

How market ecology, leverage and network dynamics explain market malfunction

Bank of Canada

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What causes markets to malfunction?

- Do markets malfunction?
- If so, efficient markets cannot explain why
- What can regulators do to shepherd markets and reduce malfunctions?

Efficient market theory

- Prices reflect fundamental values. Prices change only due to new information.
- Fisher Black: “I believe in efficient markets. Prices are within a factor of two of fundamental values 90% of the time.”
- Grossman Stiglitz: No incentive for arbitrageurs
- Markets are efficient at first order, but inefficient at second order

Do
markets
have
endogenous
dynamics?

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

Market ecology hypothesis

(Farmer, 2002)

- Investment strategies \Leftrightarrow species
- Wealth invested in strategy \Leftrightarrow population
- Strategies feed on market inefficiencies
- Wealth invested in different strategies changes in response to profits and losses and investor flows
- Profits and losses depend on the rest of the ecosystem, i.e. on wealth of other strategies

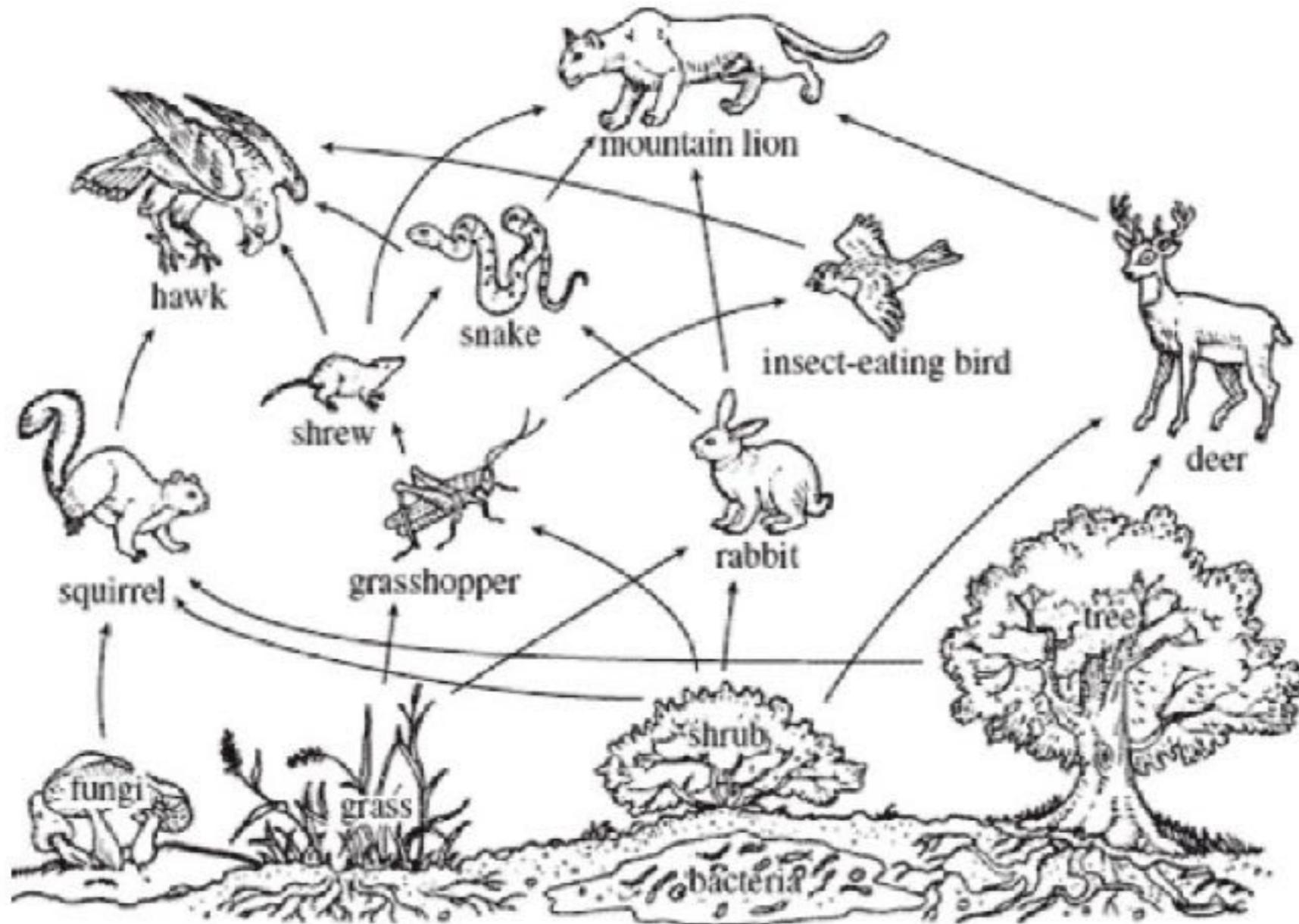
Market ecology hypothesis

- Market is a stochastic dynamical system that responds to external information but has rich endogenous dynamics which can be used to understand market malfunctions
- Can import tools and styles of thinking from biological study of ecology
- Provides a conceptual framework to interpret earlier ABM results (SFI stock market, Brock and Hommes, 1992)

Predicting malfunction in a model ecosystem

- “How market ecology explains market malfunction”, Scholl et al, PNAS, 2021
- Studied three representative strategies
- Approach to efficiency is slow and noisy
- Can define “market food web”
 - Community matrix describes relations between strategies
 - can be competitive, predator-prey, mutualistic
- Volatility and mispricing are predictable based on wealth of strategies

Food Web



Predicting Mkt Malfunction

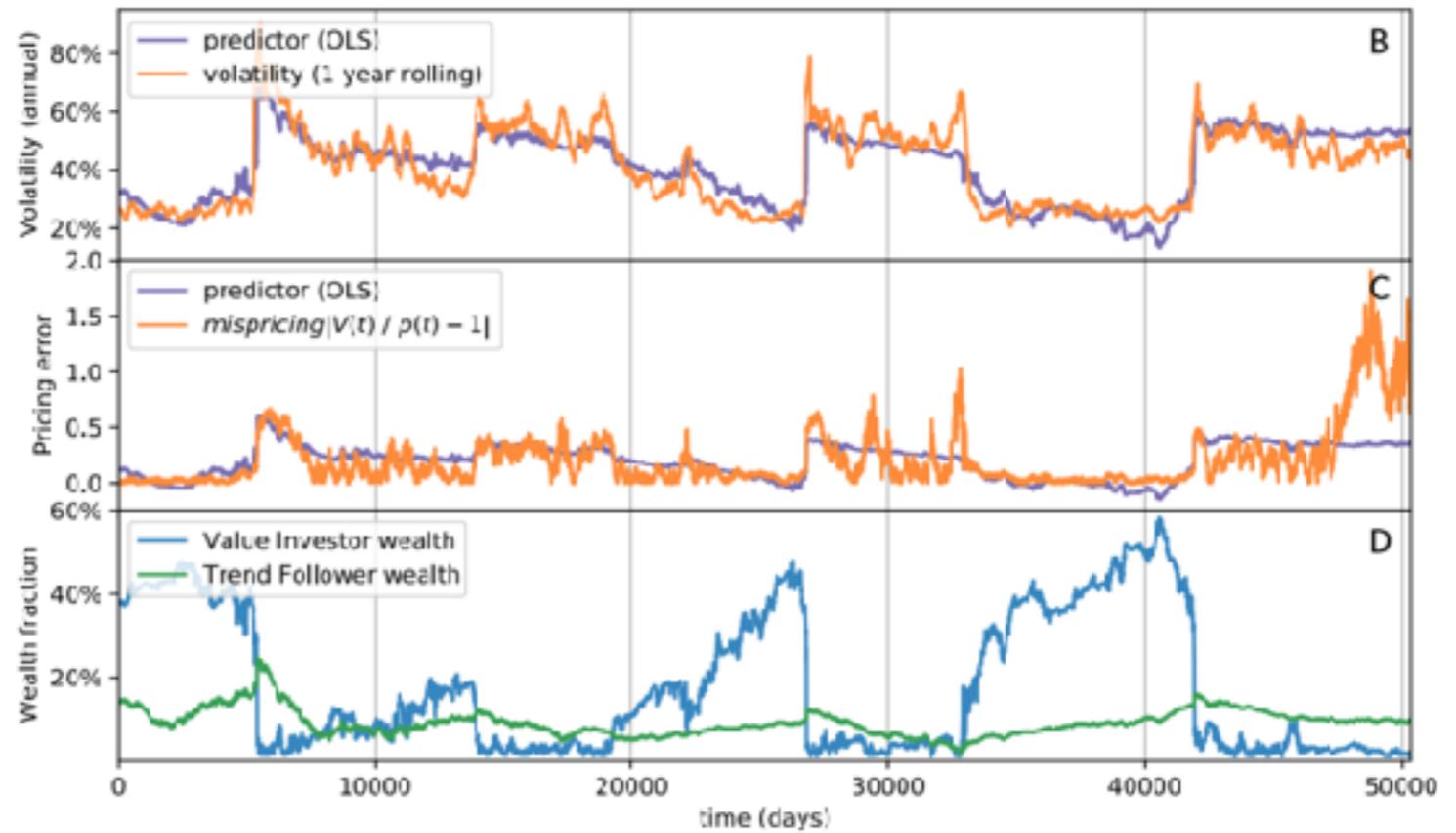
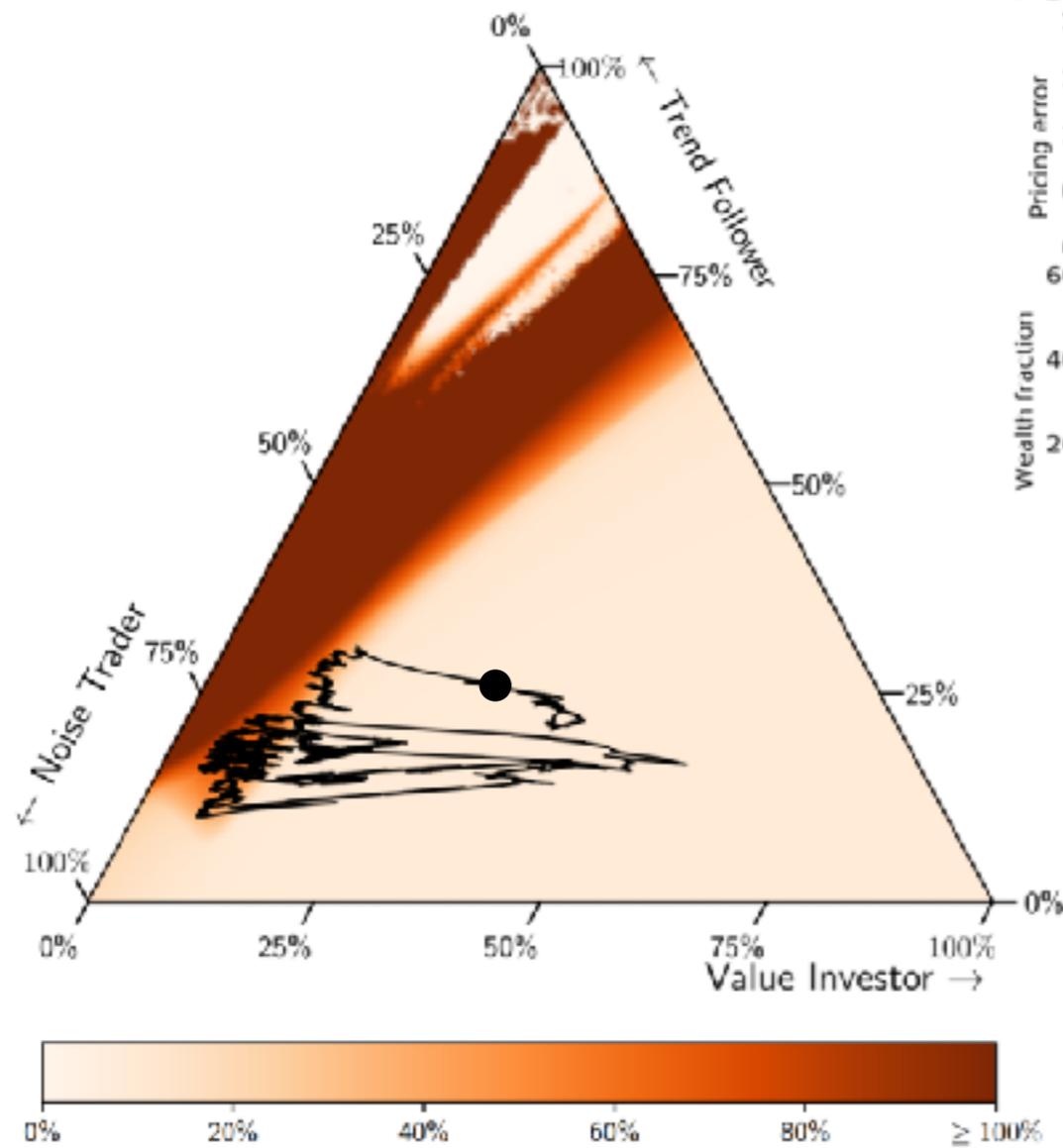


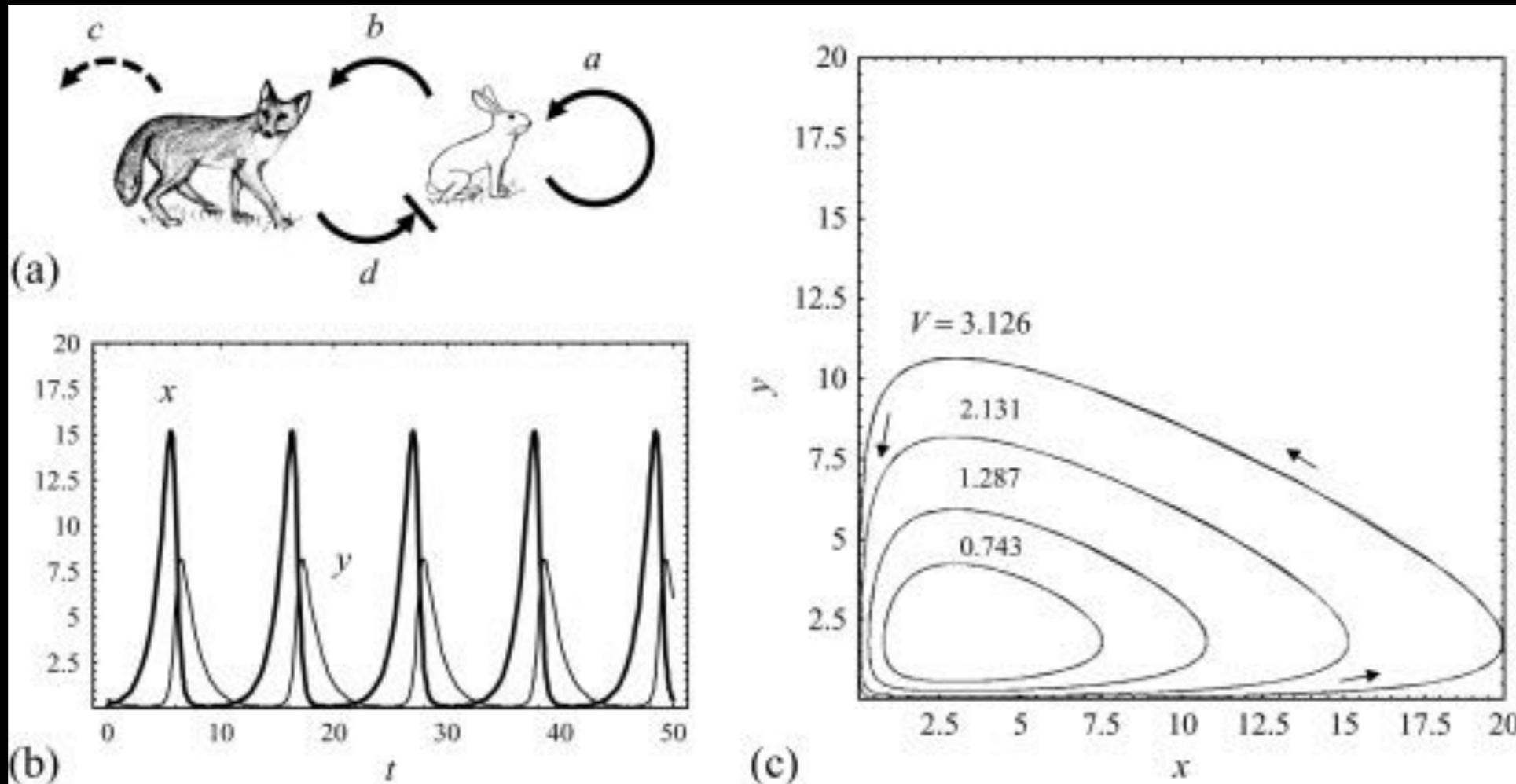
Table 3. Multivariate regressions with volatility and mispricing as dependent variables and the funds' wealth as independent variables.

volatility		
independent variable	coefficient	observations
1		50,397
noise trader	2.4	10
value investor	-68	-249
trend follower	107	169
mispricing		
independent variable	coefficient	observations
1		50,397
noise trader	-0.15	-18
value investor	-1.02	-107
trend follower	1.5	69

Implications for regulators?

- Regulators have data needed to test market ecology hypothesis
- If true, tracking strategy wealths will allow them to monitor markets, predict when they are in danger of failing, and mitigate crises or even prevent them from happening

Endogenous dynamics?



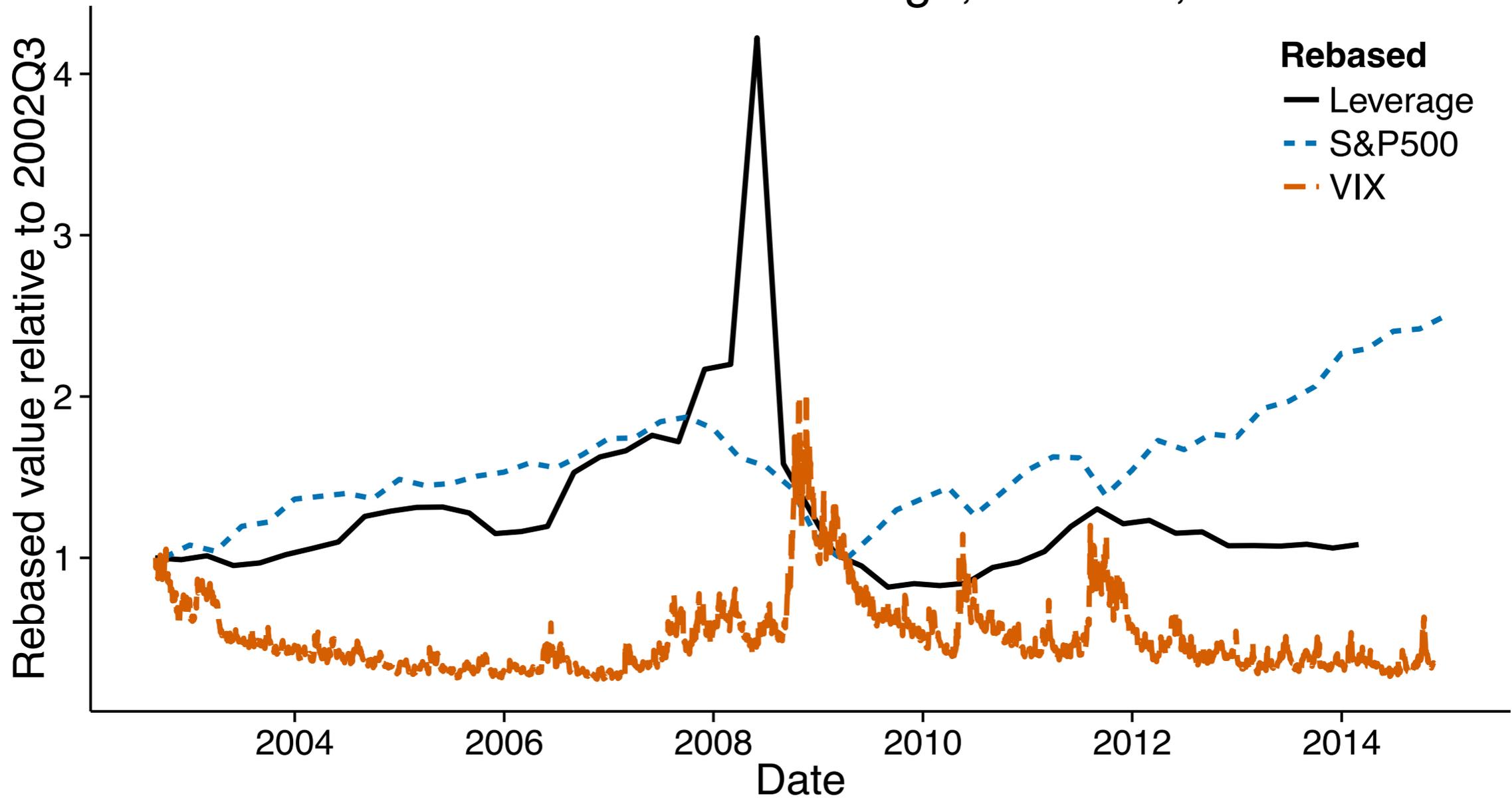
Lotka-Volterra dynamics

Also possible in markets (Farmer, 2002)

Hypothesis: Leverage can cause endogenous dynamics

Run up to crisis of 2008

US Broker Dealers Leverage, S&P500, VIX



The Basel Leverage Cycle Model

(Dynamics of the leverage cycle, Aymanns and Farmer, 2015)

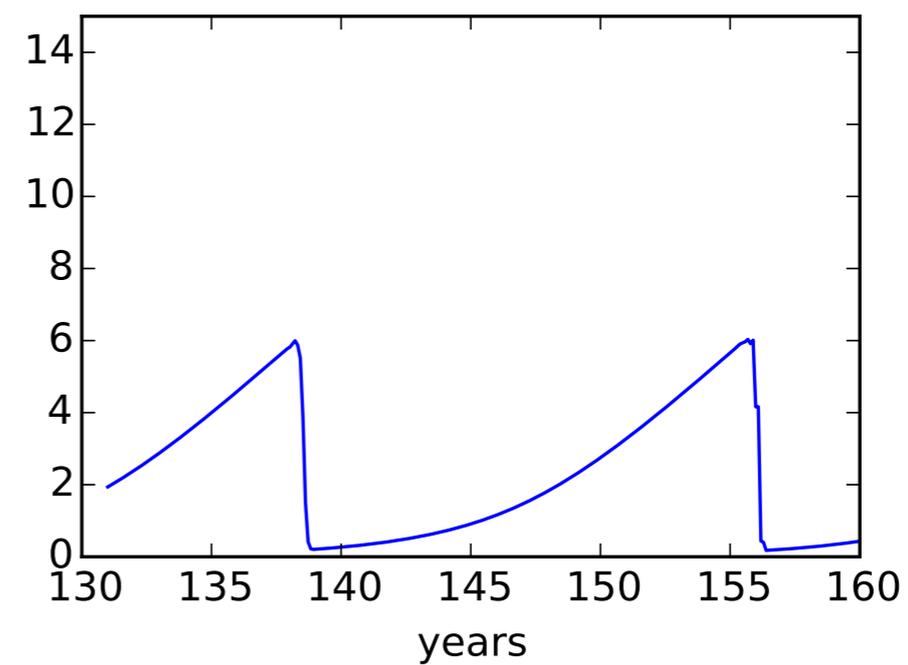
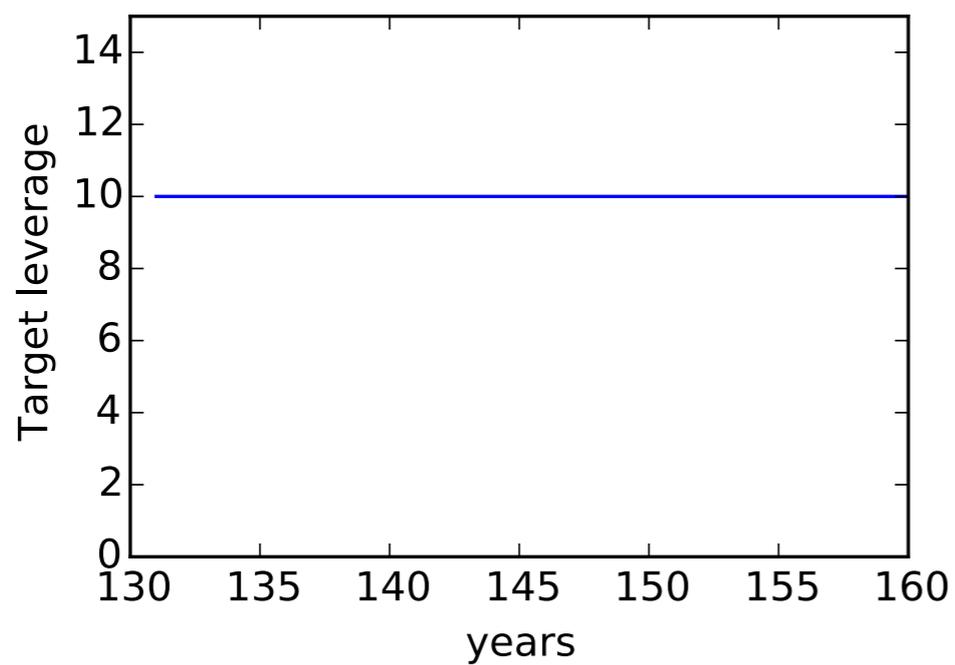
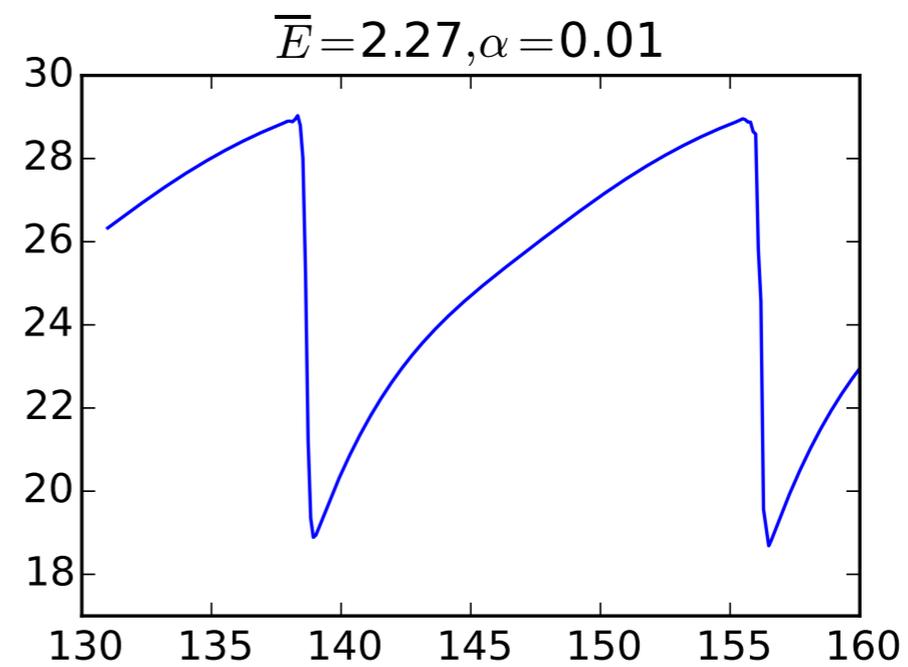
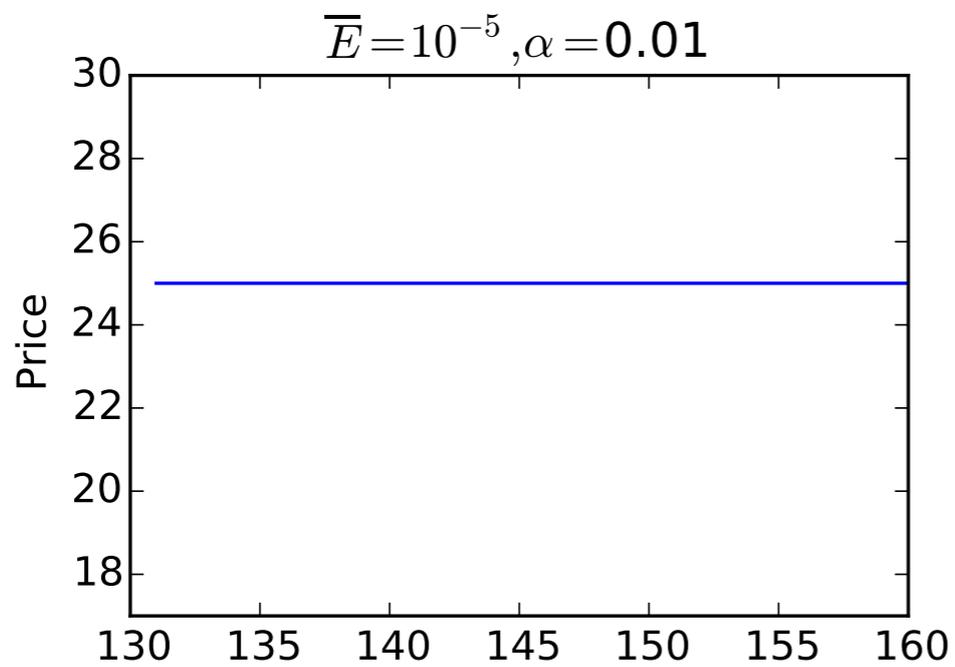
(Taming the Leverage Cycle, Aymanns, Caccioli, Farmer, Tan, 2016)

- Two agents: investment bank and fundamentalist
- One risky asset + cash
- Four assumptions:
 - Bank uses exponential moving average of historical volatility to estimate expected volatility
 - Basel II risk management (VaR) sets leverage target
 - Price formation (supply = demand) (Increasing leverage target => buying => price of asset rises)
 - Fundamentalist buys undervalued asset & v.v.

Price and leverage vs. time

Small banking sector

Large banking sector



Endogenous dynamics is due to bounded rationality + instability



See Y. Asano et al., PNAS, 2021
for an example of endogenous
dynamics from a boundedly
rational modification of a
standard macromodel

Leverage destabilizes markets

- Leverage unwinds by selling into a falling market — it is inherently destabilizing
- Thurner et al, Quantitative Finance, 2012
 - model of heterogeneous value investors
 - show how clustered volatility and fat tails appear as leverage is switched on
- Statistics of financial markets are almost identical to those of fluid turbulence (Ghoshghaie et al., Nature, 1996)
- Leverage is like forcing in fluid dynamics

Financial stability of European banking system

Farmer et al., Bank of England working paper, 2020

Alissa Kleinnijenhuis

- Tracks every SIFI in Europe
- Simulates propagation of financial contagion
- Different types of institutions in the ecosystem
 - Don't know strategies, but know binding constraints
- Shows that traditional stress tests dramatically underestimate overall impact of shocks, which are amplified by systemic interactions

A Generic Methodology for System-Wide Stress Testing



- Python-based simulation
 - Simulation engine also available in C++
 - Library online
- Five building blocks ('ontology')



Systemic implications of the bail-in design (Kleinnijenhuis et al., 2021)

- Demonstrates that a well-designed bail-in is effective in resolving financial crises, but an ill-designed bail-in can make things worse.
- The current bail-in design may be in the regime of instability

The complexity economics revolution

- Use behavioral agent decision-making
 - Gigerenzer: Ecological rationality
 - Heuristics
 - Learning algorithms
- Model dynamics through simulation
 - Equilibrium might or might not emerge
 - Unlikely when competitive, complicated (Pangallo et al, 2019) or unstable (Hommes)
- Model from the bottom up

Economics can be done without assuming equilibrium!

- No utility functions (or anything similar)
- No rational agents
- No perfect optimizers

Advantages

- Verisimilitude: “as is” rather than “as if”
- Easily incorporates behavioral economics
- Endogenous dynamics often emerges
- Scalable: Can capture complicated structure
 - Can model “real world” economies

Disadvantages

- Less formal structure
- Different set of skills are required
- Calibration is challenging
 - Works better with microdata
- Remains to be properly developed

Opportunity for regulators

- Can potentially monitor and simulate the global financial system
- Requires collecting data about balance sheets of major financial institutions
- Meteorology provides a good model
- Could mitigate or avert financial crises