Pre-conference workshop on Agent-based Models in Economics and Finance

Chapter 1 – Introduction: Economy as a complex adaptive system (CAS)

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Standard modeling approach in Economics

- Individual agents aim to maximize their welfare under constraints (of income, technology)
- They make their decisions given
  1. the characteristics of the economy (institutions, markets,...);
  2. the expected behavior of the other agents in the economy,
  3. computed at equilibrium (static models) or along the equilibrium path (dynamic models).
- The model is solved by simultaneously determining the expectations and optimal behaviors of the agents at the equilibrium
- This solution also determines the aggregate variables (prices, total production, unemployment, etc.)

1 New vision of economic dynamics

Economy as a complex adaptive system (CAS)

What is in common between:

- an industry composed by innovating firms

- a financial market
- but also;
- a megapolis
- a friends network or a criminal network
- the immune system of an individual
- evolution of species in an ecosystem

→ John Holland (1996) : *Complex adaptive systems* (**CAS**).

Five general properties of the CAS

(Arthur *et al.* , 1997):

1. Dispersed interaction
2. No global controller
3. Continual adaptation
4. Perpetual novelty
5. Out-of-equilibrium dynamics

Red Queen's

> -Now, HERE, you see, it takes all the running YOU can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that !
>
> (The Red Queen, in Through the Looking Glass, by Lewis Carrol, p.20)

Properties of complex dynamics

- Difficulty to predict aggregate properties from individual behaviors (emergence);
- Difficulty to predict final states of the system (open dynamics);
- Importance of small historical events (path dependency);
- Importance of small components of the system (strong interaction).

- Dynamics and aggregate properties of a CAS
- ← Interactions and learning of agents.
- → Necessity of developing new tools for analysis and modeling

2 Agent-based Models (ABM) as an alternative modeling approach

A new modeling framework

that

- precisely depicts the structure of the interactions between individual agents;
- allows for the study aggregate properties emerging from these interactions;
- through the dynamics of these interactions (an "history" of the system);
- does not need neither
  - the assumption of substantive rationality,
  - nor of equilibrium (modeling disequilibrium dynamics)

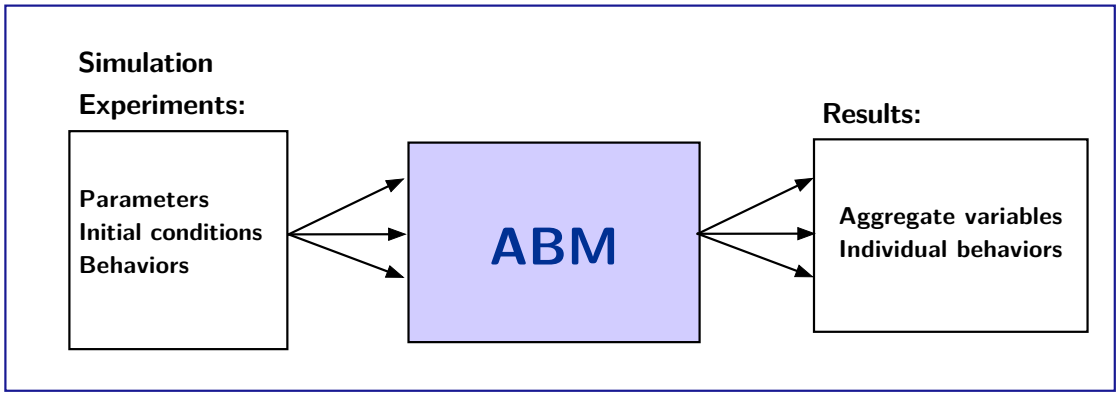
- A new tool for modeling that is compatible with
  - the introduction of policy choices in the system
  - the representations of the spatial configurations of economic activities (if necessary)
- $\rightarrow$ *Agent-based Models* (**ABM**)

Building an ABM

For modeling an economic system/problem as an ABM:

- we create individual agents (consumers, firms, etc.);
- we define the dynamics of their behavior (learning/adaptation);
- we define their interactions (global; localized in a space, in a network,...);
- if relevant, we define dynamics that directly take place at an aggregate level (aggregate shocks);
- we fix initial conditions of the systems and the values of the parameters,
- and the number of periods of observation.

Analyzing an ABM



Using an ABM

- We execute the model to obtain one "history" of the system, which can be analyze using
  - graphics in real-time;
  - statistical analysis after the execution.
- If stochastic elements in the model → necessity of sampling several histories coming from the same economy (robustness)
- We can also build experimental designs (DOE) that explore different sets of initial conditions and parameter values
- Possibility of comparing data resulting from different experiments → analysis of the role of model's parameters, or of economic policies.

Strategies of experimentation

- **Monte Carlo**:
  - random draw of initial conditions and parameter values
  - graphics
  - statistics/econometrics
  - Advantages: a through coverage of the parameter space;
  - Disadvantages: many experiments → high computation cost
- **Design of Experiments (DoE)** : (Salle & Yildizoglu, 2013)
  - Much smaller set of experiments
  - but specifically adapted statistics and econometrics (*kriging*)

– Advantages: considerable reduction of the computation cost

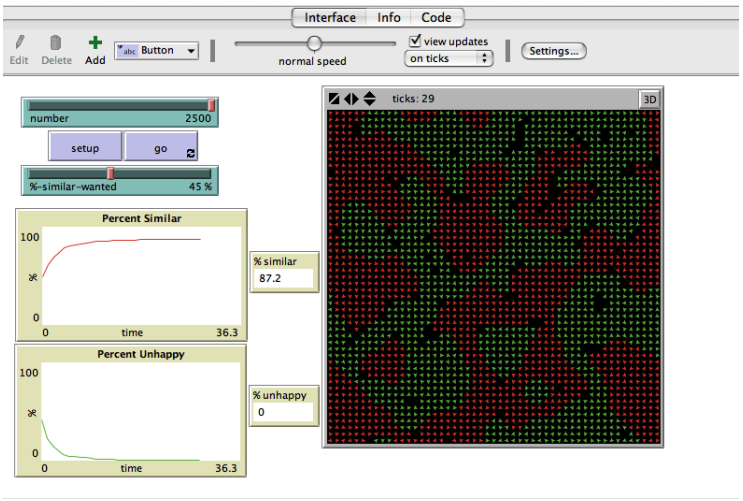
– Disadvantages: an oriented coverage of the parameter space, under assumptions about the possibility of interpolating towards unobserved values

Practical development

Programming the model:

- Using a standard language (OO): C++; Java;
- Or, benefiting from facilities of a dedicated ABM platform
  - **SWARM**: one of the oldest, developed by the Santa Fe Institute, based on ObjC, very powerful, but quite heavy and slow, with a steep learning curve;
  - **RePaST**: SWARM in Java, very powerful, easier but quite heavy and slow nevertheless;
  - **NetLogo**: ABM version of the Logo language, very easy to learn and quite powerful (final program in Java)

NetLogo: http://ccl.northwestern.edu/netlogo/



Outline of the workshop

- Chapter 1: Economy as a complex adaptive system
- Chapter 2: An introduction to NetLogo
- **Proposed applications**
  - A simple learning in a Cournot oligopoly

- Routinized R&D behavior, innovation and industrial dynamics (Nelson & Winter (1982)
- A very simple financial market

Main references

- Miller & Page (2007)
- Nelson & Winter (1982)
- Railsback & Grimm (2012)
- Web site of the course:

`http://yildizoglu.info/cef-2015/`

References

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