Agent-based models

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Definition

- Agent-based models (ABMs) portray *complex adapting systems*
- Complex system (Tesfatsion, 2006):
  - The system is composed of interacting units;
  - The system exhibits emergent properties
- Adaptive: The units react to changing environments

Economics - a "complexity science"

- Examples: Economies, ecosystems, ant colonies, the brain, the immune system etc
- Complexity is not a theory but a movement in the sciences that studies how the interacting elements in a system create overall patterns, and how these overall patterns in turn cause the interacting elements to change or adapt
- Interdisciplinary: Engineering, Biology, Meteorology, Chemistry, Economics, Other social sciences

In more familiar terms...

- Another possible (and not very different) definition of a complex system is "a system comprised of a population of interacting, heterogeneous agents in which the behavior of each agent can be described as a function of the behaviors of other agents, as well as of other factors" (Durlauf, 2012)
- Put differently:

$$y_{i,t} = f_i\left(y_{i,t-1}, y_{j,t}, y_{j,t-1}, \varepsilon_{i,t}, \theta_i\right)$$

- Which could (maybe) be solved and more generally be expressed as:

$$y_t = f\left(y_{t-1}, \varepsilon_t, \theta\right)$$

- Looks a lot like the solution to a DSGE model

Defining features of ABMs

- Simple heuristics rather than optimization
- Heterogeneity
  - the more the merrier
- Interacting agents
  - Networks
- Learning
  - bounded rationality
- Non or multiple equilibria
  - Change (endogenous) in technology, institutions and preferences
- Positive rather than normative
- Simulations rather than analytic solutions

Positive vs normative

- General equilibrium theory asks what prices and quantities of goods produced and consumed would be consistent with—would pose no incentives for change to—the overall pattern of prices and quantities in the economy's markets.
- Classical game theory asks what strategies, moves, or allocations would be consistent with—would be the best course of action for an agent (under some criterion)—given the strategies, moves, allocations his rivals might choose.
- And rational expectations economics asks what expectations would be consistent with—would on average be validated by—the outcomes these expectations together created.
- . . . But how do we actually get there (and will we ever)?

Pros of ABMs

- Allows us more easily to relax assumptions like
  - Representative agents, nonlinearities, rational expectations, instant market clearing, full information etc.
- Very flexible, easy to add or remove parts of the model
  - Thanks to the use of simulations
- Very suitable for handling nonlinearities
  - "if...then..." statements
- Easy to understand and communicate
  - At least along some dimensions
- Object-orientated analysis, design and programming

Cons of ABMs

- Lots of parameters, too much freedom?
  - but more detailed data will help
- Not so well-suited for forecasting
  - Cause and effect statements may appear more blurred
- Harder to "invert"
  - i.e. to engineer a desired outcome (less practical, but maybe also a good thing)
- Requires relatively strong programming skills
- Potentially useful as a *complementary* tool to existing macro models

Related developments

- Artificial Intelligence (AI)
  - Machine learning
- Microsimulation models (like MOSART, LOTTE?)
  - Orcutt (1957), Bergmann (1974) and Eliasson (1976)
- Behavioral Economics
  - Experimental Economics
  - Microeconometrics

Why now?

- Ever increasing computational powers
- Interdisciplinary efforts on modelling complex systems using simulation tools
- Advances in behavioral economics
  - Experimental studies
- Increasing availability of high quality micro data

An ABM for the housing market

- Wish to see how careful modelling of the choices made by heterogenous market participants can help us understand the dynamics underlying aggregate price movements
- The importance of price expectations and how they affect price behavior
- Implications of the dual role of most market participants (buyer-seller) and chain dynamics
- The interaction between housing prices and credit conditions
- Housing supply

Main features

- Partial ABM
  - Wages and interest rates given by stochastic exogenous process, otherwise model self contained
- Main classes of agents:
  - Households, construction firms, banks and realtors.
- Market clearing not imposed, result of matching process
- Rental market
- Model guided by detailed housing transaction and household finance data

Households

- Households are highly heterogeneous
  - Owner-occupier, investors, "homeless"
  - Differ w.r.t. age, income, size, children etc.
- Endogenously determined by: merging, splitting, "calving", migration and death
- Consume housing services, other consumption and save
  - Heterogenous desired budget expenditures
- Keeping track of balance sheets

other agents

- Houses characterized by a set of partly observable attributes
  - Size, location, age, standard etc.
  - Aggregate price movements determined by hedonic price index
- Banks
  - Provide loans and collect deposits
  - Mortgage approval based on checking finances against LTV and LTI requirements
- House production by separate sector
  - Pipeline of new houses, investment lags
- Realtors managing the matching process

The matching process

- Supply of houses listed on "Finn.no"
- Pool of potential buyers
- Bidding process organized by realtors
- Supplier must consider final bid
  - If kept on market, price depends on time-on-market and whether seller has recently bought
- Potential buyers still searching will extend search interval depending on "time-on-market" and if already sold