AGENT BASED MODELS
AN ALTERNATIVE TO
MAINSTREAM ECONOMIC MODELING

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Compared with physics, it seems fair to say that the quantitative success of the economic sciences has been disappointing. Rockets fly to the Moon; energy is extracted from minute changes of atomic mass. What is the flagship achievement of economics? Only its recurrent inability to predict and avert crises, including the current worldwide credit crunch.

I distinctly remember an occasion when the professor—a future Nobel Prize winner—was presenting a formal model of consumer behavior. A student remarked, “But that’s not how people behave.” The professor replied simply, “You’re right,” and without another word, turned back to the blackboard and continued his presentation of the model. We all got the idea.

ROBERT AXELROD

Gerald R. Ford School of Public Policy, University of Michigan, USA
Economists are considered “social scientists” and their judges and advices have a notable impact on decision makers. …

It seems that, sometimes, “classical” models, heavily grounded in a unified core theoretical / background are not working, specially in contexts highly conditioned by human behavior.

Something has to happen. Economists have to better model = better understand = better advice some complex emergent economic phenomena, AND THUS.
The MAIN IDEA

MAYBE, and ONLY MAYBE…

Agent Base Models deserve to be more widely studied, developed and applied, at least as a complement to mainstream applied economic modeling….

And this is not only about DOING economics but also about LEARNING economics….

YOU AS STUDENTS, may deserve a more pluralistic education at college, questioning the way in which economics is taught, demanding a wider spectrum, helping to rethink how economics is taught
How about Rethinking Economics?

Copied (without permission I’m afraid) from http://www.rethinkeconomics.org/
Do you agree with some of these sentences?

- Economics degrees are characterized by a lack of critical thinking, a lack of alternative perspectives, a lack of real world application and a lack of ethical and political context.
- Lectures teach one perspective as if it is the only legitimate way to study the economy
- There is no room for the critical discussion and debate
- Seminars are focused on memorizing and regurgitating academic theory, whilst exams test how well students can solve abstract equations.
- University departments (...) are often dominated prominent neoclassical economists, unlikely to award funding for research and teaching that does not match their own understanding of economics

THE CHALLENGE: How do we ensure that universities are hiring an intellectually diverse community of academics capable of teaching the economics we want to see?

Copied (without permission I’m afraid) from http://www.rethinkeconomics.org/
Four main questions?

1. Why do economists need simulation models?
2. Why current economic models need to improve?
3. What is the idea behind an Agent Based Model?
4. Are ABM an alternative to mainstream modeling?
before starting questioning

- A “simulation” shows the expected working of a system based on a model (simulation model).
- A “simulation model” is a technical tool that, by means of a simplified representation of reality help us to understand real complex systems...in order to take or evaluate alternative decisions.
Four main questions?

1. Why do economy policy makers need simulation models?
2. Why current economic models need to improve?
3. What is the idea behind an Agent Based Model approach?
4. Are ABM an alternative to mainstream modeling?
1. Why do policy makers need Simulation Models?

- **Growing Complexity** of economic system
- **Alternative decisions** can be taken
- **Cost of wrong decisions**
- Impossible to make real tries
Four main questions?

1. Why do economy policy makers need simulation models?

2. Why current economic models need to improve?

3. What is the idea behind an Agent Based Model approach?

4. Are ABM an alternative to mainstream modeling?
2. Why current economic models need to improve?

- **Perfect World**: Classical modeling (GEM, DSGE,..) assumes an abstract, oversimplified “perfect world” using some mainstream theoretical axioms that have solidified into dogmas.

- Mainstream modelling gives a central role to optimum, stability, equilibrium but it seems that we would need a new approach to understand disequilibrium – conflict - complexity.
2. Why current economic models need to improve?

- Formal models built up around common core theoretical foundations give economics an aura of intellectual preeminence, but sometimes, economic problems may not be tractable = computationally / math reductible, so the idea of reling in pure, reduced, clean mathematical structures to try to understand how complex things work is not a good one.
2. Why current economic models need to improve?

- We tend to assume fully deterministic structures or we simply chose to model the deterministic side of events, “regularities” of radically random systems.

- We accept randomness but only under the framework of tractable statistics, usually restricted to well described, stable, simplified, probability distributions (ergodicity)
2. Why current economic models need to improve?

- We, in effect, assume that the world is **ergodic** (expected values will stand over the long run) We premium **regularity (ergodicity)** to understand causation even when its clear that the future is not an extrapolation from the past.

- We don’t accept anyhow the notion of **radical uncertainty** (events with a very reduced chance of happening but a huge effect on the outcome)
2. Why current economic models need to improve?

- We undervalue and misunderstand the role of agents.
  - We tend to circumvent or reduce heterogeneity. Modern economies are very articulated, and highly heterogeneous institutional arrangements often govern the functioning of key markets.
  - When we look at individuals, we use to select a representative perfect rational that acts in a consistent and foreseeable way.
  - We tend to think that agents follow optimization rules under a framework of rational expectations (without any or only few bias) giving no chance for more simple heuristic (realistic) behavior.
2. Why current economic models need to improve?

- We also ignore or reduce the role of interaction between agents and between agents and environment so we concentrate in the final outcome of a system / model and not in the entire path of events.
2. Why current economic models need to improve?

- Our models are normally described in such a broad way that cannot be easily adapted to a real specific cases. Environment matters, but we tend to overuse a general analytical framework not having into account the extraordinary importance of the context where the model is used.
2. Why current economic models need to improve?

- We are absolutely focused in the outcome of a process, and not in the process itself. We want to understand if something is going to happen, or “why” things happen giving a minor role to “how” things happen. But, in some cases, the outcome does not only depend on a formal model and a set of initial conditions so the only way of approaching a process is to track its entire path.
2. Why current economic models need to improve?

- **Macro – Modelling** is still being intensively used, measuring inputs and outputs by means of **aggregation**. We give a central role to “variables” (Variables Based Models) emerging from collective behavior instead of looking at “individuals”.

2. Why current economic models need to improve?

- Related to the previous point, when it's about macro modeling, we normally focus on central values, and distribution / dispersion does not play a central role in the analysis. By looking at the aggregated macro level, the spreading / allocation of variables is misunderstood when, in fact, in reality, some events are led by issues related to inequality or asymmetrical distributions of info, income,...
Four main questions?

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3. What is the idea behind an Agent Based Model approach?

• A class of computational models for simulating the actions and interactions of autonomous agents (both individual or collective entities such as organizations or groups) with the aim of understand the system as a whole.

• Is a modeling method, half-way between a mathematical and experimental approach, used to explicitly explain the behavior of highly interactive and heterogeneous systems featured by irreducible randomness.
3. What is the idea behind an Agent Based Model approach?

Pure BOTTOM – UP: MODELING THE INDIVIDUAL BEHAVIOUR OF AGENTS, THE INTERACTION BETWEEN THEM AND THEIR INTERACTION WITH THE ENVIRONMENT WE ARE ABLE TO UNDERSTAND UNEXPECTED COMPLEX EVOLUTION, LARGE SCALE CONSEQUENCES OF COLLECTIVE PHENOMENA.
3. Simple examples of ABM: birds flock

• Have you ever wondered how a flock of starlings behave to perform this amazing “dance”?  
  https://www.youtube.com/watch?v=DmO4Ellgmd0

• You can try to reproduce the flock with equations of “critical transitions” but the movement of the flock is very hard to model, hard to simulate and unpredictable in essence.
3. Simple examples of ABM: birds flock

- They look as if a flock leader would rule the movements of the flock, but this is not true. The flock “doesn't exist” but emerges from individual behavior.

- Each single starling follow a simple set of 3 rules:
  - “Alignment” = a bird tends to **turn** so that it is moving in the same direction that nearby birds are moving.
  - “Separation” = a bird will **turn** to avoid another bird which gets too close.
  - “Coherence” = means that a bird will **turn** move towards other nearby birds (unless another bird is too close).

When two birds are too close, the “separation” rule overrides the other two, which are deactivated until the minimum separation is achieved.
3. Simple examples of ABM: birds flock

- **Let's try to explore the model with NetLogo** *(Sample Models – Biology – Flocking)*

- We need some random birds placed randomly, immobile IN TIME “t”, heading for some random direction, in a simulation space

```plaintext
;;; SEPARATE
to separate ; turtle procedure
  turn-away (Heading) of nearest-neighbor max-separate-turn
end

;;; ALIGN
to align ; turtle procedure
  turn-towards average-flockmate-heading max-align-turn
end

to-report average-flockmate-heading ; turtle procedure
  ;; We can't just average the heading variables here.
  ;; For example, the average of 1 and 359 should be 0,
  ;; not 180. So we have to use trigonometry.
  let x-component sum [x-component] of flockmates
  let y-component sum [y-component] of flockmates
  ifelse x-component = 0 and y-component = 0
    [ report heading ]
    [ report atan x-component y-component ]
end

;;; COHERE
to cohere ; turtle procedure
  turn-towards average-heading-towards-flockmates max-cohere-turn
end

to-report average-heading-towards-flockmates ; turtle procedure
  ;; 'towards myself' gives us the heading from the other turtle
  ;; to me, but we want the heading from me to the other turtle
end
```

- We write a piece of code to define “coherence”, “alligment” and “separation” behavior rules
- We then let each bird to move (“tick” by “tick”, towards its initial direction behaving according to the neighbors he find and the three rules
3. Simple examples of ABM: birds flock

• **Using the model:**
  • Set screen configuration to pxcor:115 / pycor=50. Set population to 150.
  • Run the model and follow a bird flying alone. When the bird meets other/s in his field of view (vision patches) it turns to try to move towards them (coherence) (up to a maximim of max-coherence-turn at each step)
  • When two or more fly together,
    • they all try to turn to keep alignment (up to a maximum of max-coherence-turn at each step)
    • even if they are still being influenced by coherence property (other birds passing alongside) the alignment predominates so birds don’t turn easily when other birds fly near them (it is difficulty to dissolve a flock)
  • When birds are too close, separation rule predominates forcing a new turn (up to a maximum of max-coherence-turn at each step)
  • After 3000-3500 “ticks” all birds fly in the same direction in small flocks
3. Simple examples of ABM: birds flock

• **Playing with parameters:**
  • If we increase vision (up to the maximum) all birds get together in the same flock
  • What happens if coherence max turn is increased (coh-max=allig-max=10) → flocks arise but dissolve easily
  • Flocks moving somehow like the video can be simulated with population=500, vision=10, min-separation=1, max-turn:20-10-20.
3. Simple examples of ABM: traffic

- **Objective:** simulate the longitudinal dynamics of traffic and specifically understand “jam” dynamics. [http://www.traffic-simulation.de/](http://www.traffic-simulation.de/)

“ABM like” Model Features:

- **Micro-sim:** Each vehicle-driver constitutes an active "particle" in the simulation.
- **Emergent Phenomena:** We all drive with independency and without having a full view of the traffic on a the whole road.
- **Interaction:** the decisions of any driver depends on his or her own speed BUT ALSO on the position and speed of the vehicle ahead and in other lanes.
- **Environment matters:** agents interact with the context and also change the environment.
- **Heterogeneity:** Different types of equations for different vehicles and different driving styles for each one (selfish, reckless, altruistic,...)
- **Heuristics allowed:** simple rules, not so rational, not always the same, not regular.
- **Experience (path) matters:** behavior in time “t” conditions behavior in the following periods and the change in environment.
3. Simple examples of ABM

1.- Acceleration/Deceleration Model

\[
\frac{dv}{dt} = a \left[ 1 - \left(\frac{v}{s^*}\right)^\delta - \left(\frac{s^*}{s_0}\right)^2 \right]
\]

\[s^* = s_0 + \min\left[0, \left(vT + \frac{v\Delta v}{2\sqrt{ab}}\right)\right]\]

2.- Lane-Changing Model

\[\text{acc}' (M') - \text{acc} (M) > p \left[ \text{acc} (B) + \text{acc} (B') - \text{acc}' (B) - \text{acc}' (B') \right] + a_{thr}\]

Both equations depend on a set of user parameters so we can simulate traffic outcome for different settings ("main inflow in the road", "ramp inflow", "maximum desired speed", "minimum bumper to bumper distance or time gap", "proportion of trucks", "politeness factor", "bias to the right lane", "maximum safe deceleration speed",..)
3. ABM for “serious” simulation: JAMEL

Jamel (Java Agent-based Macro-Economic Laboratory) is an open source agent-based framework dedicated to the modeling, the simulation and the analysis of complex monetary economies. It is developed by Dr. P. Seppecher (CEPN, University of Paris 13, France) and Dr. I. Salle (Utrecht University, School of Economics, The Netherlands). The "Austrian" module is developed by Dr. H. Hagedorn (Business and Information Technology School, Berlin, Germany).

Is the market really a good teacher?

Market selection, collective adaptation and financial instability

Pascal Seppecher, Isabelle Salle, Duoy Lang
25th April 2016

Se brief explanation of a simulation in the presentation TAB of JAMEL platform

http://p.seppecher.free.fr/jamel/
3. Simple examples of ABM: migration / special interaction

Modeling Cities and Displacement through an Agent-based Spatial Interaction Model

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Main features of a ABM:

1. **Inductive.** We don’t start by assuming a solid, unified theoretical model, grounded in axioms and connected to any expected particular outcome in advance.

2. We concentrate in the **specific context**, without resorting to broad abstract generalizations.

3. Central role to **individuals** / micro simulation (not variables)
3. What is the idea behind an Agent Based Model approach?

**Main features of a ABM:**

3. Central role to **individuals** (cont.)

- We allow for **high heterogeneity** of agents **(no assumptions about representative agent)**
- We look at the specific context to identify the **specific agents** we have
- We allow for **heuristic or bounded rationality behaviour**
- We allow **learning and adaptation**: agents behave with memory, path dependence, temporal correlations...
3. What is the idea behind an Agent Based Model approach?

Main features of a ABM (cont.):

4. Focused on emergent phenomena: the overall effect of individuals action is different from what the individuals are doing
   1. Interaction among agents generate network effects = deviations from predicted simple aggregate behaviour.
   2. We don’t assume a supervised, governed behavior by any central authority. Although the movements of a birds flock are uniform, complex and nonlinear at the macro level, they are not based on any systemwide program
3. What is the idea behind an Agent Based Model approach?

*Main features of a ABM (cont.):*

5. **Formal / pure tractable structures are not predominant** (although we still using mathematical formulas)

6. **Highly dynamic** (time dependent): we have to follow the full path of the process because we cannot predict how a process ends just considering its the starting point. The model inform about the whole process (the path) and not only the final outcome and this is specially of interest for the study of dynamics
3. What is the idea behind an Agent Based Model approach?

*Main features of a ABM (cont.):*

7. Flexible:

1. The model itself adjusts as often as the agents / institutions / environment changes, sometimes in an unexpected way (radical uncertainty)
2. None or few fixed assumptions from the beginning and adaptable to new constrains.
3. What is the idea behind an Agent Based Model approach?

Main features of a ABM (cont.):

8. **The dimension of Space** can be explicitly incorporated in the analysis (of interest in several fields such as diffusion, networking, logistics,....)

9. **Time is a key parameter**: We will replicate agents models, let them interact and then observe the evolution of the system over time; the way we implement passing of time, the number of interactions per unit of time, the way in essence we play with time parameter use to be crucial. For example, some outcomes only come after a given number of interactions (i.e. after a long period of time)
3. What is the idea behind an Agent Based Model approach?

Main drawbacks, obstacles and limitations of ABM:

- External VALIDITY is the critical point:

Over - parametrization: As an ABM gets more complex, trying to gain realism, including more rules, types of agents, interactions, the “player” loose easily control over the outcomes, ABM models can lead to infinite solutions. Keeping the equilibrium between simplicity and realism is crucial.

At the end, there is a risk that an ABM become useful to understand a kind of “what if” experiments but **Can we use them to BUILD a theory?**. For that, calibration gets more and more complex and equilibrium is elusive intensifying external validity problems.
3. What is the idea behind an Agent Based Model approach?

Main drawbacks, obstacles and limitations of ABM:

About, VALIDITY problem:

- I would say that some other approaches in empirical science have the same shortcomings

- And, at the end of the day, is it reductionism the solution when the reality is in fact over parametrized?

Maybe ABM are useful to observe regularities that might suggest theories/theorems that could then be proved. Maybe is not about building hard science but about finding a new and maybe complementary way of empirics.
3. What is the idea behind an Agent Based Model approach?

Main drawbacks, obstacles and limitations of ABM:

• Internal VALIDITY poses another problem: Very sensible to coding bugs and artefacts

• The need of behavioural rules: We need to replace rational, mechanical, formal, unbiased behavior of agents with more realistic simple/heuristics/if-then rules. This is OK, but, How to identify those rules to code them in an ABM framework?. For instance, we better understand how agents behave during a financial crisis that how the do during calm.
3. What is the idea behind an Agent Based Model approach?

Main drawbacks, obstacles and limitations of ABM:

- Outcome depending on randomness and radical uncertainty makes prediction essentially impossible. ABM’s assume non ergodicity so they essentially can not be used for forecasting porpoises.

- High computational cost / computer skills and resources needed

- Lack of standards
Four main questions?

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• Relevant studies in quite different areas

• Specially interesting those in the field of interdisciplinary collaboration

• Adaptive Vs Rational behavior
• Consequences of Heterogeneity in populations
• Institutional mechanisms to achieve goals in populations with autonomous agents
• Effects of network structures
• Diffusion of innovation
• Cooperation among egoists
4. Are ABM an alternative to mainstream modeling?

- **Successful examples in economy:**
  - Finance: Unstable systems with crashes and booms that develop out of non-linear (disproportionate) responses to proportionally small changes
  - Organization: organizational design, operational risk
  - Diffusion of innovation / adoption dynamics network structures,
  - Logistics, operation research, customer flow management

- **Take a look at** [https://swarmfest2017.org/](https://swarmfest2017.org/) for a list of topics
4. Are ABM an alternative to mainstream modeling?

- **FINANCE**

- Doyne Farmer – Leverage and stock prices fluctuations
4. Are ABM an alternative to mainstream modeling?

**INNOVATION**

- Ma, T. and Nakamori, Y., (2005) “Agent-Based Modeling on Technological Innovation as an Evolutionary Process”
4. Are ABM an alternative to mainstream modeling?

- OPERATIONS RESEARCH

- Proctor & Gamble. Optimize the flow of goods through its network of suppliers, warehouses and stores.
- Southwest Airlines of Dallas, Texas: Routing cargo.
4. Are ABM an alternative to mainstream modeling?

- Hard to sell:
  - Is about simulation, not about formal theoretical modeling after all, and some people really don't understand simulation practice itself
  - People is used to deductive mathematical models and reluctant to ABM logic
  - Readers demand ABM results being as general as mathematical
4. Concluding remarks

- It is obvious that classical modeling is not working properly.
- Mainstream economy should pay more attention to behavioral micro economy and to ABM as an alternative way of understanding complex collective phenomena.
- Nevertheless, classical mathematical analysis and ABM studies should not be regarded as alternative or opposed approaches to the formal study of social systems, but as complementary.
- More development and testing of ABM is needed (more resources) in order to convince people to trust this approach.
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