

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

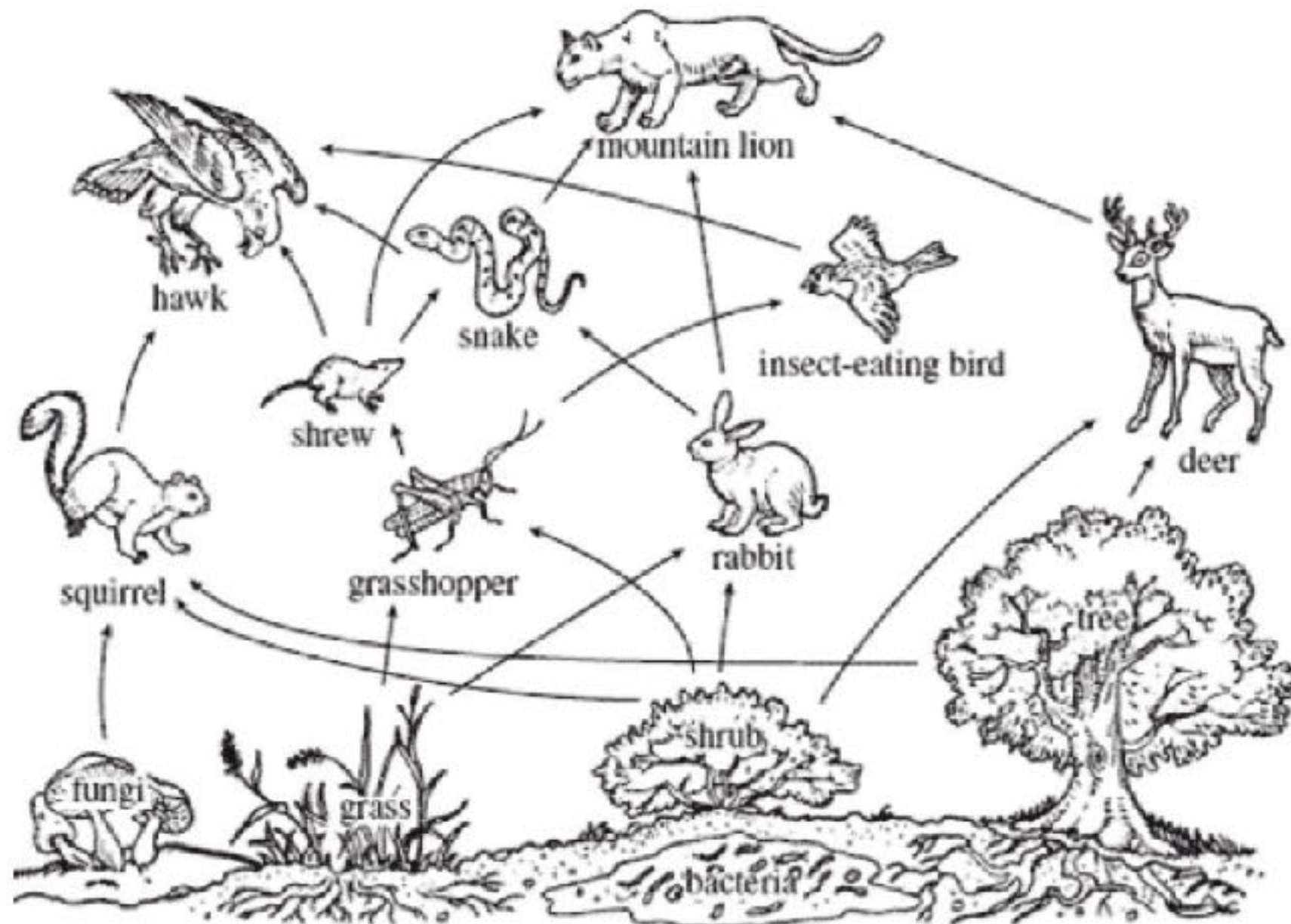
Market ecology hypothesis

- 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



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

Predicting Mkt Malfunction

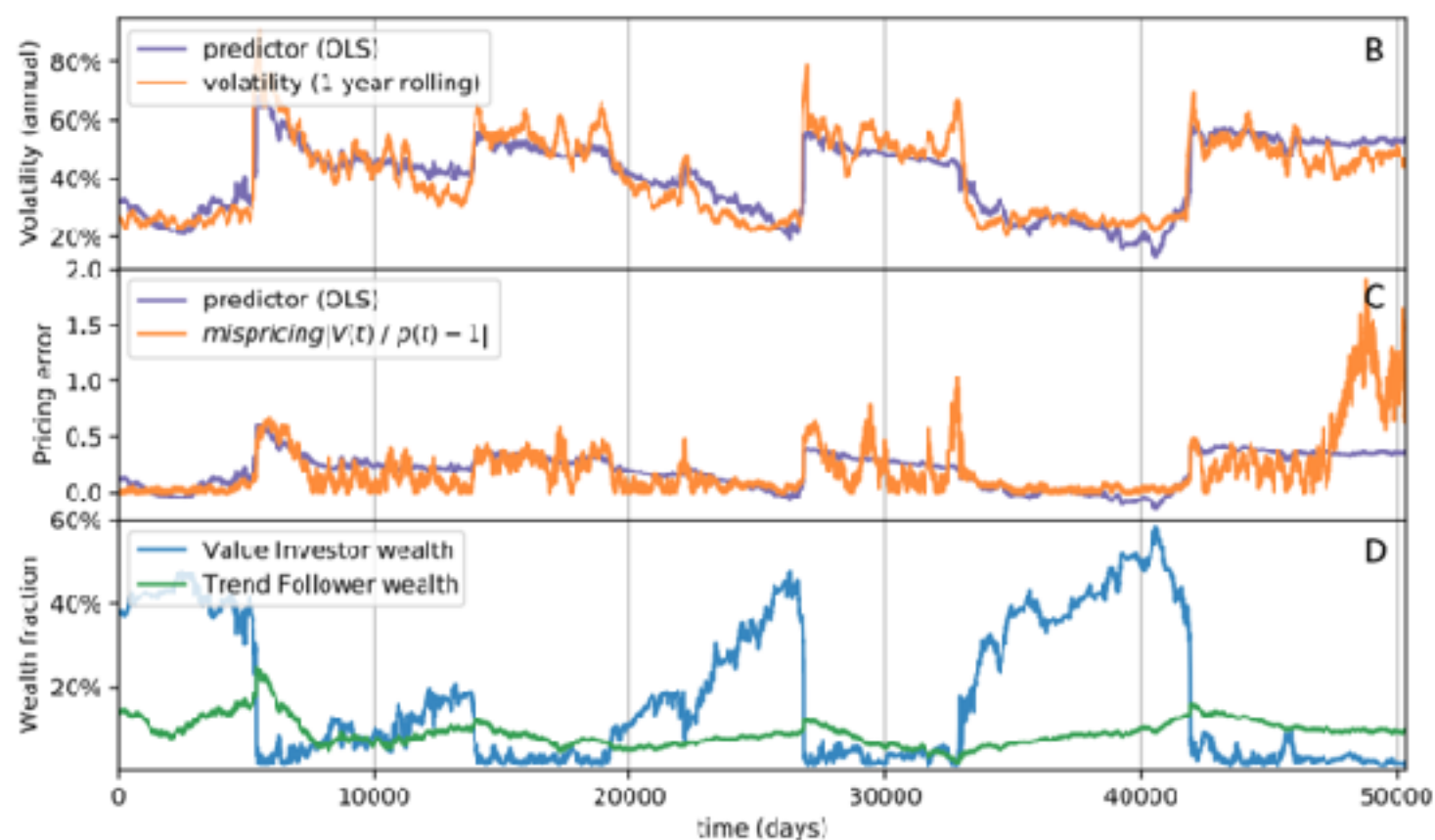
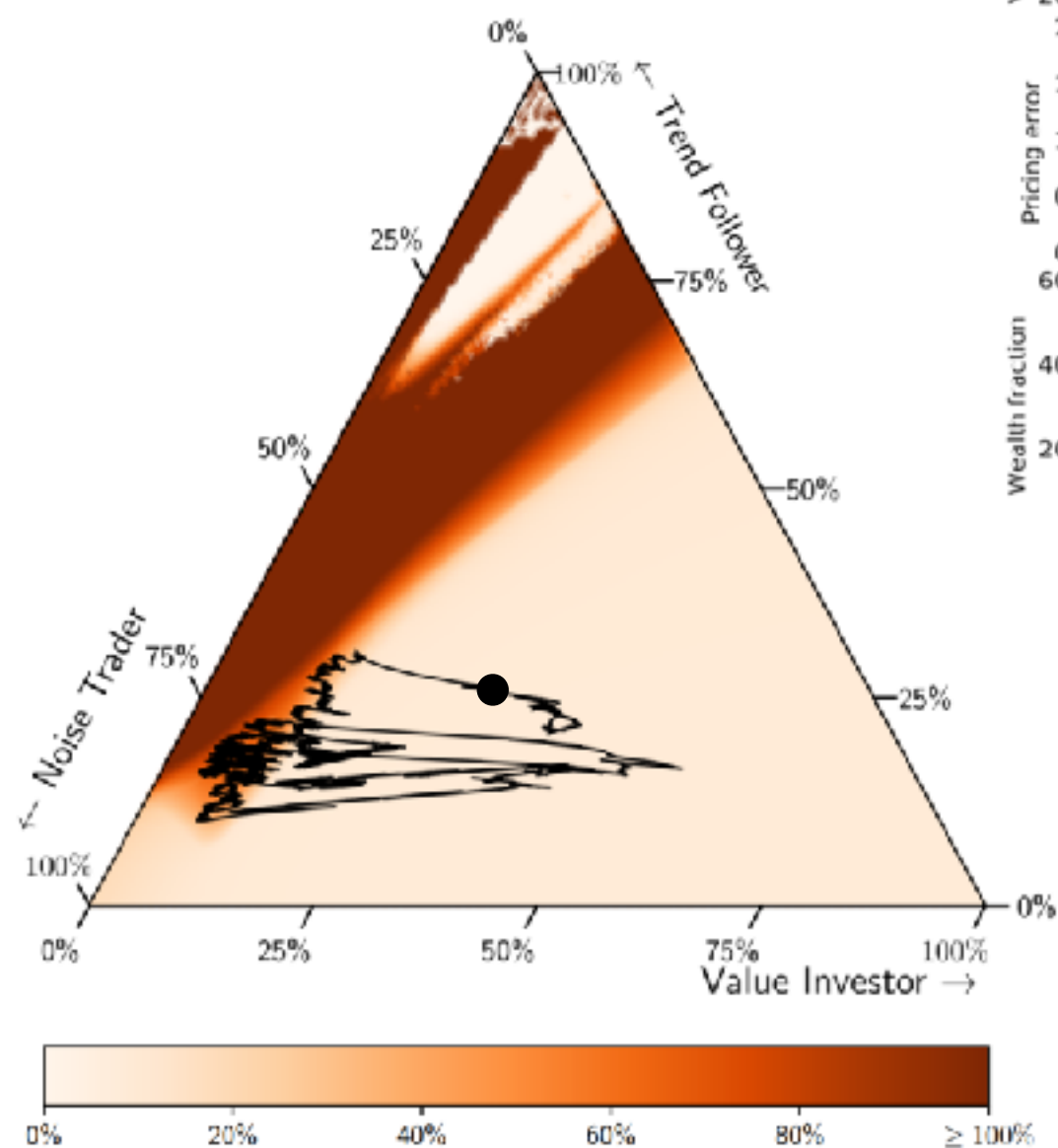


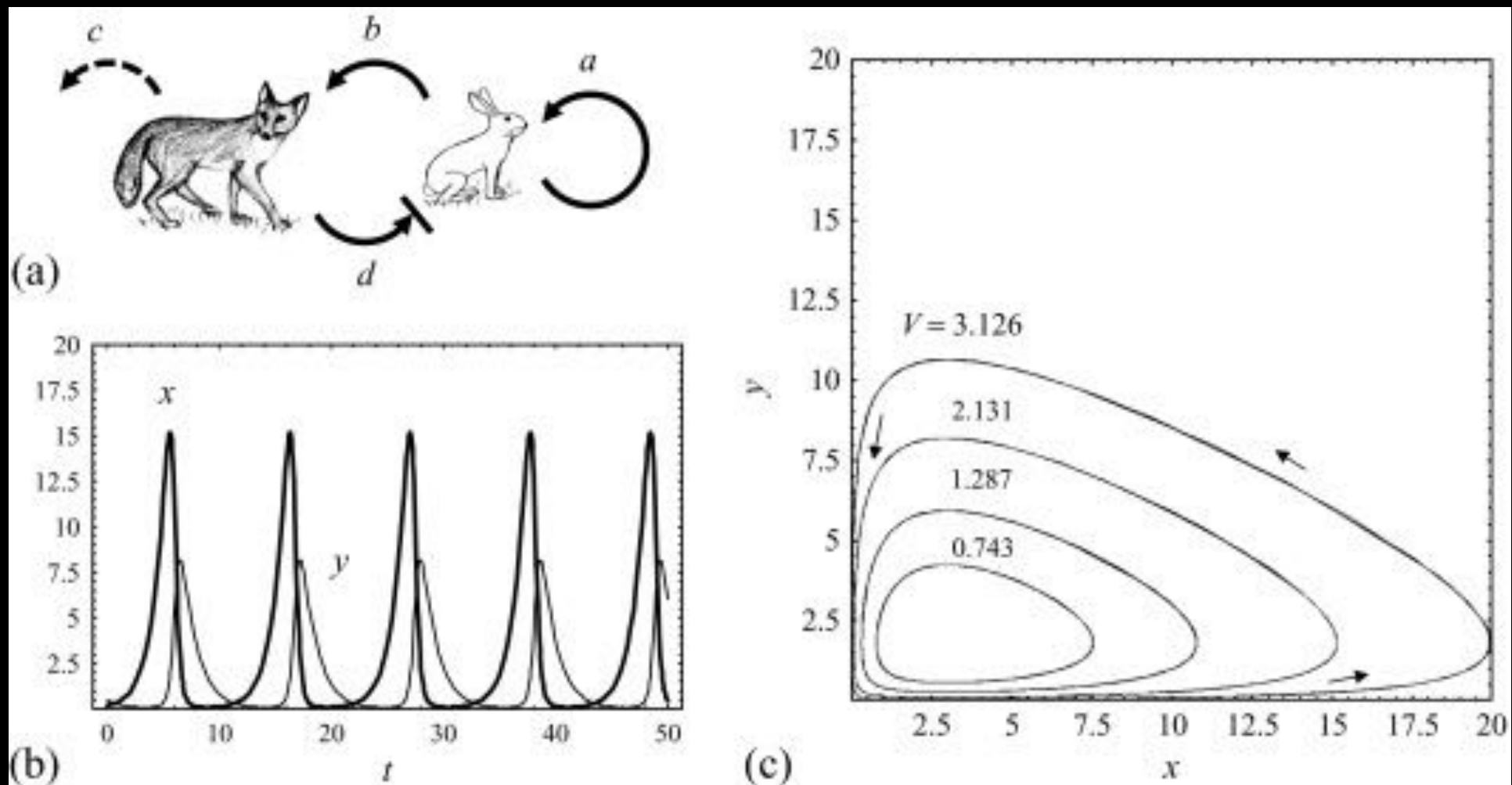
Table 3. Multivariate regressions with volatility and mispricing as dependent variables and the funds' wealth as independent variables.

| | | | | |
|----------------------|-------------|------|--------------|----------------------|
| volatility | | | $R^2 = 0.79$ | observations: 50,397 |
| independent variable | coefficient | t | | |
| noise trader | 2.4 | 10 | | |
| value investor | -68 | -249 | | |
| trend follower | 107 | 169 | | |
| mispricing | | | $R^2 = 0.33$ | observations: 50,397 |
| independent variable | coefficient | t | | |
| 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?



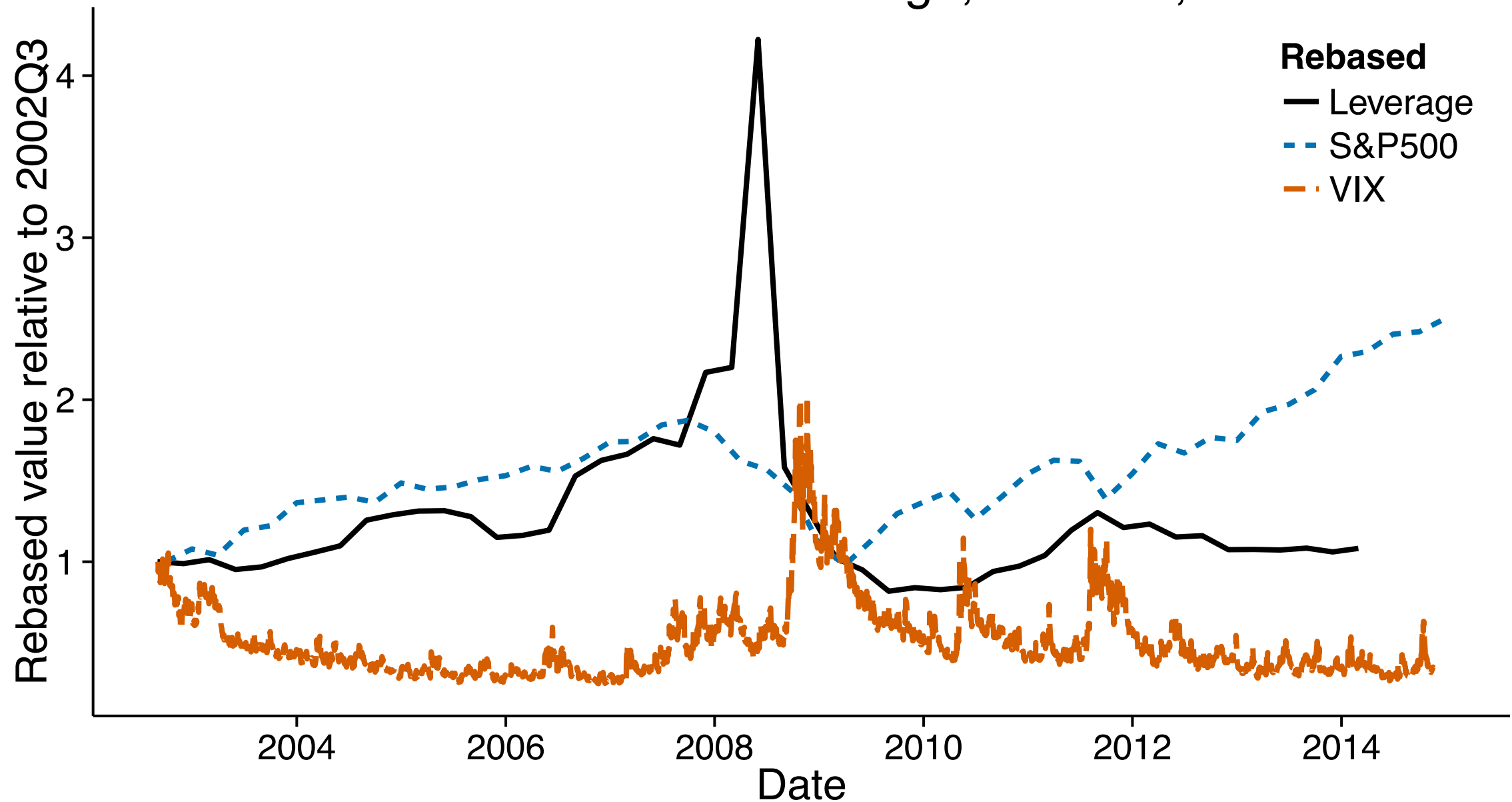
Lotka-Volterra dynamics

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)

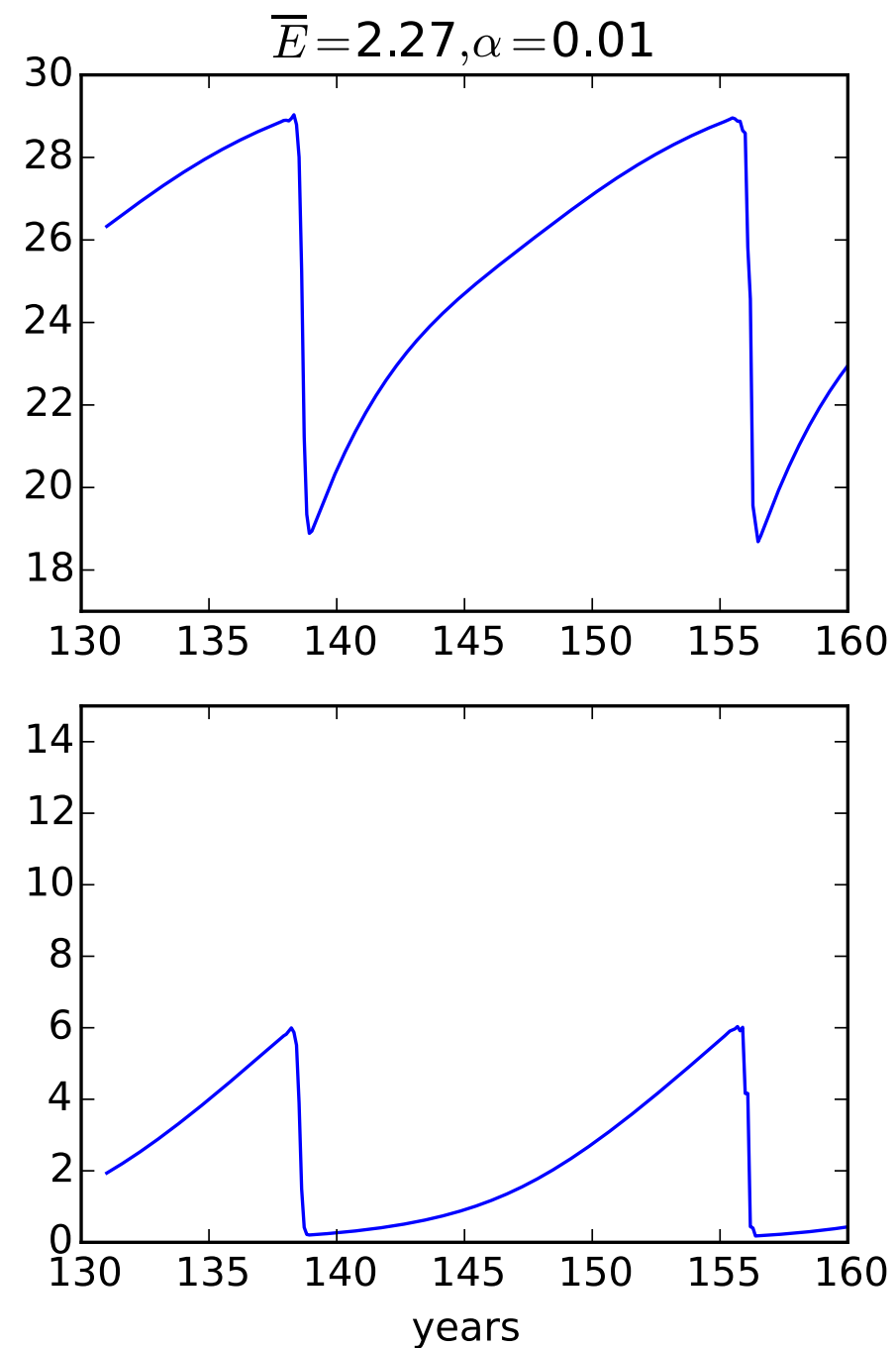
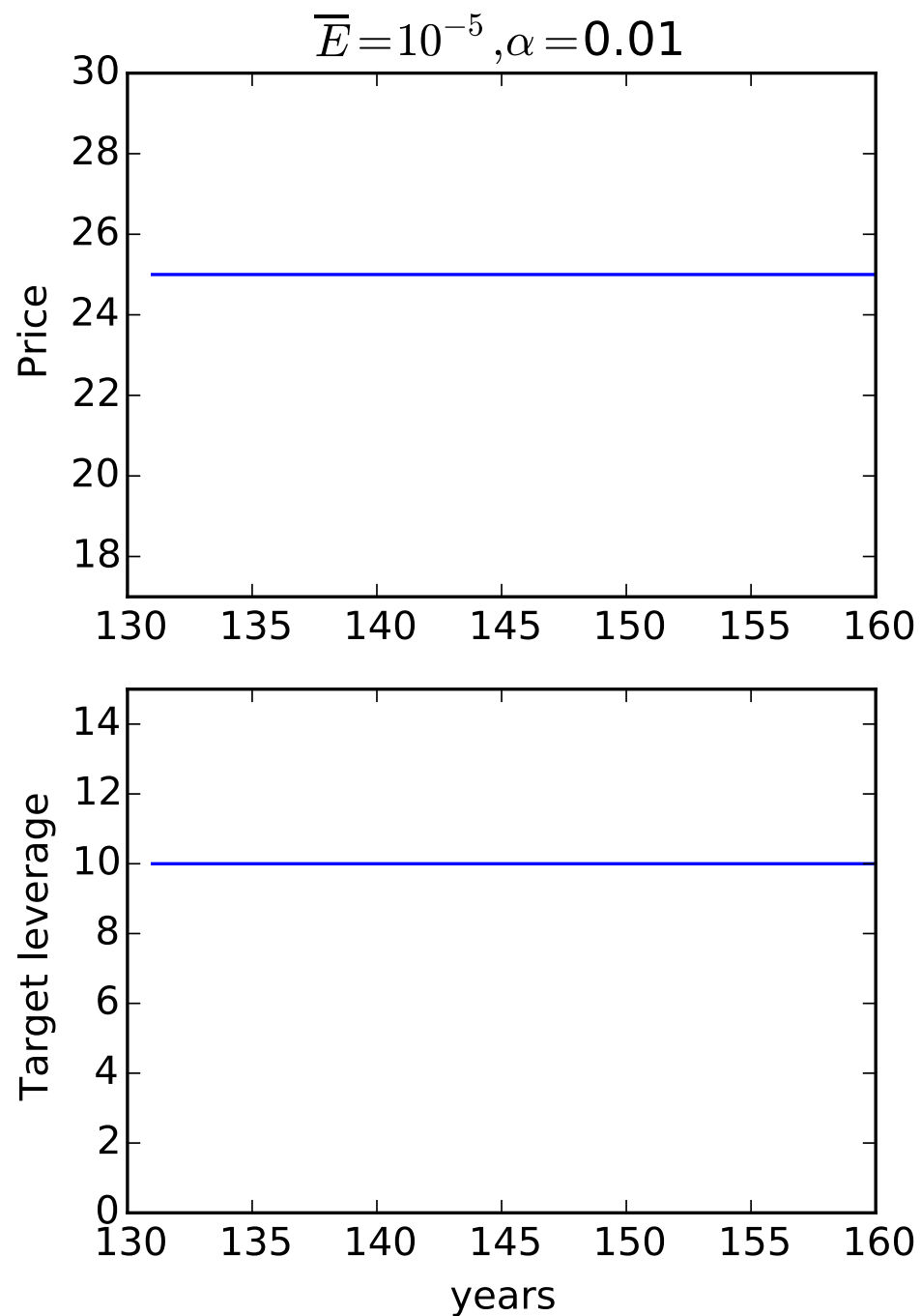
(Taming the Leverage Cycle, Aymanns, Caccioli, Farmer, Tan, 2016)

- 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 (Ghashghaie 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