Physicists attempt to scale the ivory towers of finance (ten years later, looking forward)

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Opportunities and dangers

• Economics, and particularly finance, present huge opportunities
  – we bring new perspective
  – low hanging fruit
  – laws of social systems!
  – laboratory to study social evolution

• Downside
  – entrenched, pre-existing social order
  – physics envy by economists, arrogance on both sides
  – narrow mindedness of physics establishment
Laws of markets?

- Are markets on other planets anything like those on earth?
- Prediction: They will have money, markets derivatives, ...
- They will obey many of same regularities as our markets do.
Market laws

- Pareto’s Law for income, (exponential for body ?)
- Long-memory of supply and demand
- Power law for trading volume
- Relation between exponents of volume, S&D
- Anomalous scaling of firm size
- Laws of market impact
- Volatility = 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
- .... (many more)
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Financial markets provide a perfect laboratory in which to study social evolution.
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- Define “evolution” as any process with descent, variation, and selection.
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- Social evolution differs in detail, but has the same three elements. But what is evolving?
- Of course, comparison should not be taken literally: Important to understand both similarities and differences.
What is biggest difference between social and biological evolution?

People can think.

• In this respect, biology is easier: Accurately modeling thinking humans is very difficult.
  – Innovation
  – Strategic anticipation

• Limiting cases (tractable but far-fetched):
  – Perfect rationality
  – Zero Intelligence

• ZI is like biology (if you define “ZI” so as to include 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 environment
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Statistical mechanics of human systems

- Many human systems exhibit emergent phenomena generated by low level interactions of many individuals.
- In constrained settings these exhibit consistent laws, like physical systems.
- Challenge to make microscopic models of actors.
- Two strategies:
  - Find situations where institutional constraints dominate human choice.
  - Find situations where we can use simple heuristics to characterize human reasoning.
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Market efficiency?

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

Signal 1:

[Graph]

Signal 2:

[Graph]
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INTERPOLATION VS. EXTRAPOLATION
Problems with neoclassical economics

- Utility
- Measure of expected states of nature
- Cognitive model of agents
- Need to model institutions!
- Economy is an evolving complex system
- Difficulty of making falsifiable predictions
  - toy models vs. real models
Developmental stage?

- Medieval culture of knowledge
- Need for fancier math?
- Pre-Newtonian?
  - taxonomy of strategies
  - search for empirical regularities
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Risk under open-ended evolution

- Reducing risk by controlling the environment is a tried and true evolutionary strategy.
- Increasing complexity makes fitness increasingly endogenous (coevolution, niche construction)
- Makes optimization difficult
  - fitness determined by actors (self and others)
- Extrapolation rather than interpolation
- Effort to reduce risk can create risk
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Hedge fund/leverage model

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

- Hedge funds can use **leverage**, defined as ratio of value of holdings to their wealth. Maximum leverage is key parameter.
- Hedge funds differ in their aggression, i.e. how much they buy for a given mispricing (slope).
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Wealth vs. time, 10 funds

- Hedge fund wealth fluctuates
- There are crashes
- Evolutionary pressure favors more aggressive funds
Leverage causes extreme stock price movements
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Leverage causes extreme stock price movements
Leverage causes power law tail for stock returns

\[ P(r > R) \sim R^{-\gamma} \]
Extreme risk increases with leverage
Leverage and volatility

Stock returns vs. time

- When mispricing is small, funds lower volatility
- At maximum leverage they amplify volatility
- Extreme events caused by attempt to control risk.
- Other examples: stop-loss orders, call options, ...
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Extreme risk increases with leverage
Standard bank risk control policy is counterproductive

- When $k > 0$, banks lower maximum leverage when historical volatility is higher
- Results in more defaults.
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\[ \lambda_{\text{max}} = 1 \]
\[ \lambda_{\text{max}} = 10 \]
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Results in more defaults.
Evolutionary pressure for higher leverage

(a)

\[ \Lambda \] vs. \[ \lambda_{\text{max}} \]

- Blue squares: fund 1-9; \( \lambda_{\text{max}} = 3 \)
- Red circles: fund 10; \( \lambda_{\text{max}} = 1-10 \)
Need to regulate leverage

- Evolutionary pressure drives funds toward increasing leverage.
- Causes increased defaults, more extreme events, and lowers returns for everyone.
- Goldilocks principle: What leverage is “just right”?
  - Peters: Kelly criterion suggests $\mu / \sigma^2$
- Social experiments: Friedman was wrong!
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
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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
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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 model
  - Need to explain macroeconomy from microeconomic arguments (Axtell)
  - caution: much less data