Title: A physicist's approach to economics

Date: Oct 14, 2009 02:00 PM

URL: http://pirsa.org/09100104

Abstract: Physicists have been working for banks and hedge funds on applied problems in finance for more than two decades, and recently have doing academic research as well. This talk will survey academic research by physicists and contrast it with mainstream economics. I will argue that the difference comes not from the application of alternative techniques or new mathematics, but rather from fundamental differences in what questions are considered interesting and how one should go about solving them. This will be illustrated with a simple model for how systemic risks and extreme price movements are generated by the use of leverage (buying with credit). The current financial crisis illustrates that the economy is indeed a complex system, and that new approaches are needed that properly take this into account.

# Outline

- A few remarks about complex systems
- Motivation for why and how physicists can contribute to economics.
- Illustration with a simple model of leverage (relevant to current crisis)
- Agent-based model of the economy?

# (Adaptive) complex systems

Discipline of complex systems is motivated by belief in two principles:

- Complex behaviors emerge from simpler rules operating at a lower level, e.g.
  - living organism
  - brain
  - society
- There are similarities between such examples that justify studying them together
  - "strong" vs. "weak" belief

# Economy as evolving complex system

- Adam Smith's invisible hand (1776)
- Economy should be best understood based on evolutionary principles (Marshall)
- System of prices is self-organizing means of parallel processing information (Hayek)
- Contrast to most modern literature
- Empirically useful science?

# Neoclassical economics

- Agents selfishly maximize utility
- Market clearing (supply = demand)
- Price taking (negligible impact of individual)
- Rationality
  - ability to calculate anything
  - complete information (states of nature)

Last 30 years of economics devoted to generalizing or modifying these assumptions

# Problems with neoclassical economics

- Utility
- Measure of expected states of nature
- More realistic behavioral assumptions?
- Rationality makes models too intractable
  - too much simplification
  - must model an evolving complex system!
- Math over reality

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# Opportunities and dangers

- Economics, particularly finance, is fertile ground for a physics-style approach
  - new perspective
  - low hanging fruit
  - different vision of scientific method
  - laws of social systems!
  - laboratory to study social evolution
- Downside
  - narrow-mindedness of disciplinary boundaries

# MARKET LAWS

- Pareto's Law for personal income
- Long-memory of supply and demand
- Power law for trading volume
- Relation between exponents of volume, S&D fluct.
- Anomalous scaling of growth fluctuations of firms
- Laws of market impact
- Volatility = average market impact = spread/2
- Power law for price fluctuations
- Equation of state of price statistics and order flow
- Distribution of mutual fund sizes
- Scaling of impact with market capitalization
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- Define "evolution" as any process with descent, variation, and selection.
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- Comparison should not be taken literally: Important to understand both similarities and differences.

What is biggest difference between social and biological evolution?

# What is biggest difference between social and biological evolution?

## People can think.

- In this respect, biology is easier: Accurately modeling thinking humans is difficult.
  - Innovation
  - Strategic anticipation
- Limiting cases (tractable but often far-fetched):
  - Perfect rationality
  - Zero Intelligence (ZI)
- Biology is ZI (if one includes rules of thumb).

# Advantages of financial markets as laboratory of study

- Rapid timescale of evolution
  - Market force, ecology and evolution
  - Conjectured law for evolution to efficiency (Reality game, Cherkashin, Farmer, Lloyd)
- Huge data sets
- Highly constrained decision-making environment

PREDICTION COMPANY



## Market efficiency?

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

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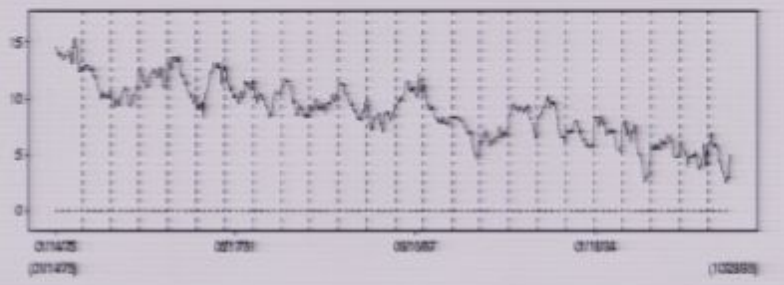

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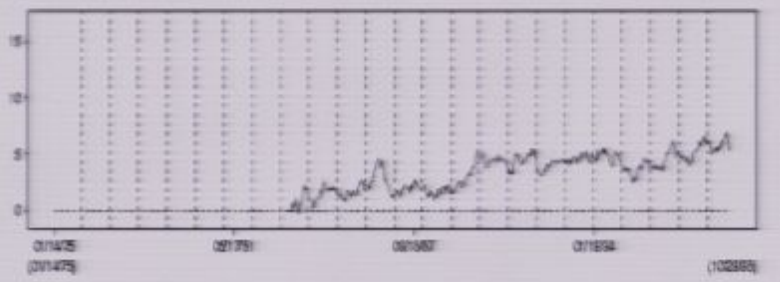

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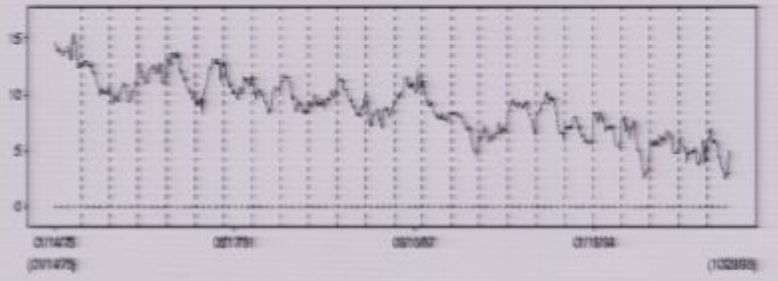


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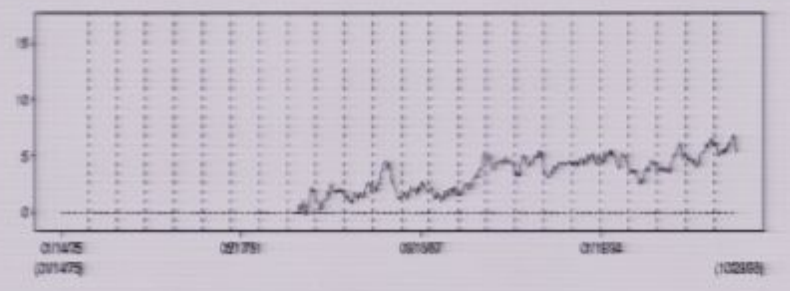

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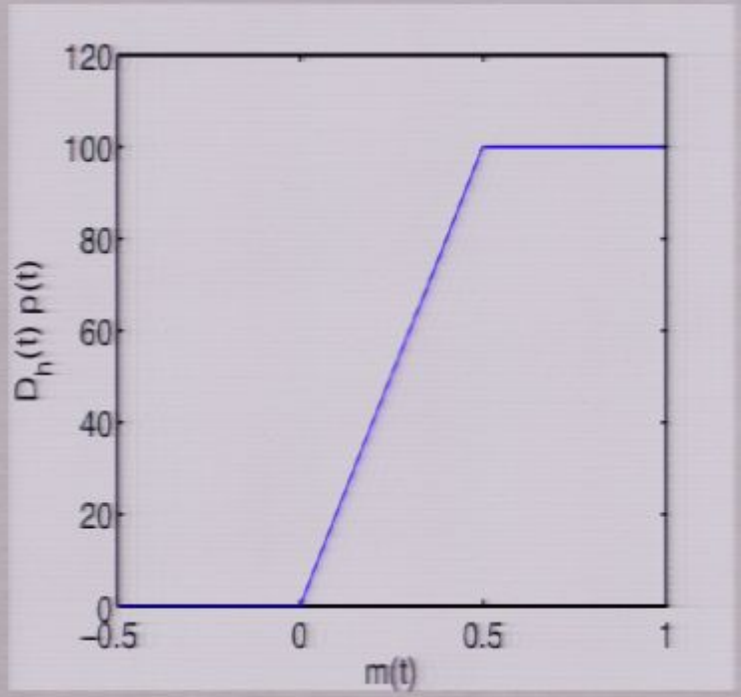
# Hedge fund/leverage model

- With Stefan Thurner and John Geanakoplos
- Agents
  - funds (long only value investors)
  - noise traders reverting to a fundamental value
  - investors choosing between fund and cash; base decisions on trailing performance of funds
  - bank lending to funds

# FUND DEMAND FUNCTION

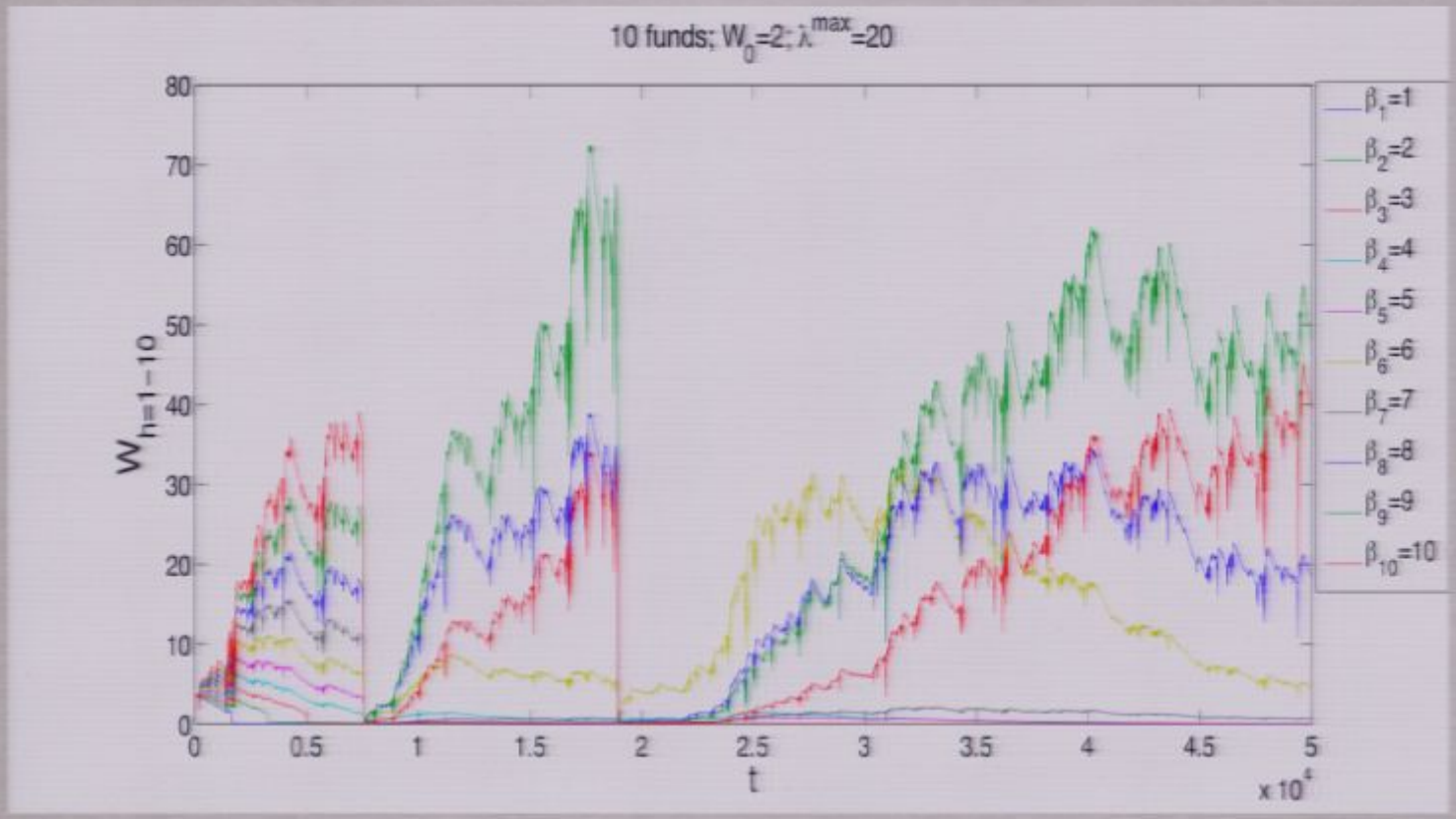
Fund demand




mispricing $m = V - p$

- Funds can use *leverage*, defined as ratio of value of holdings to wealth. Max. leverage is key parameter
- Funds differ in their aggression, i.e. how much they buy for a given mispricing (slope)

# Wealth vs. time, 10 funds

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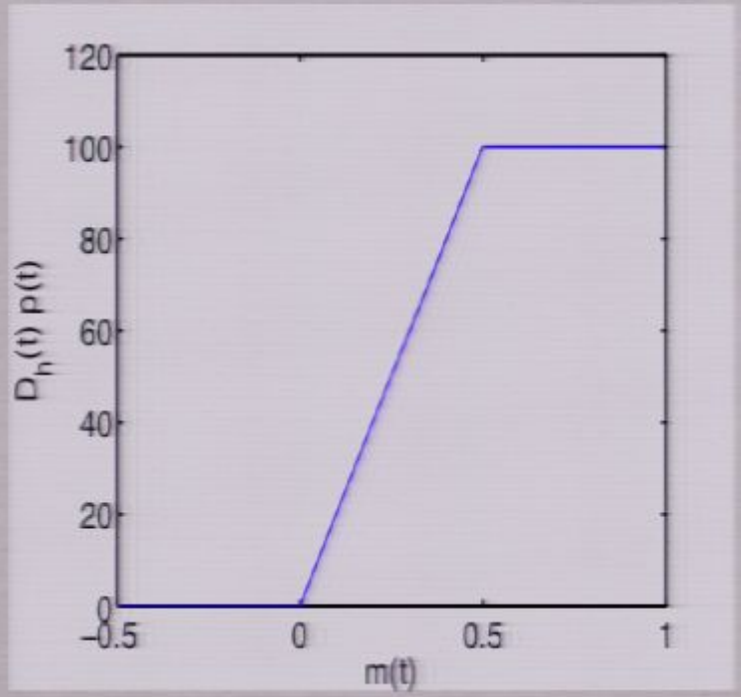


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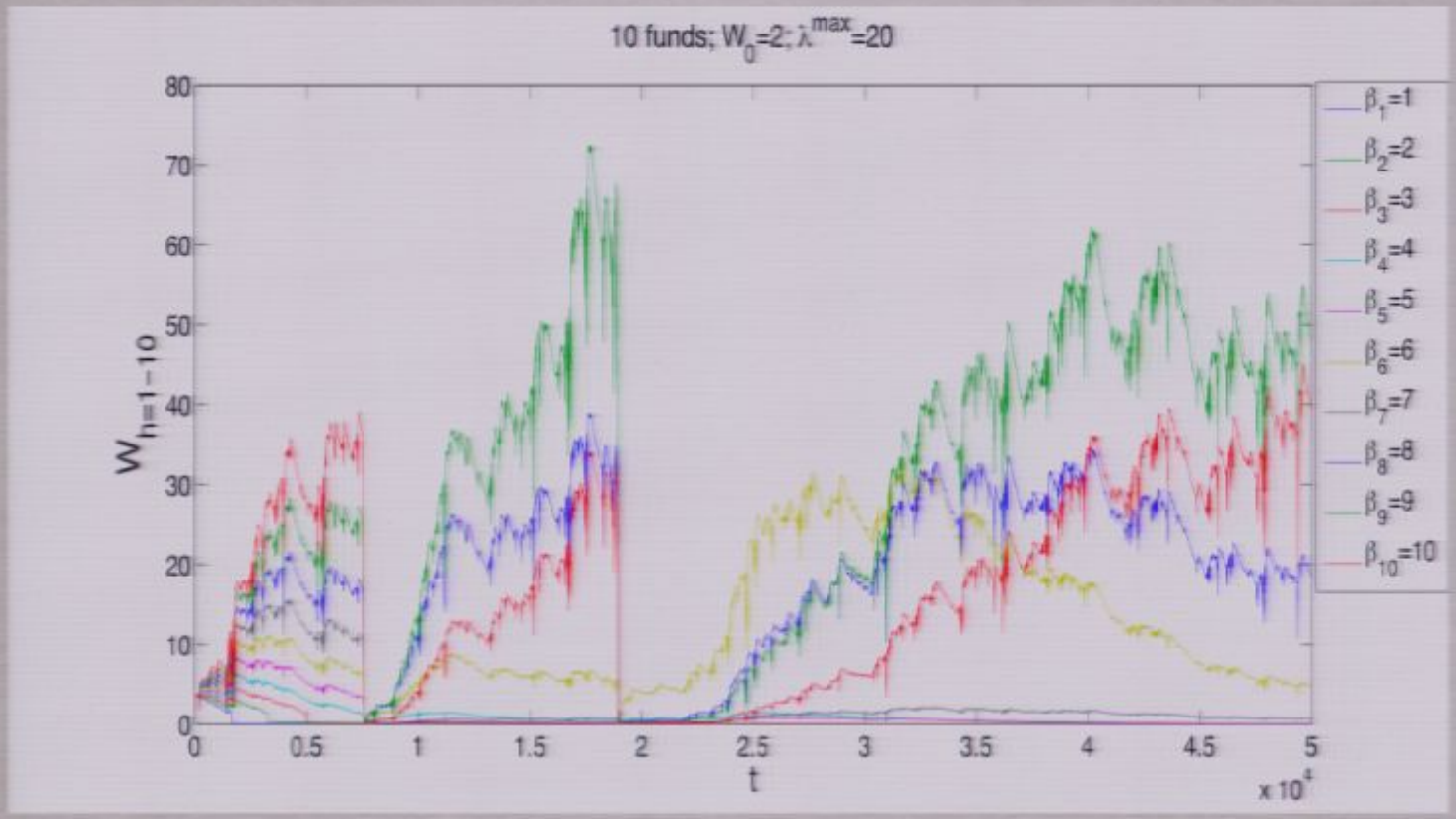


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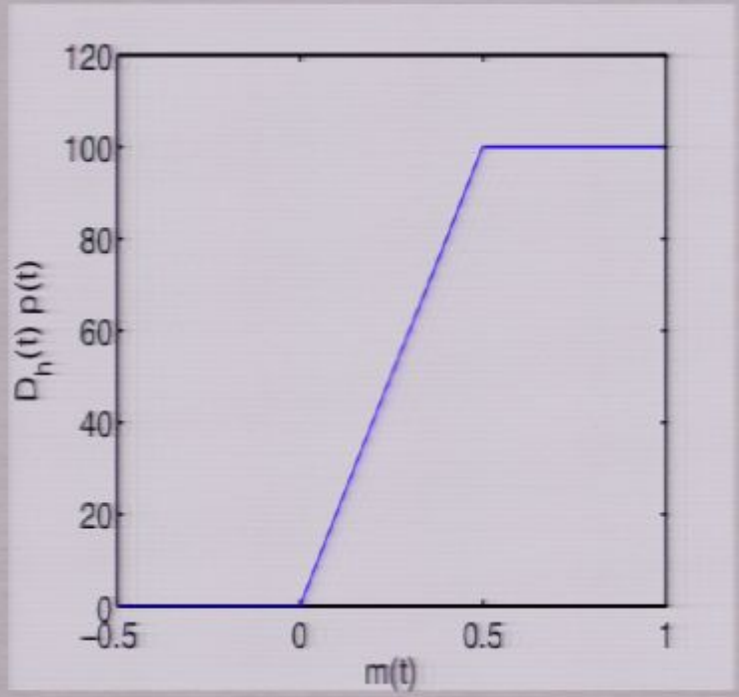


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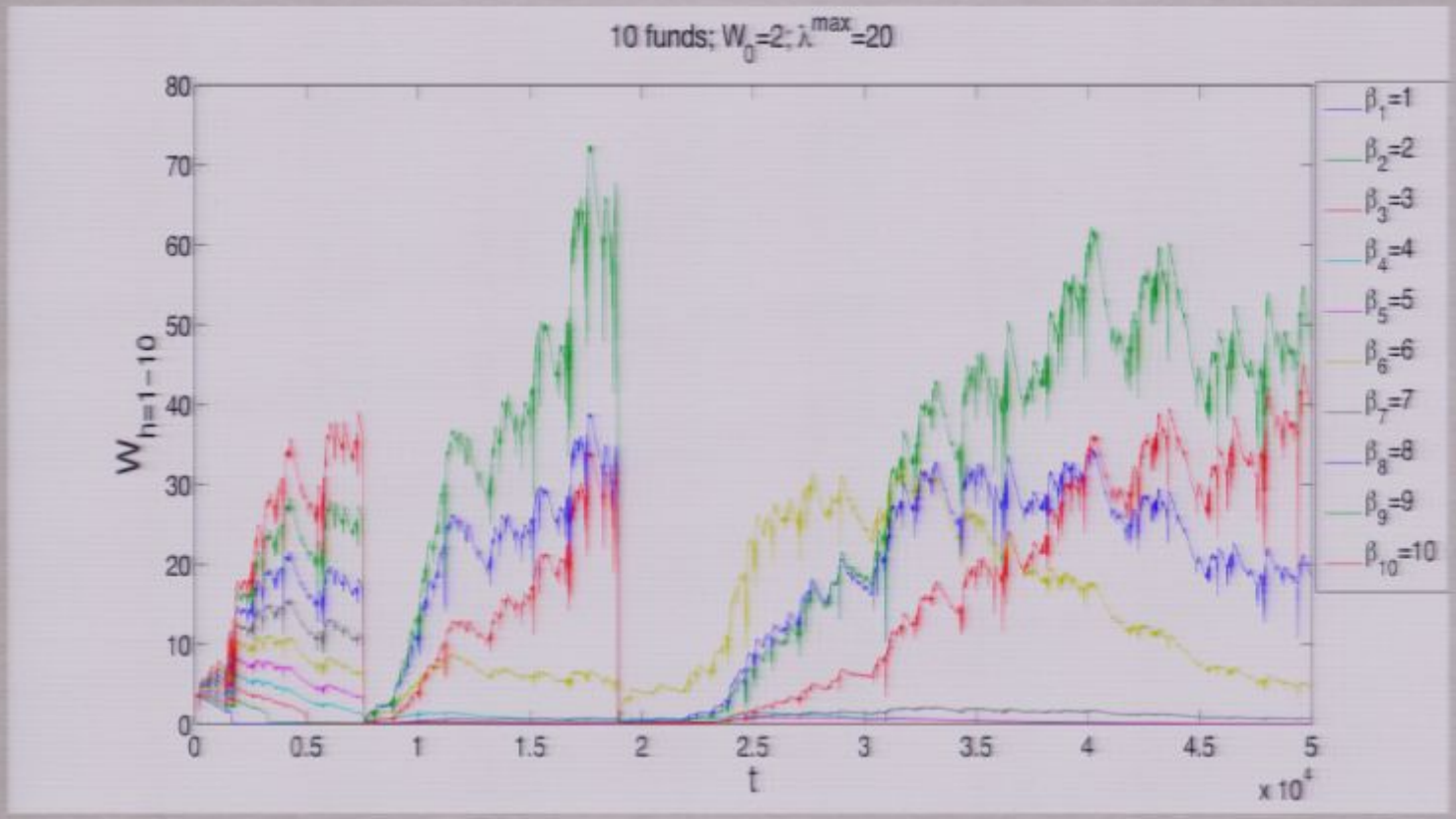


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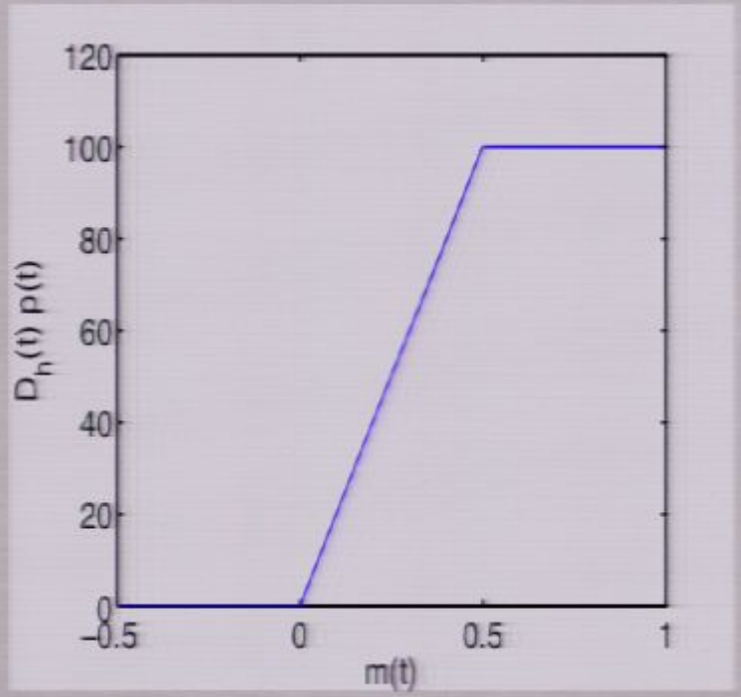


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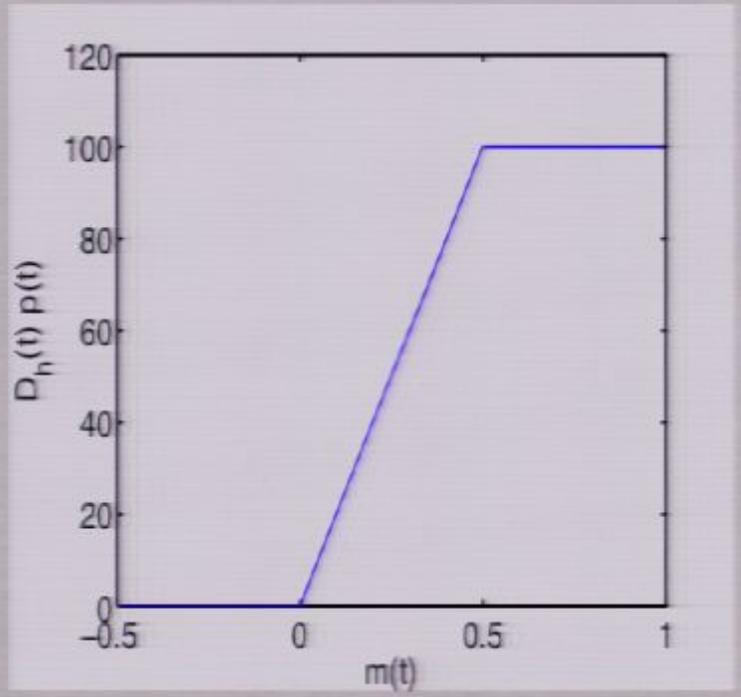


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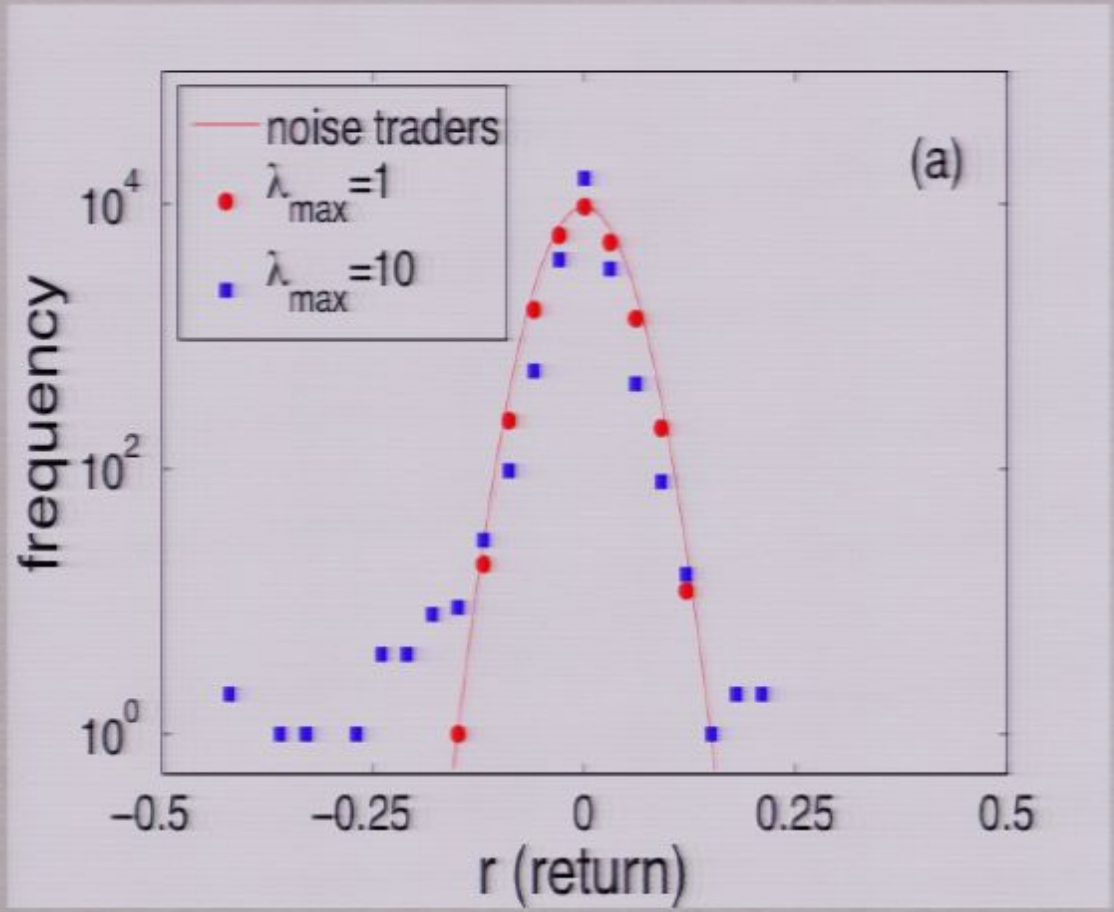

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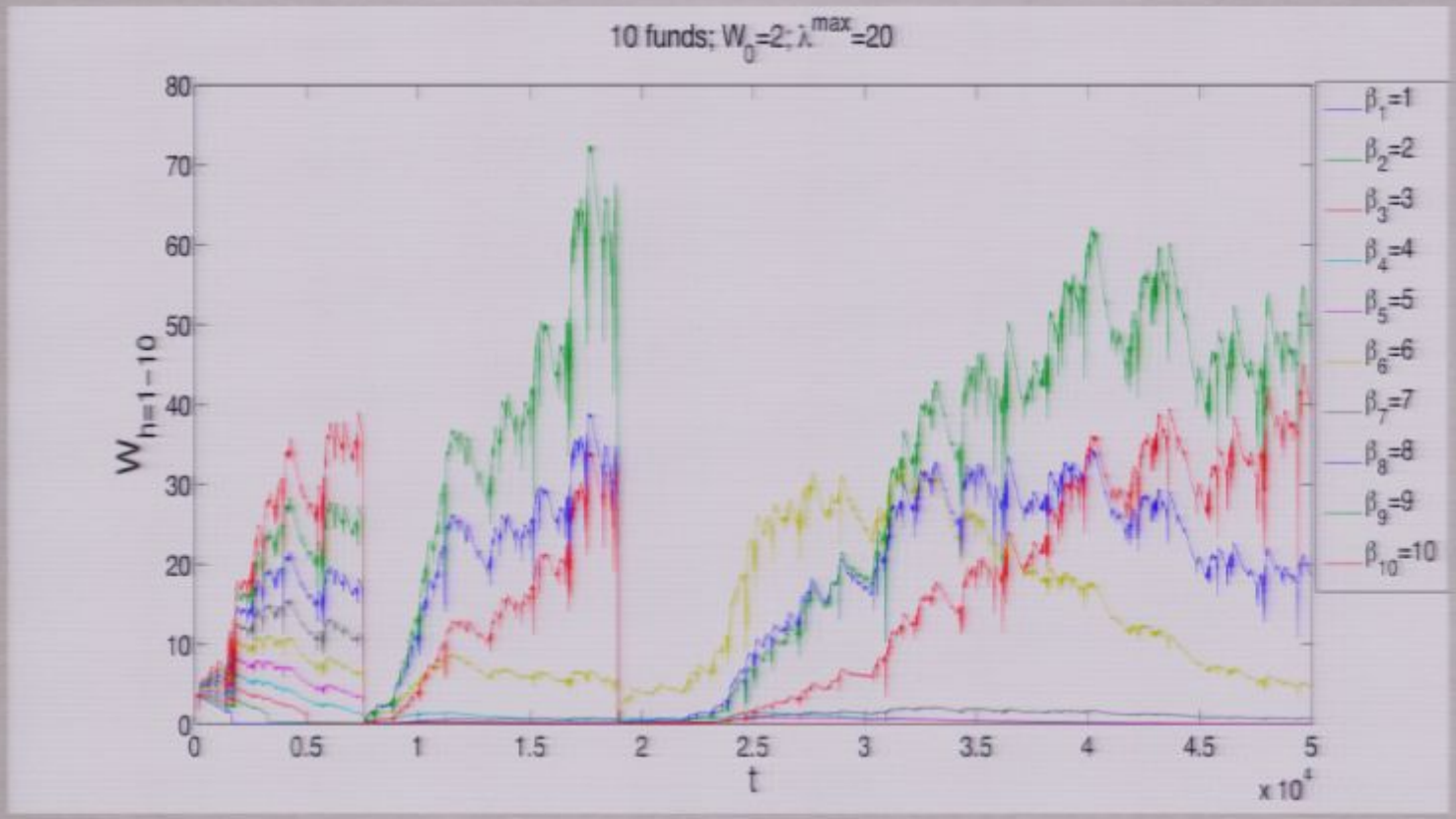


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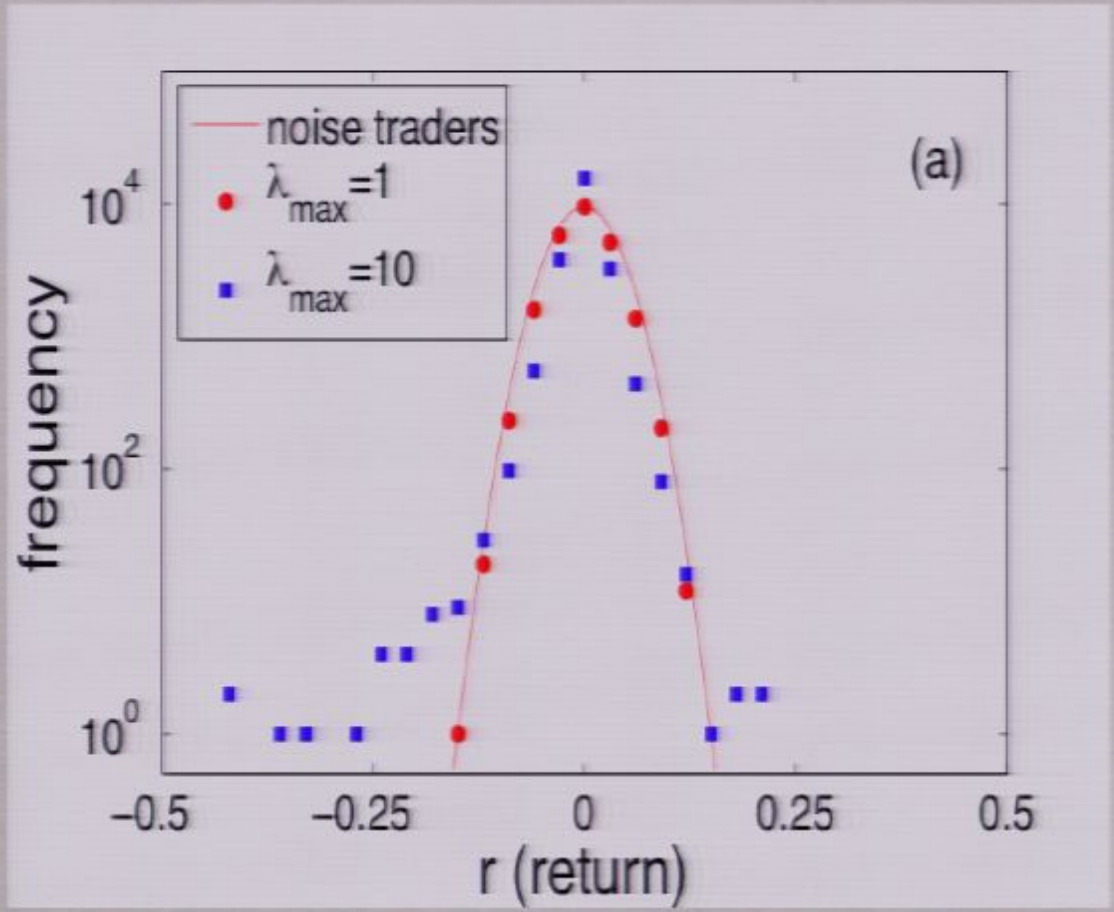

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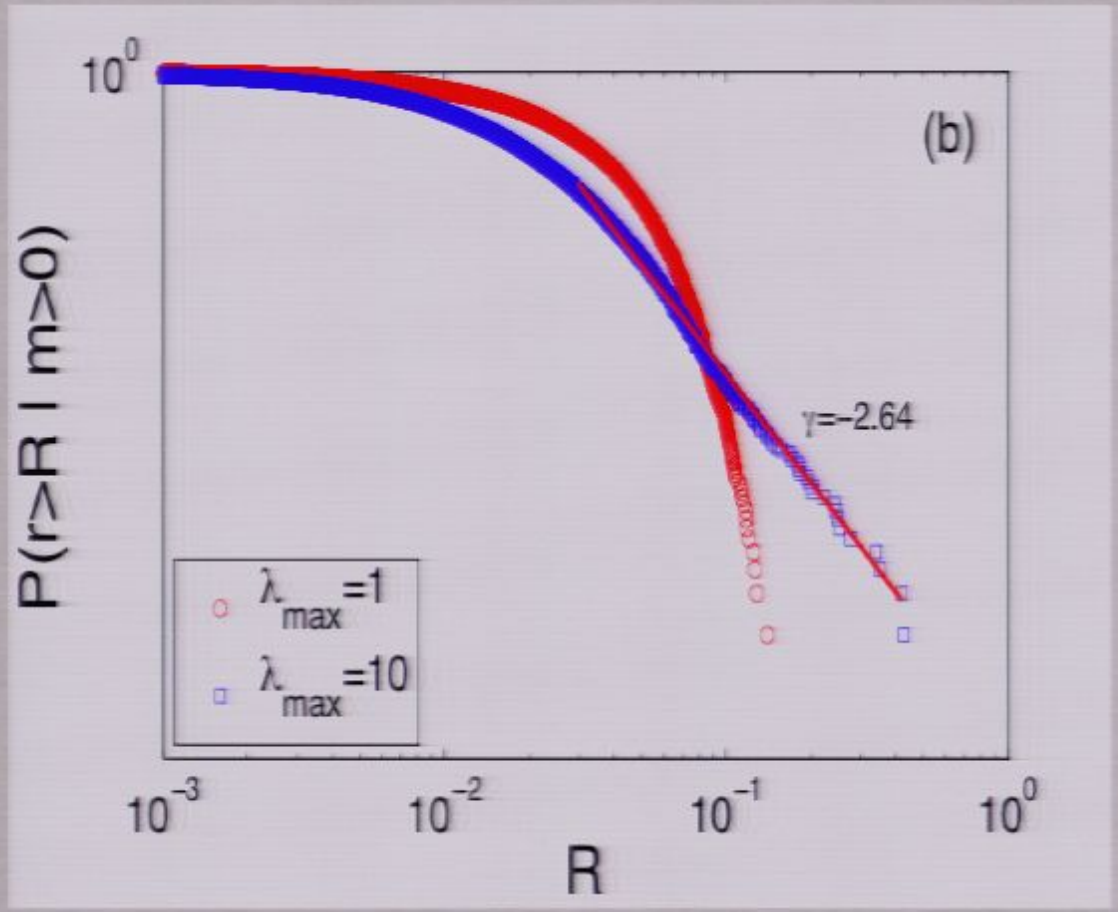


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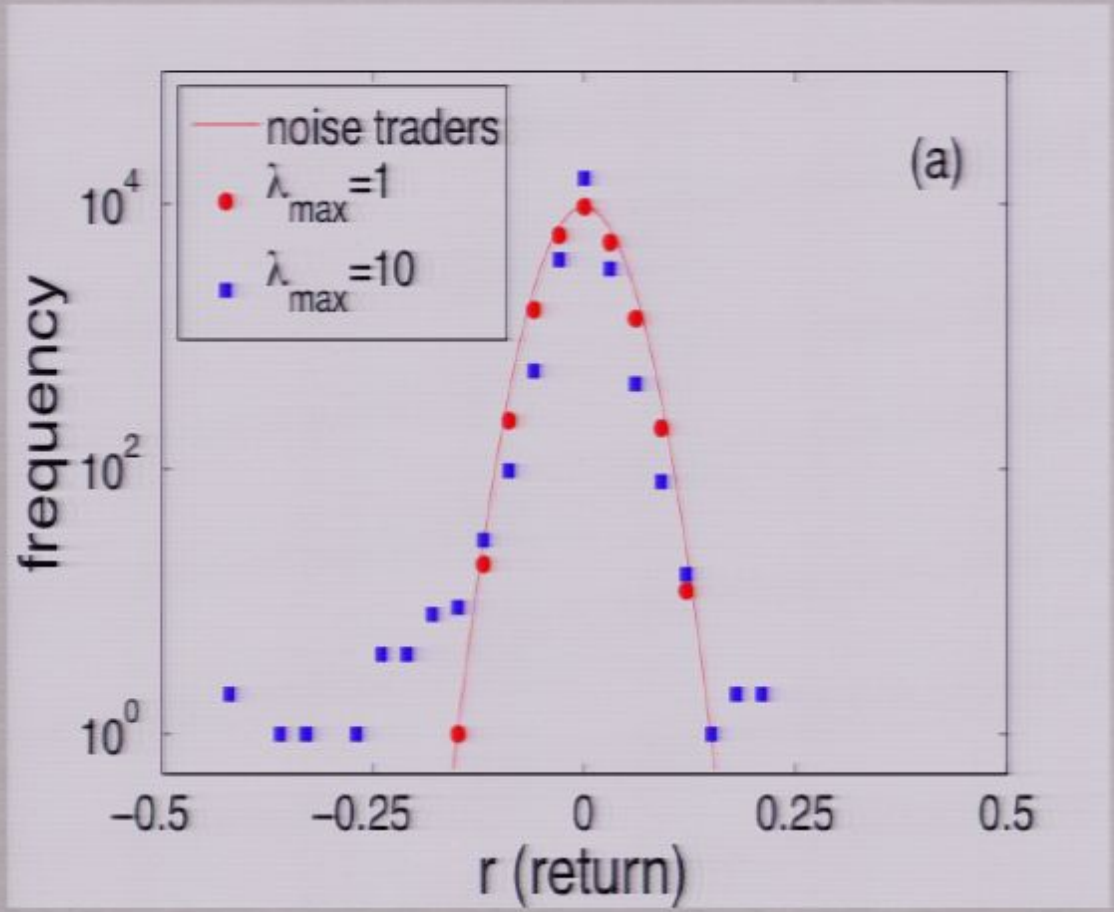

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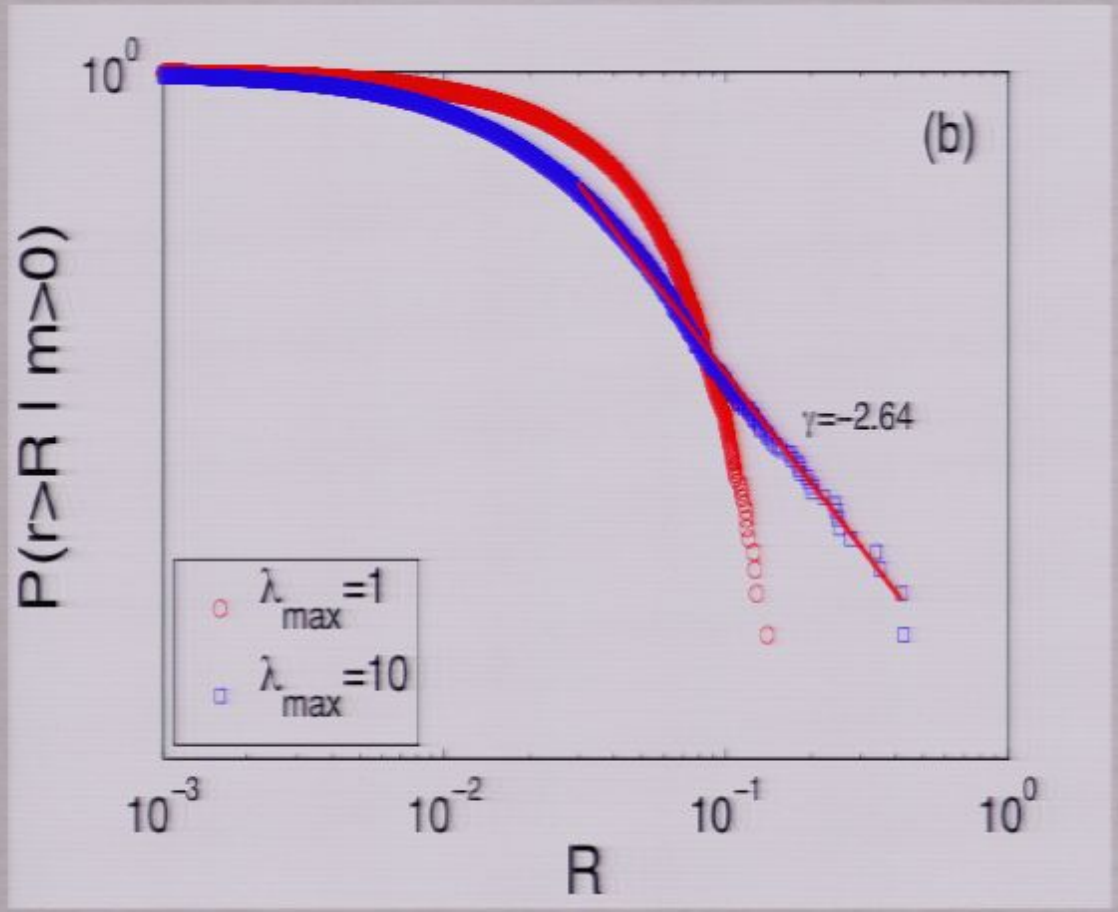


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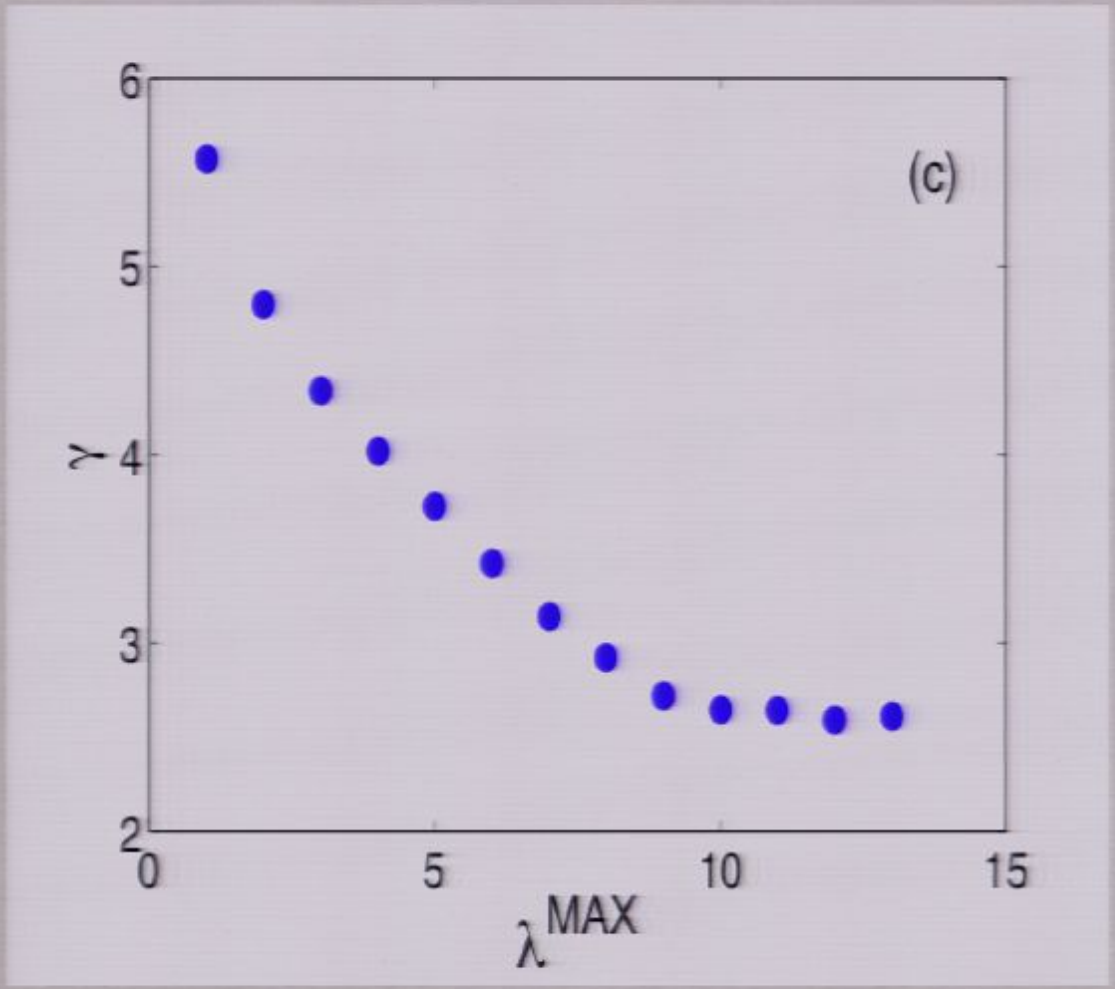

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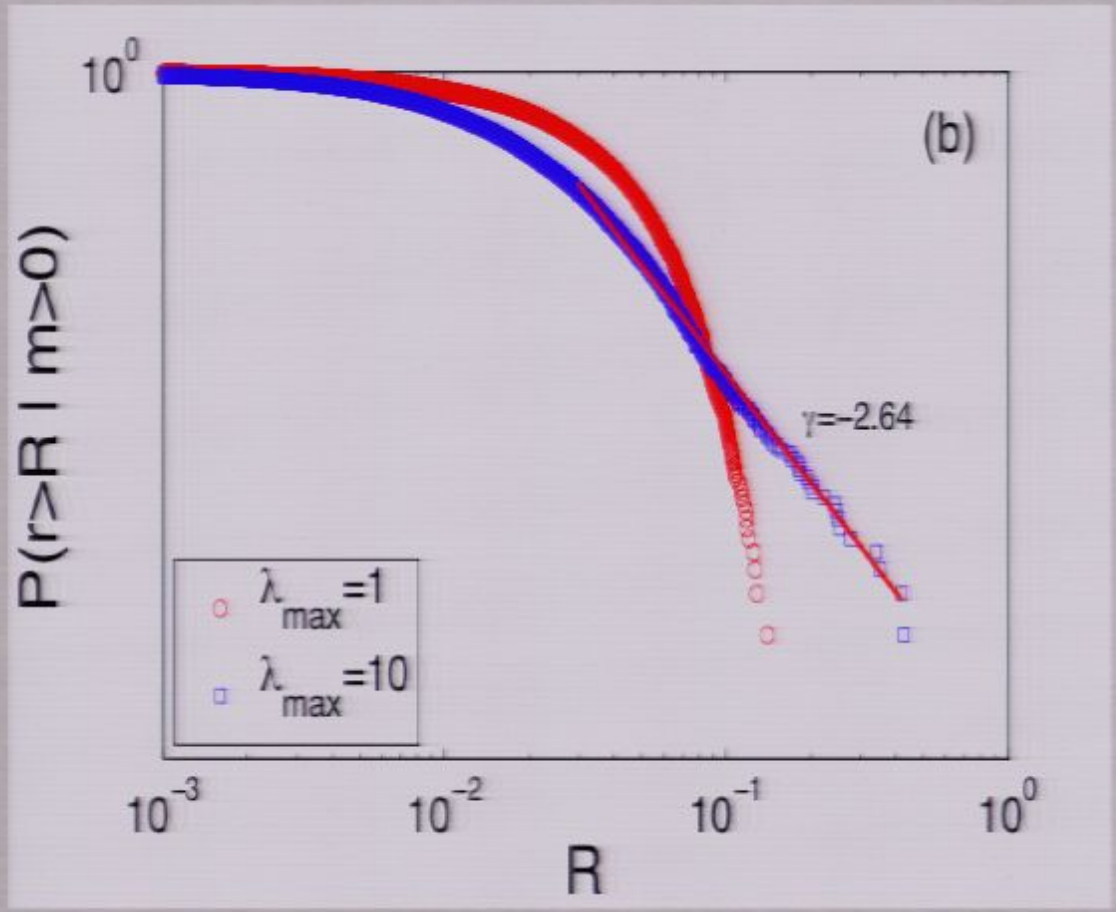


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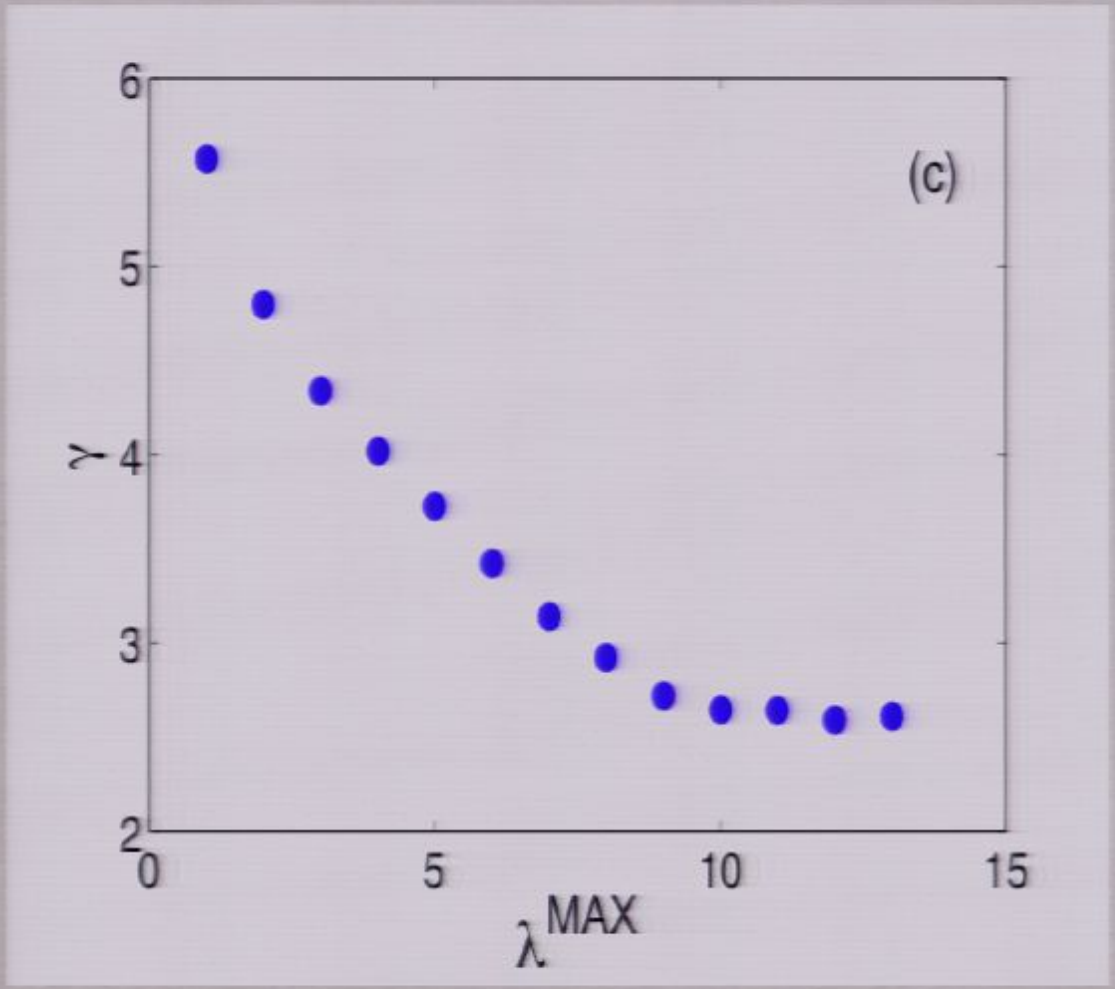
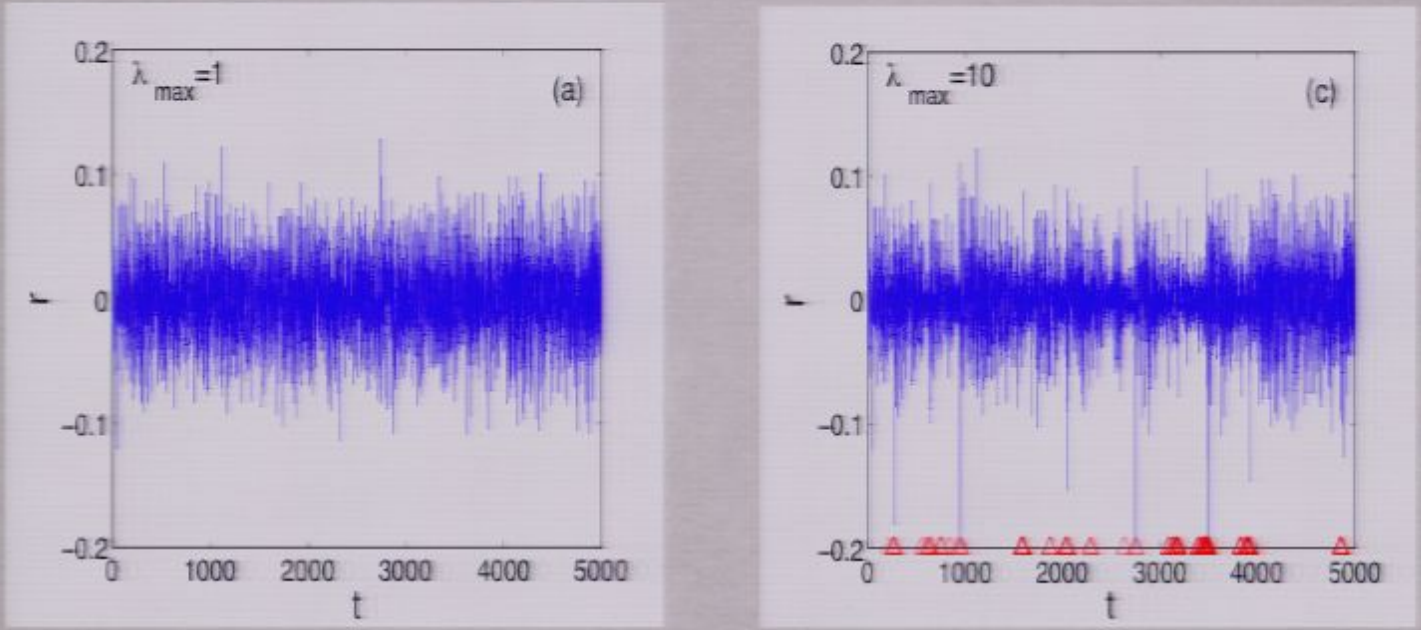


# LEVERAGE AND VOLATILITY

Stock returns vs. time

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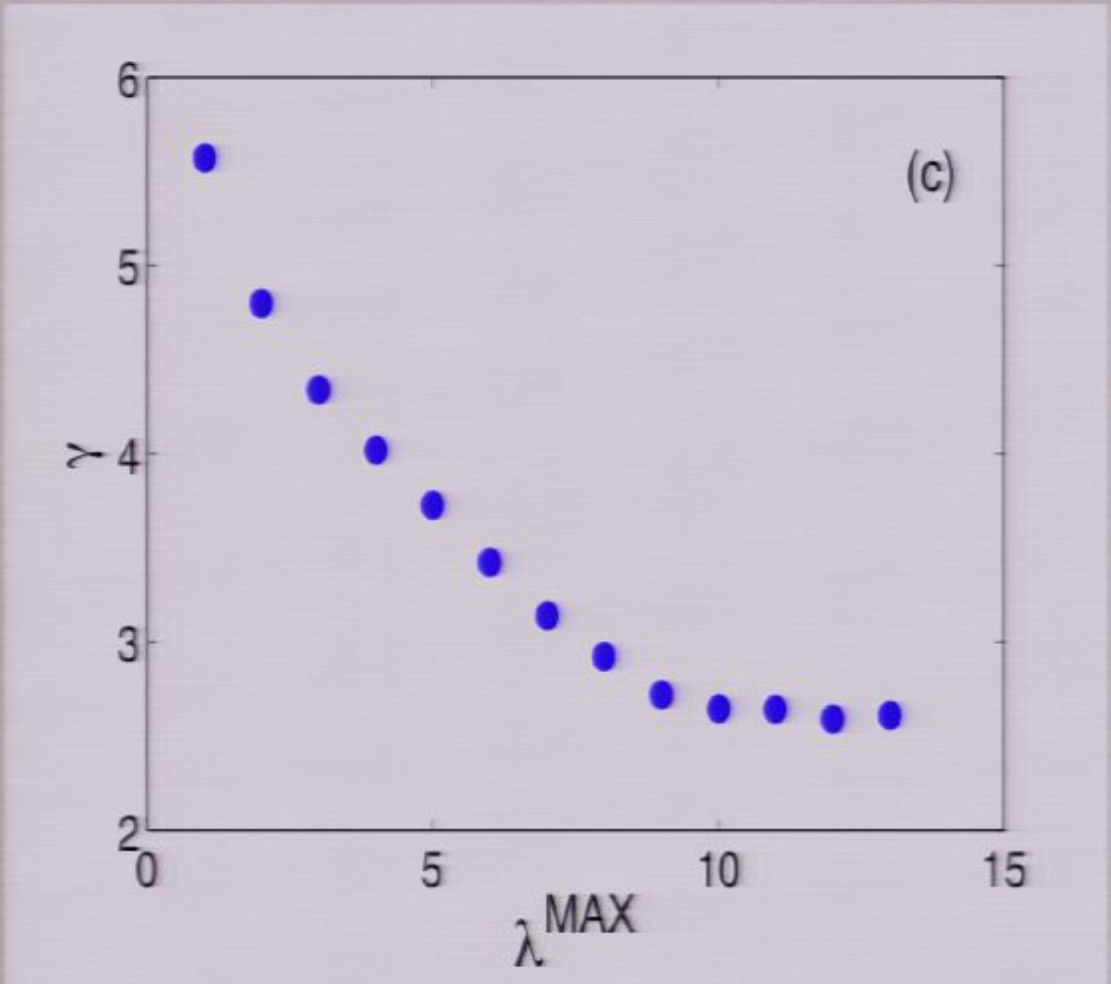

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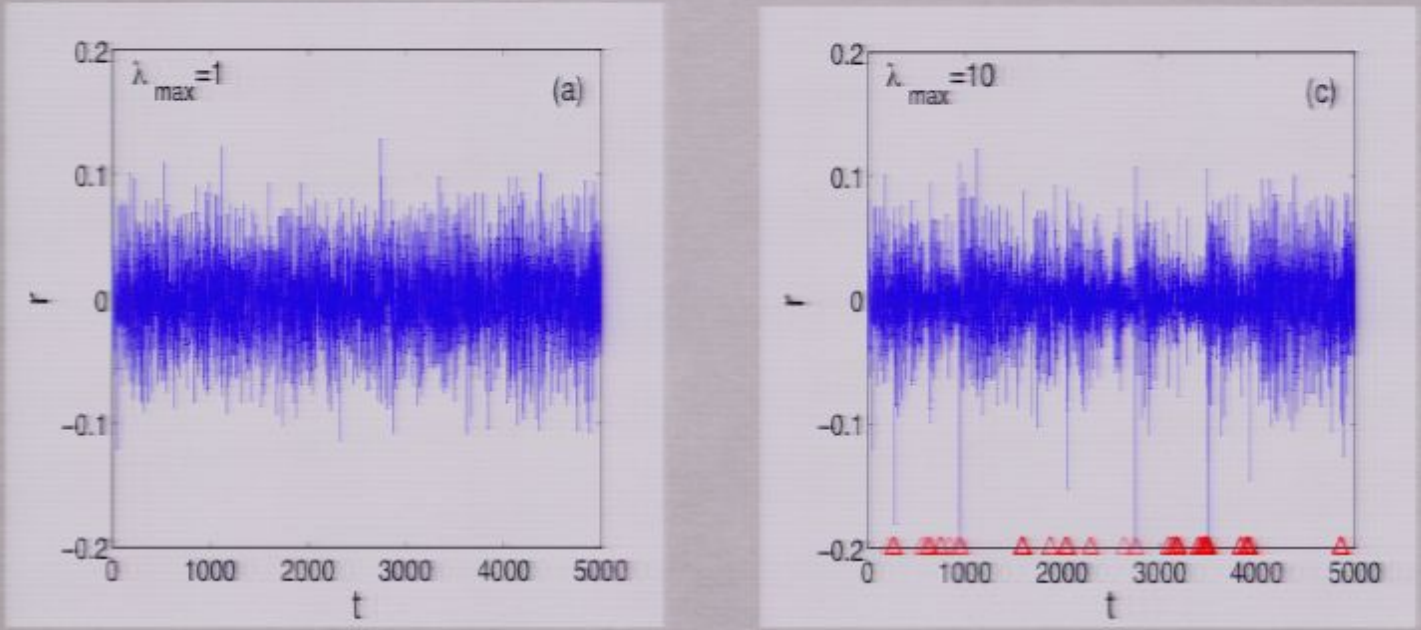


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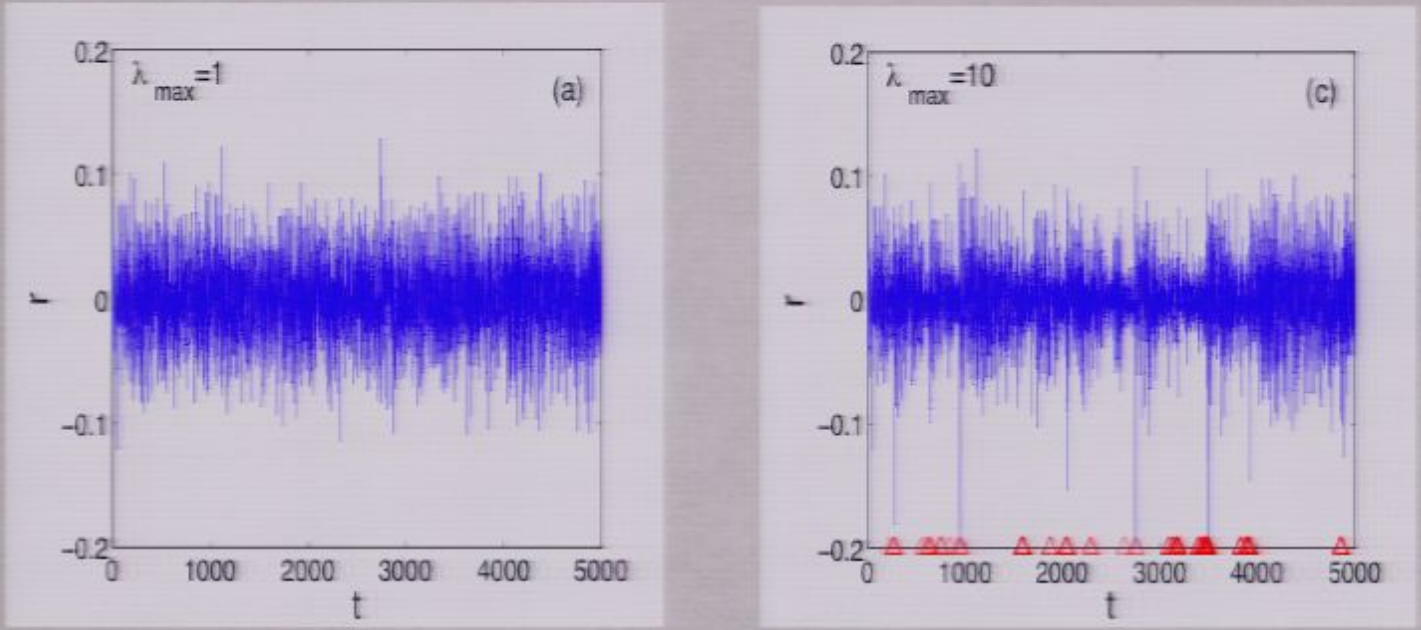


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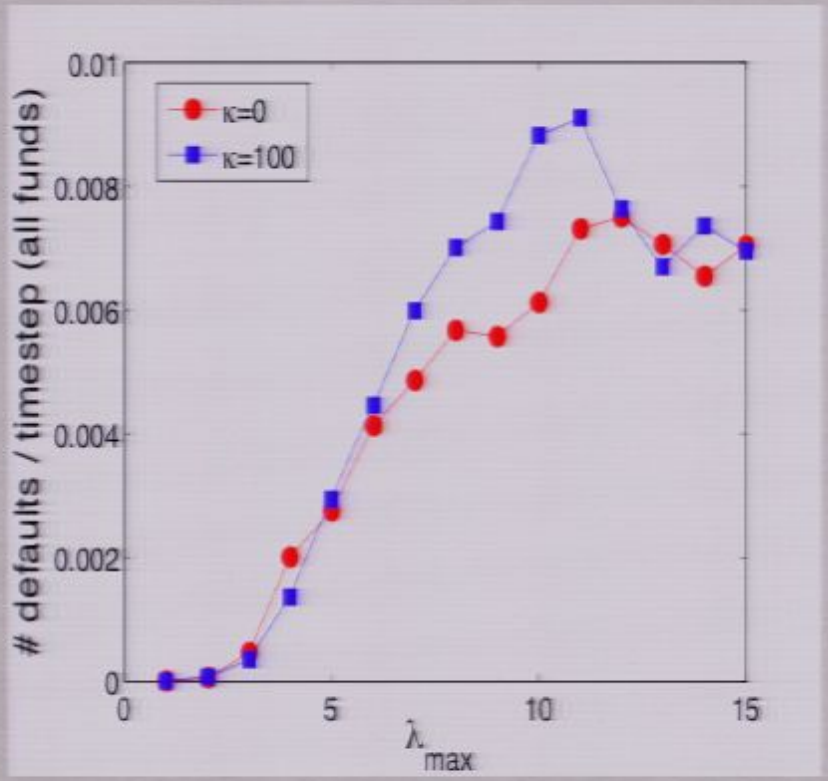
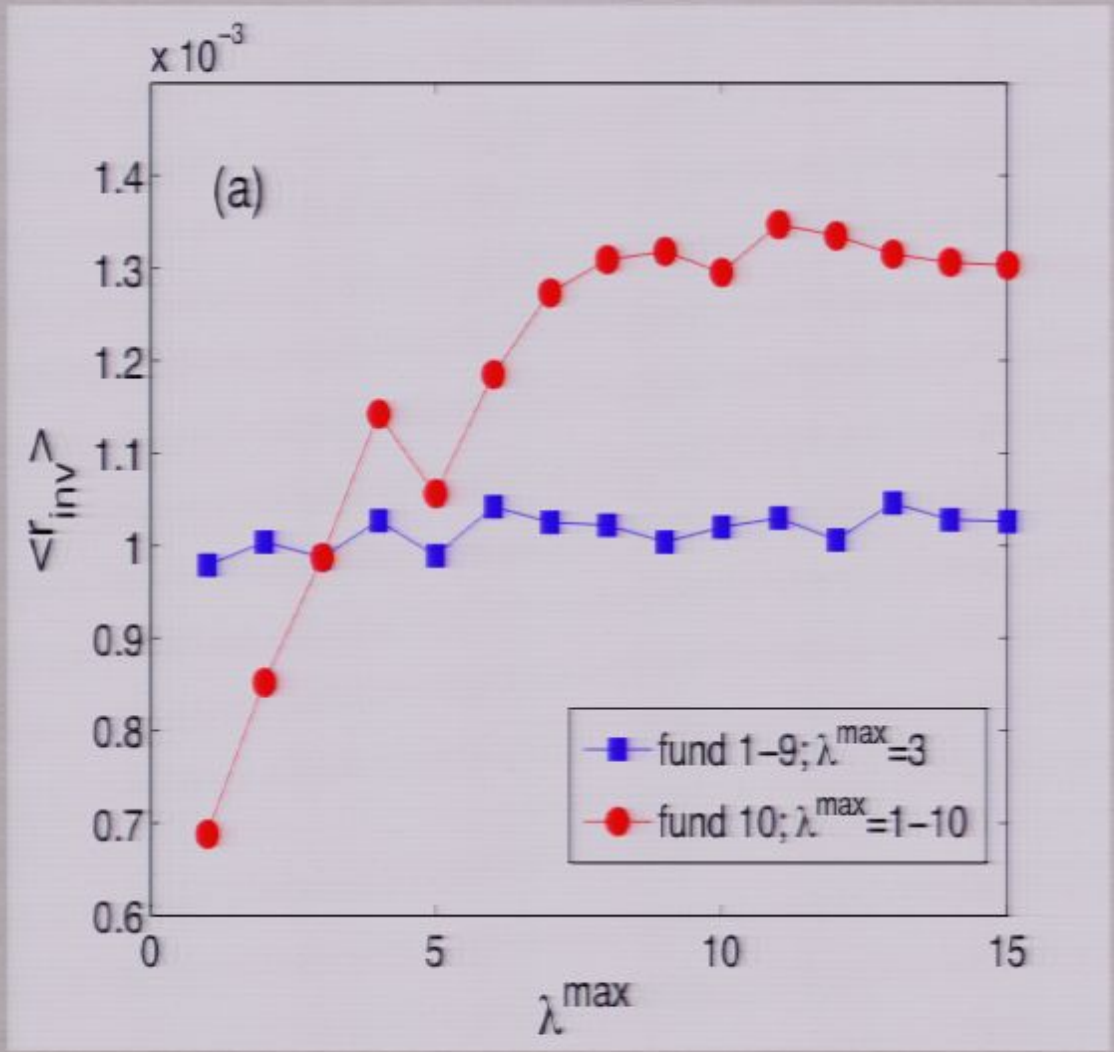



- When k > 0, banks lower maximum leverage when historical volatility is higher
- Results in more defaults.

# Evolutionary pressure for higher leverage



# NEED TO REGULATE LEVERAGE

- Conjecture: Evolutionary pressure drives funds toward leverage above the social optimum.
  - increased defaults, extreme events, lower returns
- Goldilocks principle: What leverage is "just right"?
  - Kelly criterion suggests $\mu/\sigma^2$
- Need for regulation?

# EXTENSIONS

- Let the bank leverage too
- Network of banks and hedge funds
- Multiple assets, derivatives, stop-loss
- Optimal control of risk by banks and hedge funds
- Evolution of strategies

# WE ARE INCREASINGLY ENGAGED IN SHAPING OUR OWN ENVIRONMENT

- How do we reduce risks?
- Two basic approaches
  - Distribute risks: Decentralize, decouple
  - Keynes: Manage the economy macroscopically
  - Not mutually exclusive

# NEED TO TREAT THE ECONOMY AS AN EVOLVING COMPLEX SYSTEM

- Current macro models are much too simple
- Current financial models take macro as given
- Lucas critique, falsification of Phillips curve
  - resulting devolution of macroeconomics
- Need to model interacting institutions
  - obvious approach: agent-based simulation model
  - Need to explain macroeconomy from microeconomic arguments (Axtell)
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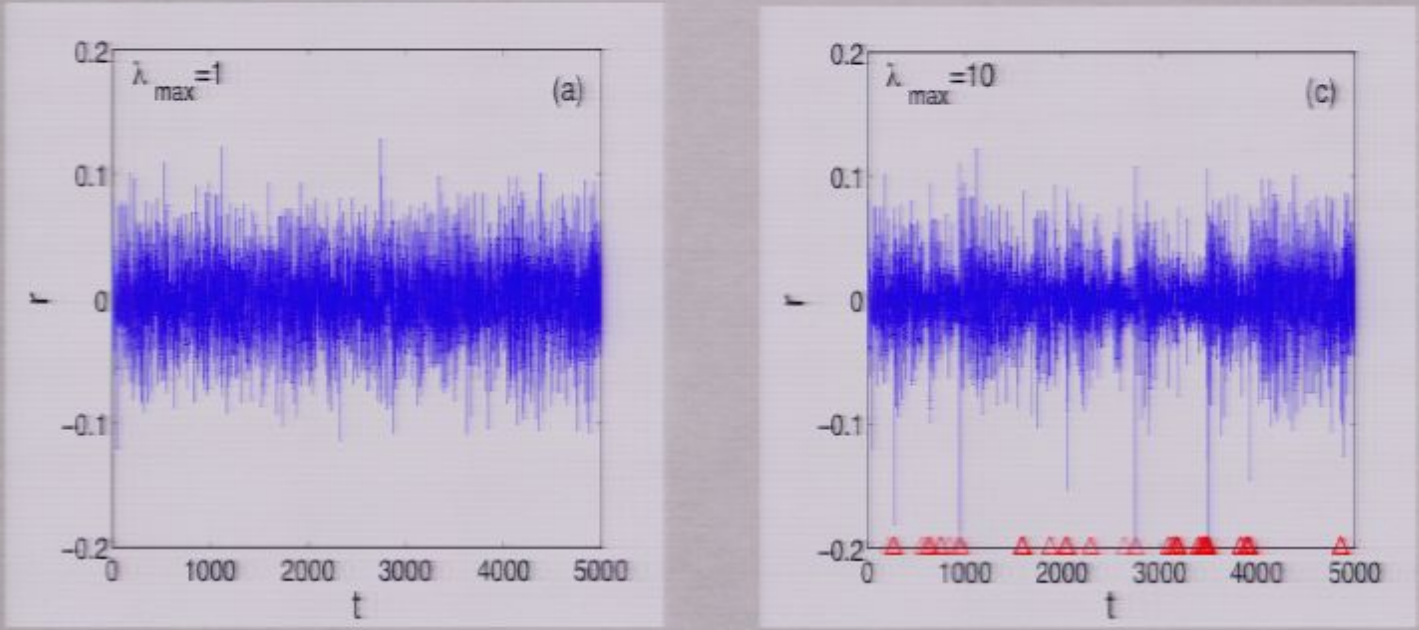


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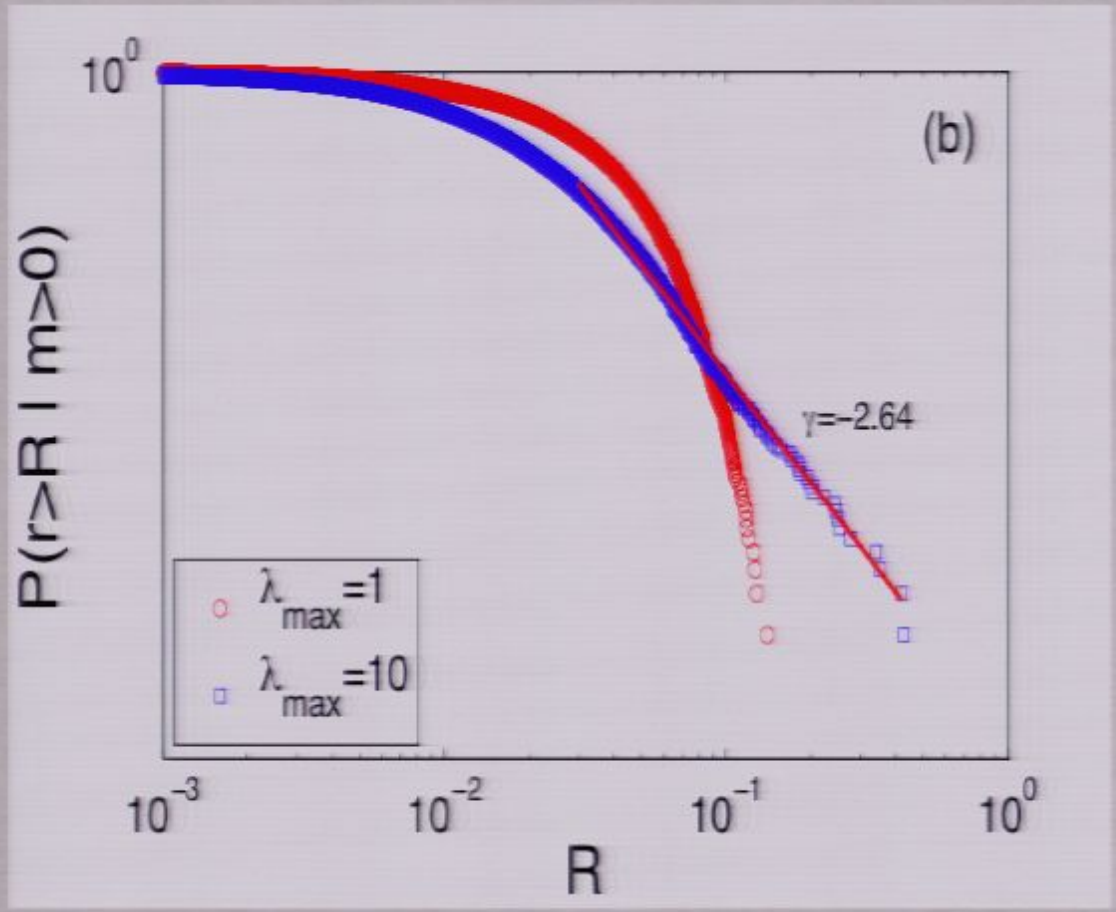


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# Statistical Mechanics of Human Systems

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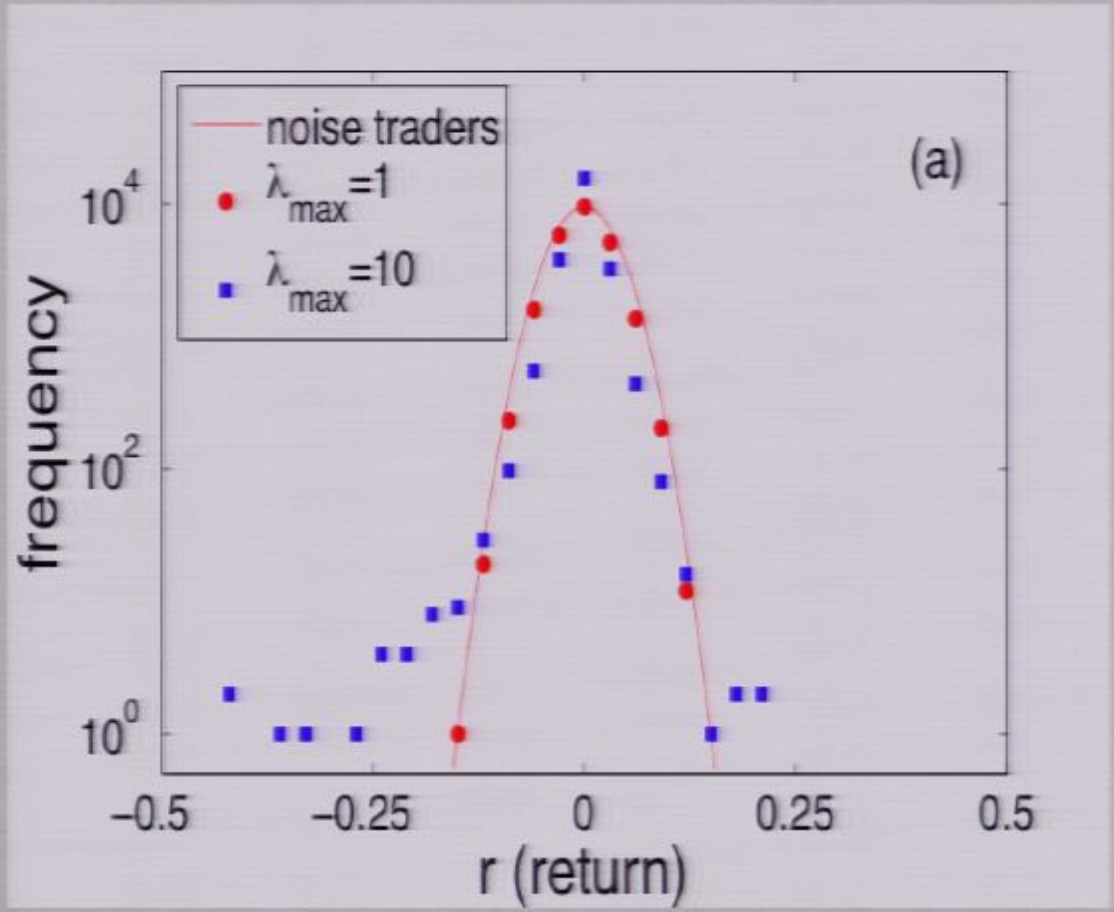

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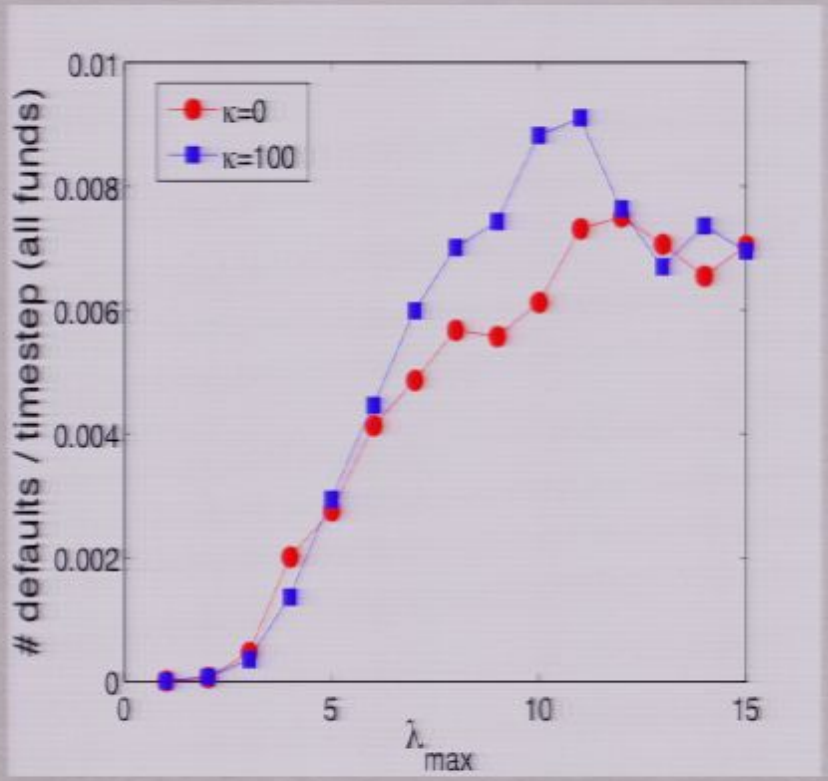


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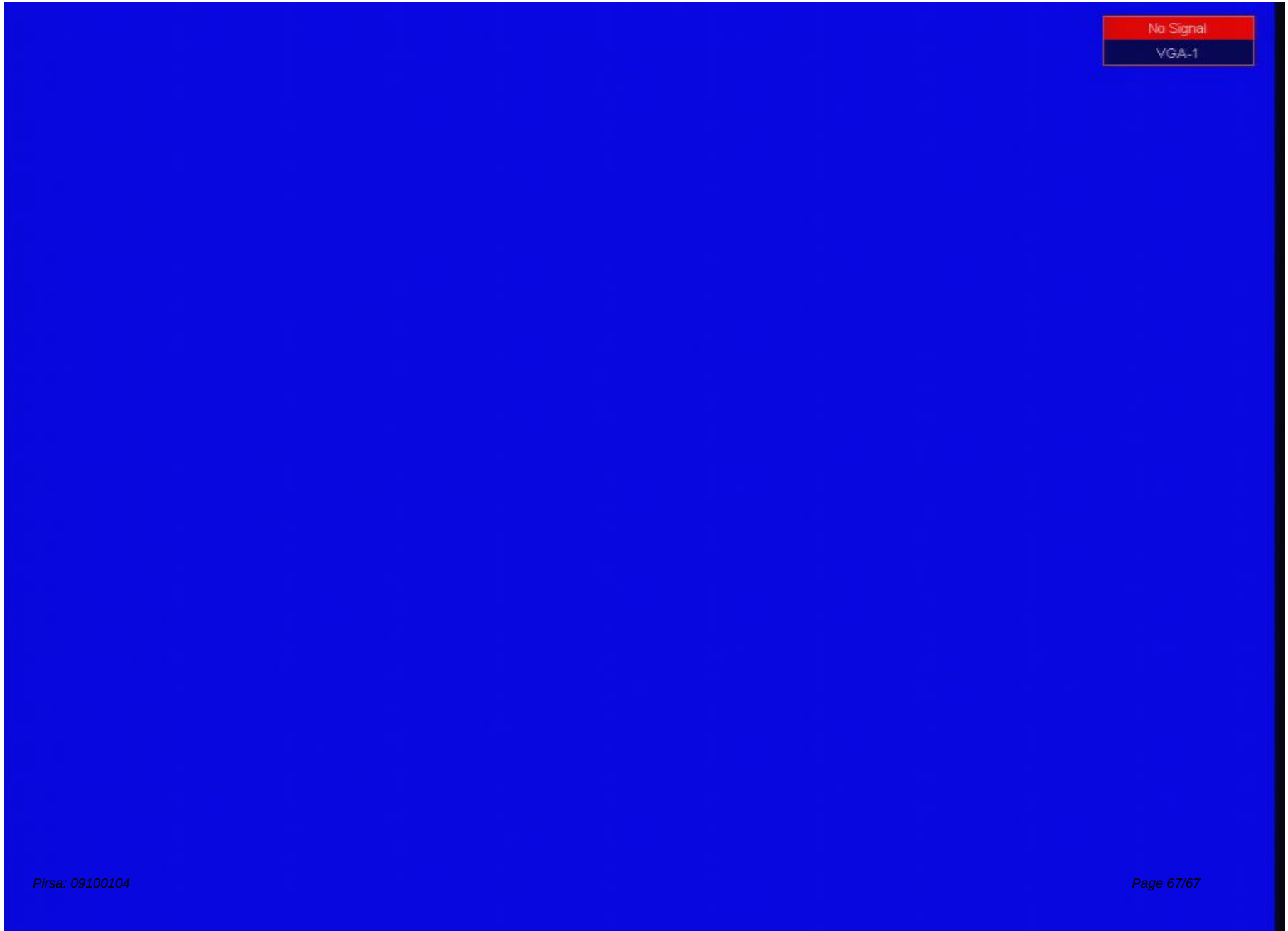
No Signal
VGA-1