A vision of the economics of the future II

Pasargad Advanced Research Initiative
Big Data Economics Summer school
Khatam University, Tehran
Sept. 5, 2016

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Outline

1. What is an economic model?
2. When is equilibrium assumption justified?
3. Some simple examples of ABMs
4. Complex systems
5. Market ecology
6. Challenges for ABM and Big Data
7. My vision of future economics

My vision

- Real time tandem simulation of economies of the major countries of the world.
- Micro-big data inputs directly from internet.
- Coupled to other social models?
- Used by central banks
- Teams focusing on each component, e.g. households, firms, banks, …

My vision

- Forecast unemployment, economic prosperity, …
  - *would not* forecast stock market, interest rates, …
- Main use would be policy analysis
  - forecasting mainly to provide reality check
- Variant would be an integrated assessment model for economy- environment interactions.
- These models would be built out of a library of standard plug and play components.
  - similar to current climate models

Motivations and challenges

- Why do I think this could work?
- What are the challenges and bottlenecks to achieving it?

First a little background …

Efficient markets theory

- No arbitrage: It is not possible to make a consistent profit from trading in financial markets without inside information.
- Markets are efficient because of arbitrageurs, who remove any inefficiencies.

Prediction Company

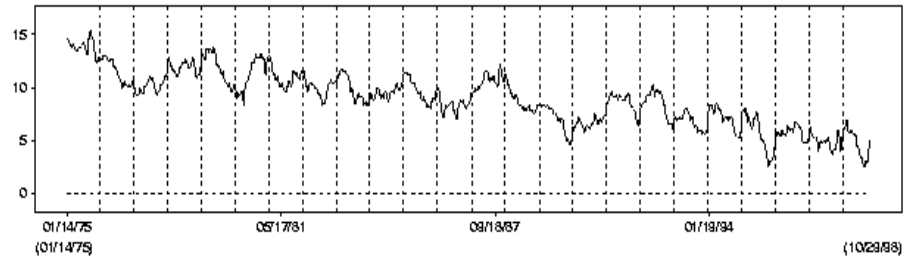
- One of the earliest purely quantitative funds
- Founded by Norman Packard and I in 1991
- Completely automated trading
- I left in 1999, sold to UBS in 2006
- Volcker rule — recently sold to Millenium.

- Basic idea: Find reproducible patterns in financial time series to create a "financial cerebellum"

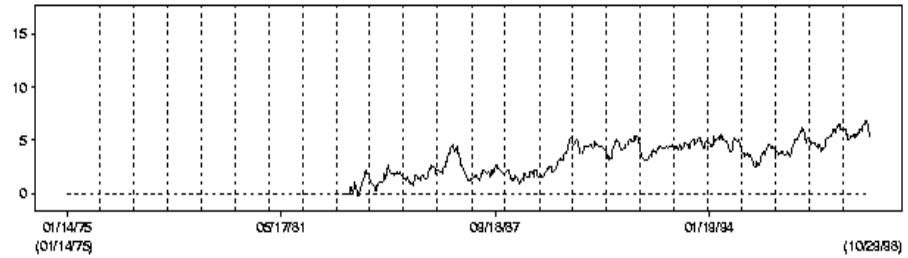
Market efficiency?

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

Signal 1:



Signal 2:



How did I come to complexity economics?

- When I left Prediction Company in 1999, I decided to merge my complex systems background with my domain knowledge of finance

Discipline of complex systems

Motivated by belief in two principles:

- Complex behaviors emerge from interactions at a lower level, e.g.
  - living organism
  - brain
  - ant colony
  - human society
  - economy
- There are similarities between such examples that justify studying them together
  - "strong" vs. "weak" vision of complex systems

Science and technology will shift from a past emphasis on motion, force, and energy to communication, organization, programming, and control.

John von Neumann, 1950

Add: Structure, form, function, information, computation, emergence, evolution, …

An example of this approach

Market ecology

(Farmer, 2002; Farmer and Skouras 2013)

Grossman and Stiglitz paradox

Market efficiency requires arbitrageurs but arbitrageurs require inefficient markets.

- Markets necessarily deviate from efficiency
- It is difficult but not impossible to make consistent profits (e.g. Renaissance, Prediction Company, …)
- Markets are (informationally) efficient at first order but necessarily inefficient at second order

Market ecology hypothesis

- Agents follow specialized strategies that exploit niches, corresponding to inefficiencies generated by activity of other agents
  - cost/benefit => increasing returns to specialization
- Profit relationships define a market food web that specifies who profits from whom
- The market food web evolves with time
- Evolution of new strategies unbalance web
- Imbalances in market food web drive crises

Practical use?

- Stress testing:
  - 1.0: Shock balance sheets of individual banks
  - 2.0: Shock banks and assets and monitor failures as they propagate through network
  - 3.0: Simulate ecology of agents using models calibrated against historical transactions with counterparty identifiers (with Alissa Kleinninjenhuis and others)

Back to agent-based modeling in general

Why isn't ABM the mainstay of economics?

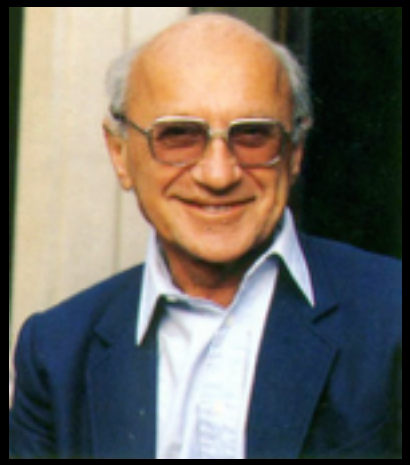
- Math culture is deeply rooted
  - papers scored too much on math vs. science
  - disdain and distrust of simulation
  - fascination with rationality and optimality
- ABM is a fringe activity, hasn't delivered home runs needed to enter establishment
  - contrast to behavioral economics
  - chicken/egg problem
- Lucas critique

Paul Krugman's view of agent-based modeling

"Oh, and about ~~Roger~~Doyne Farmer (sorry, Roger!) and Santa Fe and complexity and all that: I was one of the people who got all excited about the possibility of getting somewhere with very detailed agent-based models — but that was 20 years ago. And after all this time, it's all still manifestos and promises of great things one of these days."

Paul Krugman, Nov. 30, 2010, in response to an article about INET housing project in WSJ.

Lucas Critique



- Recession of 70's. "Keynesian" econometric models.
- Phillips curve: Rising prices ~ rising employment
- Following Keynesians, Fed inflated money supply
- Result: Inflation, high unemployment = stagflation
- Problem: People can think
- Conclusion: Macro economic models must incorporate human reasoning
- Solution: Dynamic Stochastic General Eq. models

Structure vs. strategy

- Strategy: Agent decision making
- Structure: Structural constraints on decision making, e.g. institutions, environment, accounting, social networks, …
- Can't model everything at once: Inherent tradeoff between structure and strategy.
- Requirement to compute equilibrium makes it difficult to model structure realistically

Advantages of DSGE

- "Micro-founded" (unlike econometric models)
  - can be used for policy analysis.
- Time series models
  - initializable in current state of the world, can make conditional forecasts
- Describe a specific economy at a specific time.
- In some sense parsimonious

Why agent-based modeling?

- Diversifies toolkit of economics: Complements DSGE and econometric models.
- Time is ripe: increased computer power, Big Data, behavioral knowledge. Never let a crisis go to waste.
- Hasn't really been tried yet -- crude estimates:
  - econometric models: 30,000 person-years
  - DSGE models: 20,000 person-years
  - agent-based models: 500 person-years
- Successes elsewhere: Traffic, epidemiology, defense
- Examples of successes in economics:
  - Endogenous explanations of clustered volatility and heavy tails; firm size; neighborhood choice

Advantages

- Can faithfully represent real institutions
- Easily captures instabilities, feedback, nonlinearities, heterogeneity, network structure,...
- Shocks can be modeled endogenously
- Easy to do policy testing
- Easy to incorporate behavioral knowledge
- Can calibrate modules independently using micro data -- much stronger test of models!
  - In some sense between theory and econometrics
- ABMs synthesize knowledge:
  - Possible to understand what is not understood

Challenges

- Little prior art
- Developing appropriate abstractions
  – What to include, what to omit?
  – How to keep model simple yet realistic?
- Micro-data to calibrate decision rules?
- Data censoring problems
- Realistic agent-based models are complicated.
- No theoretical foundation

Cautionary tale of weather forecasting

ABM and Big Data

- Two ways to model the world
  - statistical (e.g. econometrics)
  - fundamental (e.g. DSGE)
- Big data is complex end of statistical modeling
- ABM is complex end of fundamental modeling in social science
- ABM and big data go hand in hand
  - Can use big to to calibrate and construct models for individual agents

Design philosophy

- As simple as possible (but no more)
- Design model around available data
- Fit modules and agent behaviors independently from target data, using several different methods:
  - micro-data for calibration and testing
  - consult domain experts for behavioral hypotheses
  - adaptive optimization to cope with Lucas critique
  - economic experiments
- Systematically explore model sensitivities
- Plug and play
- Standardized interfaces
- Industrial code, software standards, open source

Formulating decision rules

- Make something up
- Take from behavioral literature
- Perform experiments in context of ABM
- Interview domain experts
- Calibrate against microdata
- Learning and selection, Lucas critique
- Rationality

Existing ABMS in economics

- All are qualitative
- Range of complexity, e.g.
  - zero/low intelligence continuous double auction
  - latent order book (Bouchaud group)
  - Lebaron, Brock Hommes trend follow/fundamentalist
  - Axtell firm size
  - Thurner et al. leveraged value investors
  - SFI Stock Market
  - Dosi-group
  - EURACE

Agent-based model of Washington DC housing market

- Goal: conditional forecasts and policy analysis
- Simulation at level of individual households
- Exogenous variables: demographics, interest rates, lending policy, housing supply.
- Predicted variables: prices, inventory, default
- 16 Data sets: Census, mortgages (Core Logic),tax returns (IRS), real estate records (MLA), ...
- Goal: Model housing prices for Washington DC metro area and understand housing bubble

Housing model project

- Senior collaborators: Rob Axtell, John Geanakoplos, Peter Howitt
- Junior collaborators: Ernesto Carella, Ben Conlee, Jon Goldstein, Matthew Hendrey, Philip Kalikman
- Funded by INET for $375,000.

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- Current goal: Model Washington DC metro area
- Future goal: All metro areas in US

Module examples

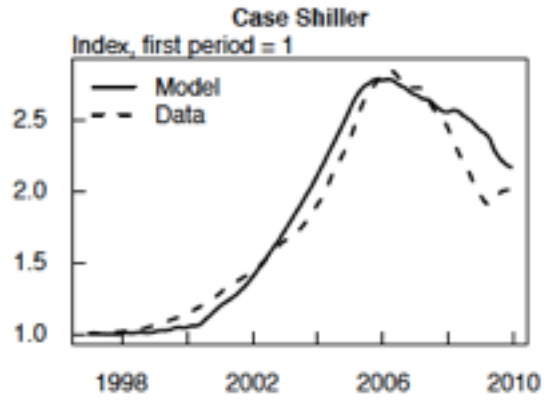
- Desired expenditure model
  - buyers' desired home price as a function of household income and wealth
- Seller's pricing model
  - seller's offering price as a function of home quality, time on market, and total inventory
- Buyer-seller matching algorithm
  - links buyers and sellers to make transactions
- Household wealth dynamics
  - models consumption and savings
- Loan approval
  - qualifies buyers for loans based on income, wealth; must match issued mortgages

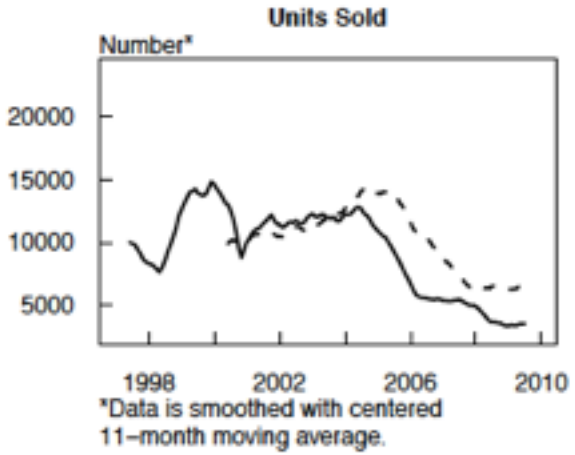
Housing model algorithm

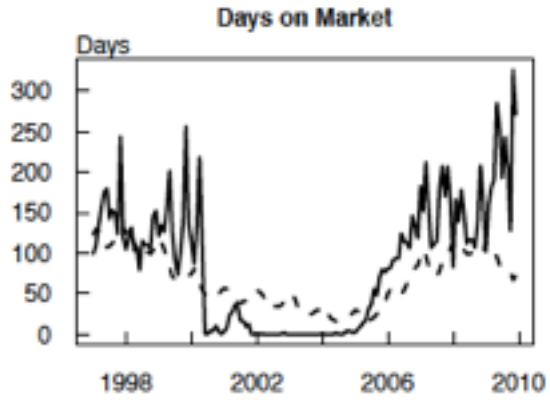
At each time step:

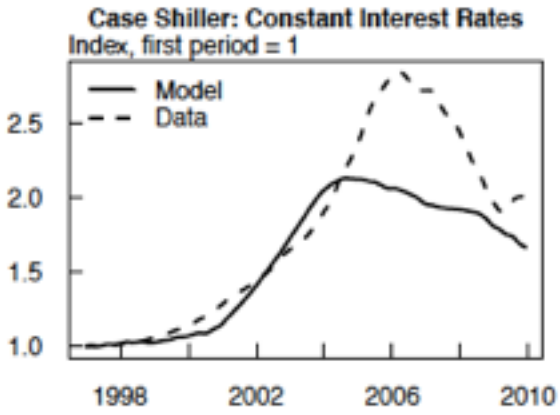
- Input changes to exogenous variables
- Update state of households
  - income, consumption, wealth, foreclosures, ...
- Buyers:
  - Who? Price range? Loan approval, terms?
- Sellers:
  - Who? Offering price? Price updates?
- Match buyers and sellers
  - Compute transactions and prices

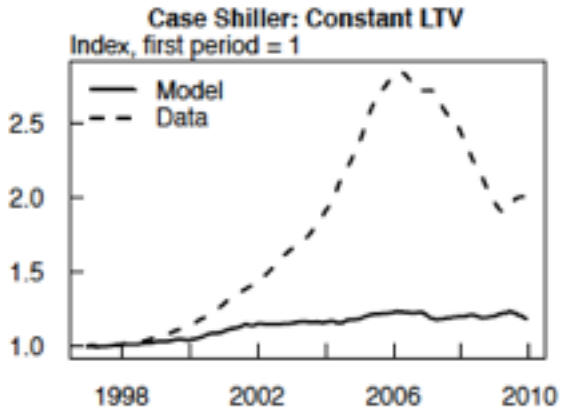
Comparison of data to model*

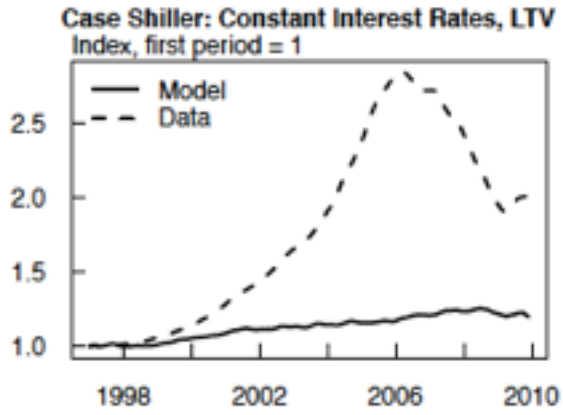












Tentative conclusion: Lending policy is dominant cause of housing bubble in Washington DC.

(model is overfit)

Bank of England model
(Tang, Hinterberger, Uluc, Low, Baptista, Farmer)

- Used to give advice to the Financial Policy Committee on lending policy and for policy relating to buy to let investors

Economic agent project

(Ben Herd, David Pugh, Paul Rauwolf, Davoud Taghawi-Nejad)

- Economic agents are special because
  - they have balance sheets
  - interact with markets
  - form expectations
  - make contracts
- Embody with modern software
- Open source project “wiki-economics”.

Concluding thoughts

- We have lots of work to do to make agent-based models that can compete with or surpass existing alternatives
- Must solve chicken and egg problem
- In economic models of future (e.g. for central banks) ABM and Big Data will play a prominent role
  - but when?

The new economics that I envision will require a cultural shift

- Different knowledge set
- Different approach to posing and solving problems
- Different criteria for credit assignment

Scientific method in economics

The epistemology of economics is quite different from that used in natural sciences, particularly in regard to the approach for accumulating and explaining empirical facts.

Hypotheses Non Fingo, Journal of Economic Methodology, 2013

How to expand horizons of economics?

Demonstrate that methods emerging from alternative epistemologies are more successful at explaining and predicting empirical phenomena.

- Determine which theories have empirical backing
- Catalogue empirical laws
- Develop phenomenological theories matching data
- Agent-based models

Evolution of collective consciousness

- Consciousness: A model of oneself
- Collective consciousness: The collection of models we use to understand our society
  - cause-effect relationships
  - What are our options?
  - Where will they lead us?

Complex systems engineering is like gardening

- Complex systems built from the bottom up.
- Engineering complex systems is like gardening: Lay down rules, observe consequences, modify rules.
- Since structure is emergent, inherently difficult to predict
  - some properties are robust
  - others sensitive to details, path dependent