex games with many players!

Strategy dynamics



Non-equilibrium behavior of typical games

- In chaotic regime strategies never settle down
  - ~ appearance of "fads"
  - ~ reflexivity
- Players use simple heuristics
- Motivates agent-based modeling
- Clustered volatility in time dependence of payoffs



Is market efficiency only approach to understanding systemic risk?

- How to understand market failures such as instabilities and feedback loops leading to systemic risk or crashes?
- Two paths:
  - neoclassical approach with relaxed assumptions: asymmetric information, institutional constraints, incomplete markets, ...
  - Acknowledge deviations from efficiency at outset, and investigate how they affect markets.

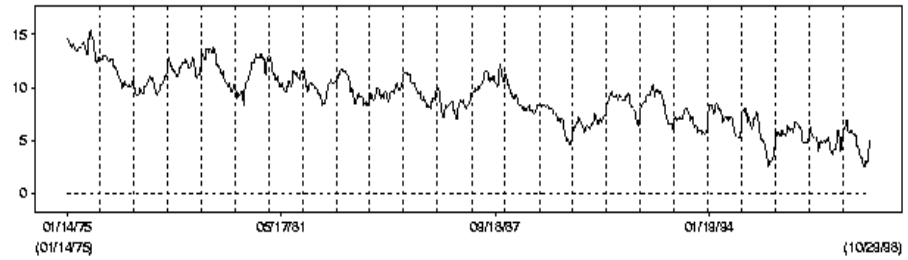
Friedman paradox

- Market efficiency requires arbitrageurs but arbitrageurs require inefficient markets.
  - see also Grossman and Stiglitz
  - markets necessarily deviate from efficiency
  - It is difficult but not impossible to make consistent profits (e.g. Prediction Company)
  - markets are (informationally) efficient at first order but necessarily inefficient at second order
  - standard approach assumes perfect efficiency
- Do deviations from efficiency drive market instabilities, e.g. systemic risk?

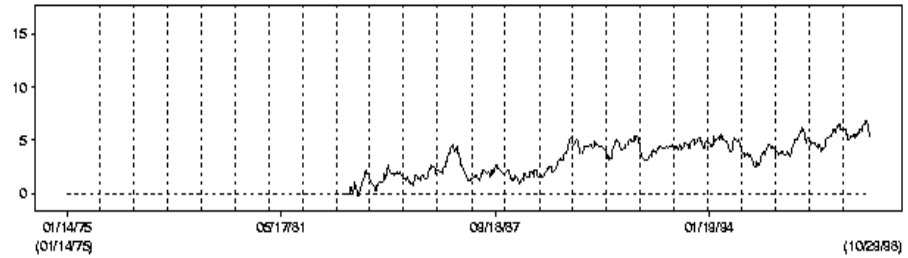
Market efficiency?

Strength of two proprietary predictive signals (1975 - 1998), (measured as smoothed average % correlation between signal and future weekly return)

Signal 1:



Signal 2:



Market ecology

- Inefficiencies driven by demand for diversification and liquidity. Supports a rich ecology of predators.
- Market impact makes it possible to understand market food web in terms of pairwise interactions.
- Trading moves prices, price movements cause trading, ...
  - on longer timescale profits affect the ecology
- Instabilities in price dynamics depend on ecology.
- Hypothesis: Many market malfunctions driven by disruptions of evolutionary dynamics of ecology.

  Market force, ecology and evolution (Farmer, 2002)

  An ecological perspective on the future of computer trading, Farmer and Skouras, (driver review, 2012)

Market ecology

- Key question is to identify inefficiencies and study their interactions.
- How are inefficiencies removed?
- What price dynamics does this lead to?
- How is trading capital redistributed as a result (i.e. how is ecology reconfigured)?
- Makes it possible to identify instabilities