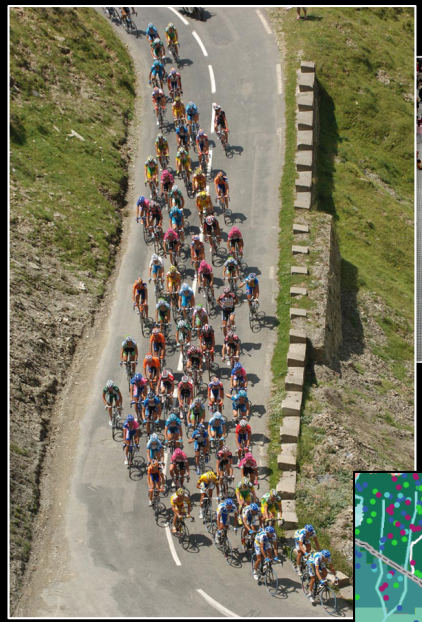
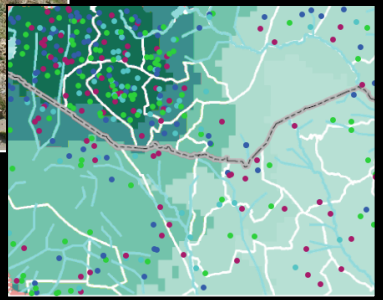
Embracing Complexity in Economics Education

Experiences from a new unit in complex adaptive systems and agent-based modelling





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Brett Parris

Behrooz Hassani

MONASH University
Business and Economics

'Mechanics' vs. 'Economic Biology'

The Mecca of the economist lies in ***economic biology*** *... But biological conceptions are more complex than those of mechanics; a volume on Foundations must therefore give a relatively large place to* ***mechanical analogies, and frequent use is made of the term 'equilibrium' which suggests something of a static analogy.***

Alfred Marshall, ***Principles of Economics*****, 1948, p.xiv**

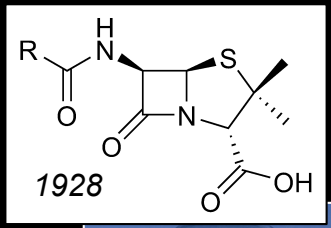
the dominance of 'equilibrium' thinking ... (because it is less complex)

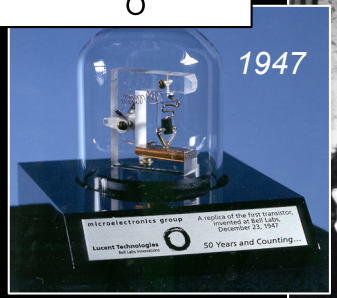
Marginal Economics vs. Thresholds/ Criticality/Phase-Changes

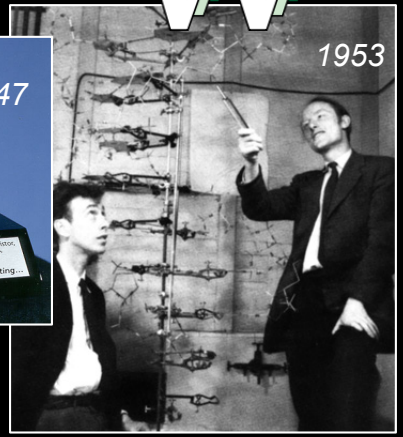
[W]hat we are about to consider is that kind of change arising from within the system which so displaces its equilibrium point that the new one cannot be reached from the old one by infinitesimal steps. Add successively as many mail coaches as you please, you will never get a railway thereby.

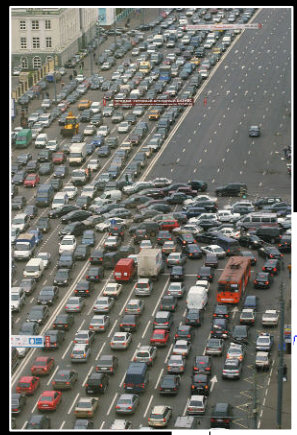
Joseph Schumpeter, (1934) p. 64, fn 1.

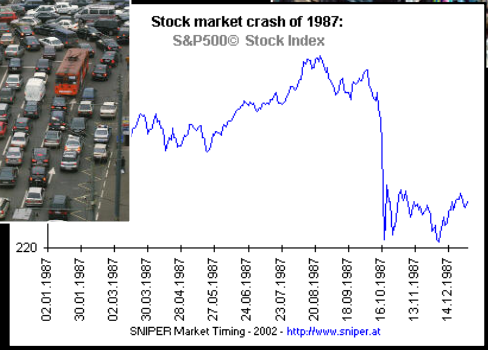
'abrupt' changes, criticality, thresholds, regime-change (structural breaks)











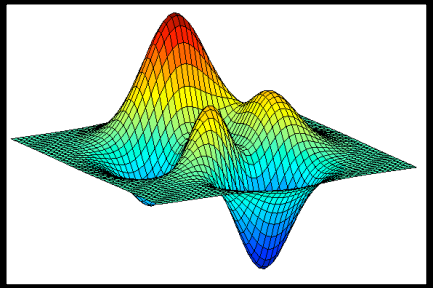
'Optimisation' vs. 'Adaptation'

Few economists confuse the formal static or dynamic equilibrium theory with the reality. Most readily acknowledge that at least some economic situations need to be understood as involving ***signficant elements of novelty, so that the actors should be regarded as searching for a best action, as constrasted with actually having found it****. In their analysis of certain economic phenomena, for example technical advance, many economists recognize that frequent or continuing shocks, generated internally as well as externally, may make it hazardous to assume that the system ever will get to an equilibrium; thus the fixed or moving equilibrium in the theory must be understood as an "attractor" rather than a characteristic of where the sytem is.*

Richard R Nelson, *JEP* 1995, p.49

novelty ... implies a changing optimisation landscape: continual search, not 'finished' search

the system does not ever reach 'equilibrium' (if it exists), but orbits near or far from it perpetually



Complexity ... everywhere (but nowhere)

Another look at the role of 'mathematical analogies'

Type of Equations	**Linear**			**Nonlinear**		
Equations	*One equation*	*Several equations*	*Many equations*	*One equation*	*Several equations*	*Many equations*
Algebraic	Trivial	Easy	Possible	Very difficult	Very difficult	Impossible
Ordinary Differential	Easy	Difficult	Essentially impossible	Very difficult	Impossible	Impossible
Partial Differential	Difficult	Essentially impossible	Impossible	Impossible	Impossible	Impossible

Credit: Parris, B. (2008), from Keen (2001, Table 12.1, p. 265) adapted from Costanza (1993, p. 33)

Another look at the role of 'mathematical analogies'

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Complex Adaptive Systems

As economic analysts ***we are directed by, if not prisoners of, the mathematical tools that we possess.*** ... Tom Sargent (1987)

Use of the equilibrium tool channels both the way in which the answers to economists' questions are pursued and the substance of the answers. But ***the use of the equilibrium tool also channels and thereby limits the questions the economist is likely to ask or the questions that conventional protocol and procedure permit the economist to ask****. The unasked questions tend to be those dealing with system and structure, with conflict, with operative factors and forces, and with the substance and operation of the adjustment process. ...* Warren Samuels (1997)

Credit: Parris, B. (2008), from Keen (2001, Table 12.1, p. 265) adapted from Costanza (1993, p. 33)

A response: ECC/ETC 3860 "Integrated Economic Modelling"

Timeline

2008 -- Pilot with pre-honours students

2009 -- unit proposal to faculty

2010 [s2] -- 30 students took ECC/ETC 3860

(2011 [s2] -- 35 students enrolled ...)

The pilot

17 pre-honours students

~ 6 weeks of lectures by Angus

Group (of 2) project (view online)

"Compared to other topics I have undertaken in other units this year, by level of interest, I would rank the NetLogo/Complexity topic:"

My favourite	*3*
In the top few	*9*
Top third	*3*
About mid-way	*2*
Bottom third	*0*
My most disliked	*0*
Not applicable	*0*

"If the NetLogo/ Complexity topic were offered as a full unit, I would recommend it to other students in the Faculty of Business & Economics"

Strongly Agree	*6*
Agree	*10*
Disagree	*0*
Strongly Disagree	*0*
Not Applicable	*1*

IEM: Layout of the Unit

Part 1 Motivation

What characterises the traditional Economic perspective?

How is the Complex Adaptive Systems (CAS) perspective different?

What are the key features of the CAS perspective?

What are some examples of particularly 'complex' problems that are very difficult (impossible?) for the traditional method to analyse?

Part 2 Method

What is Agent Based Modelling (ABM)?

How should one design a 'good' ABM?

What can ABM design learn from gaming design?

What are the main ABM platforms, and what are their strengths and weaknesses?

What are the 'foundational concepts' often evident in CAS models?

Part 3 Verification & Interpretation

How can GIS data be incorporated and used in an ABM?

What does it mean to verify, validate and calibrate an ABM?

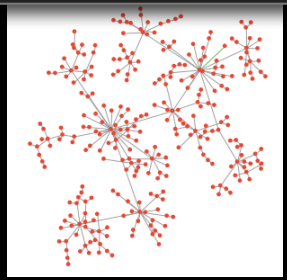
What are some real-world examples of ABMs?

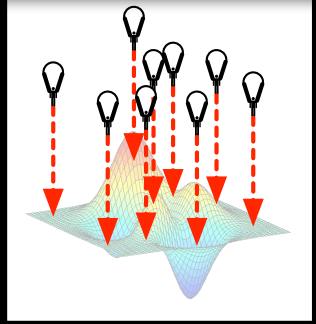
How should I interpret, analyse and present my ABM outputs?

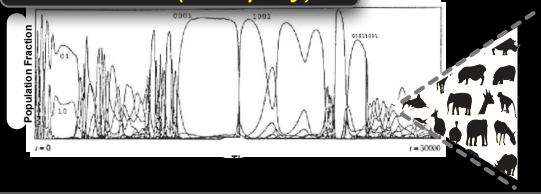
IEM: Agent-Based-Modelling

Bottom-up Philosophy

- The representation problem
- Learning vs. Optimisation
- Co-evolution
- Defining 'Agents'
- Heterogeneity
- Genetic Algorithms, Evolutionary updating
- Realistic Economic Networks
- The 'Interest in between' (Interplay)
- Verification, Validation and Calibration
- Data Sampling

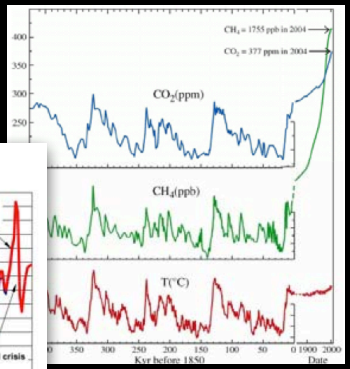


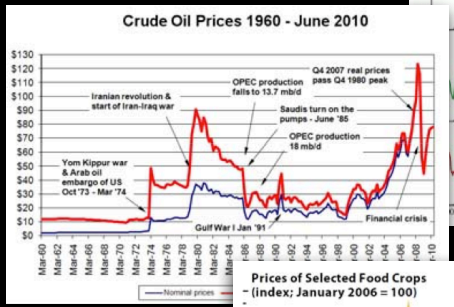


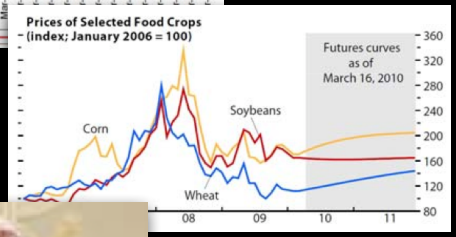


IEM: Policy Examples

- ***Climate Change***
- ***Energy***
- ***Food***
- ***Finance***
- ***Economic Development***







Why is this system 'Complex'?

What are the significant feedbacks in the system?

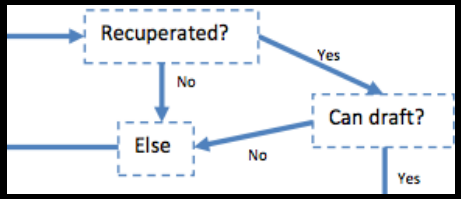
What are the significant players (agents) in the system?

What are the time-scales of build-up and relaxation in the system?

IEM: Assessment

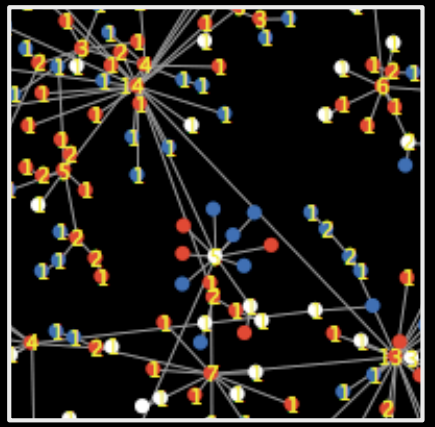
Complexity Assignment (10%)

"Find an example from everyday life that operates as a complex system."



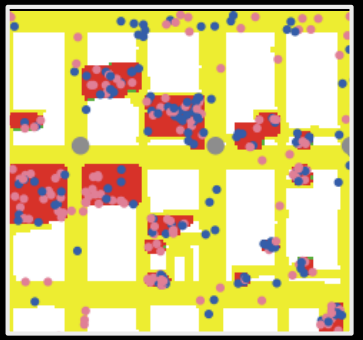
'El Farol' Assignment (15%)

iPad vs. Kindle on campus



Major Project (30%)

Development
Conflict
Water systems (Murray-Darling)
The firm



Discussion Log (online) (5%)

Exam (40%)

Why NetLogo?

The shopping list ...

- ✓ Free
- ✓ Multi-platform
- ✓ Useful ABM primitives (e.g. 'neighbors')
- ✓ Well-documented
- ✓ High-level language (e.g. 'ask X [...]')
- ✓ Weakly typed
- ✓ Object-oriented (e.g. inheritance)
- ✓ Experiment-ready
- ✓ Data-exporting

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

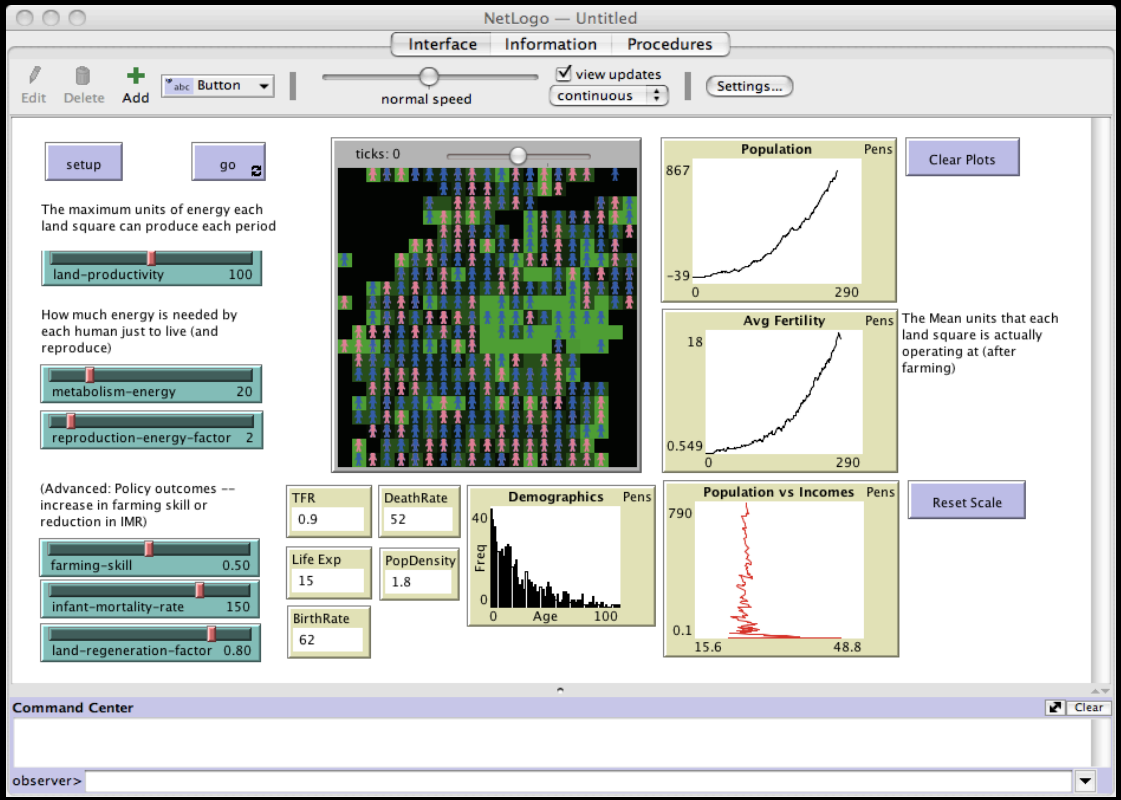
Bonuses in NetLogo

- ✓ Simple web-applet export
- ✓ Large pre-existing ABM model library
- ✓ Entry level, but academic use
- ✓ Graphical user interface (GUI) fundamental
- ✓ Handles Networks
- ✓ Fun ...

Drawbacks with NetLogo

- No compiling ...
- 'World' default is 2D
- Linear algebra?

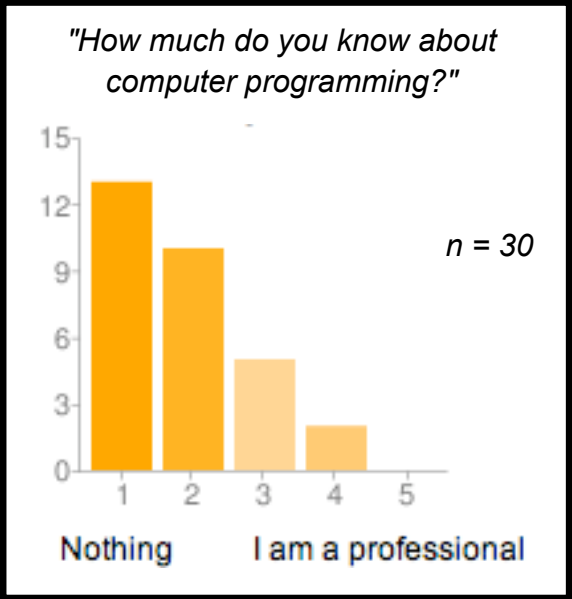
NetLogo: example



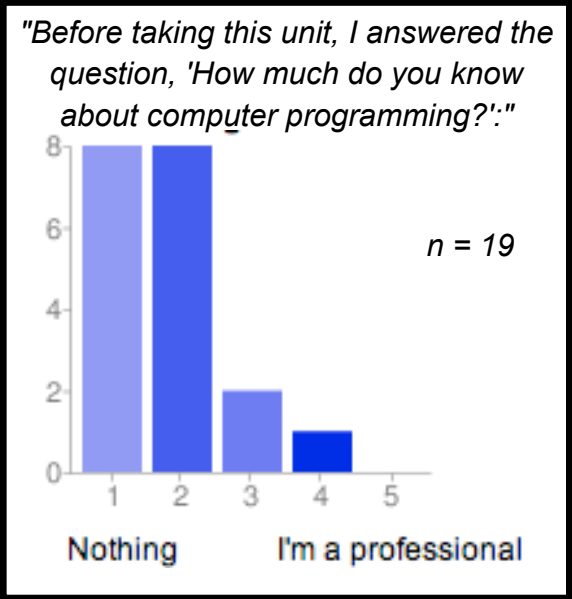
http://users.monash.edu.au/~sangus/Malthus/

Could students handle learning an ABM computer language?

Pre-Unit



Post-Unit



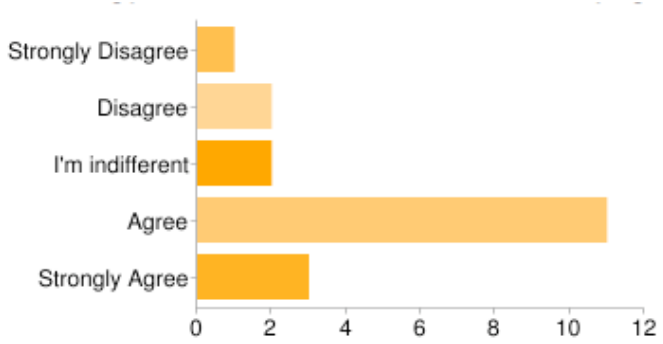
"If you have done any programing so far, please indicate the languages that you have used:"

C/C++ ... 7
MATLAB ... 6
Others: Python, VBA, Pascal, HTML, BASIC, Machine Code (!)

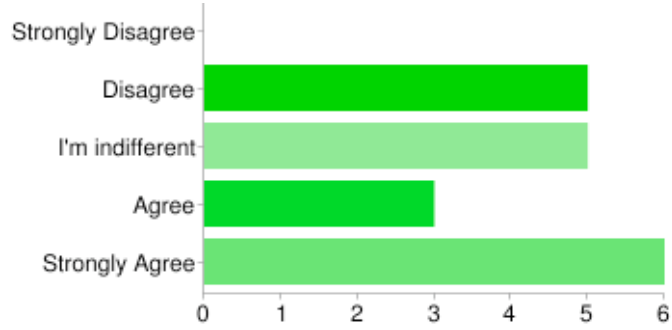
Could students handle learning an ABM computer language? ... *Yes* (according to them)

Post-Unit

"After being a part of ECC/ETC 3860 ... I feel confident to program with NetLogo"



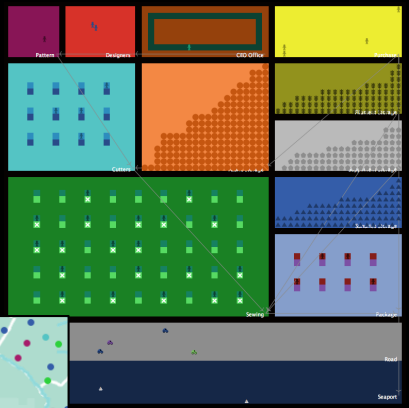
"After being a part of ECC/ETC 3860 ... I feel confident to try and learn a different programming language (e.g. Java, C, RePast, MATLAB)



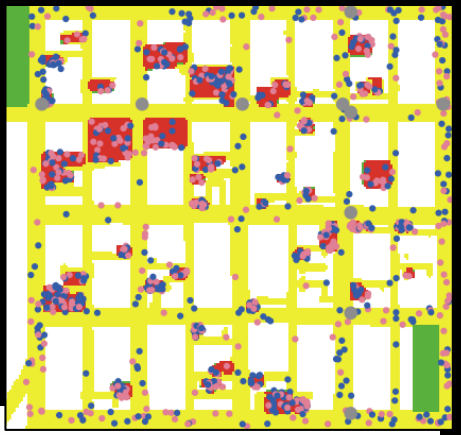
Could students handle learning an ABM computer language? ... *Yes* (according to us)

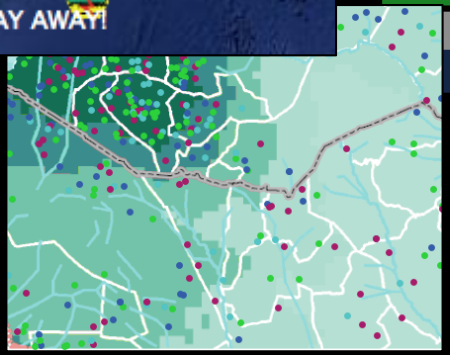
Piracy off the Somali coast

Explicitly modelling the firm

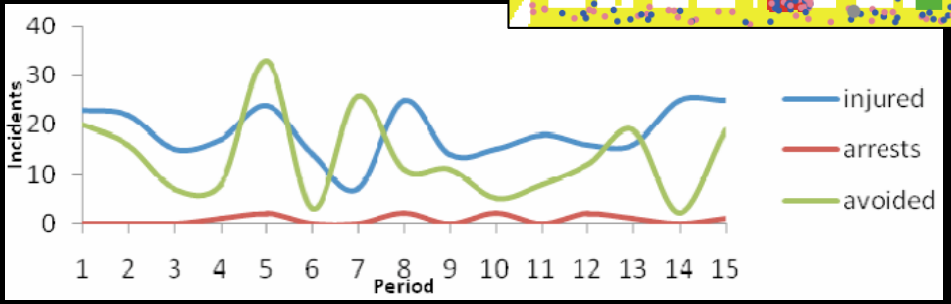


Optimal policing in the Melbourne CBD





Conflict & Farming on the Eithiopian/Kenyan border

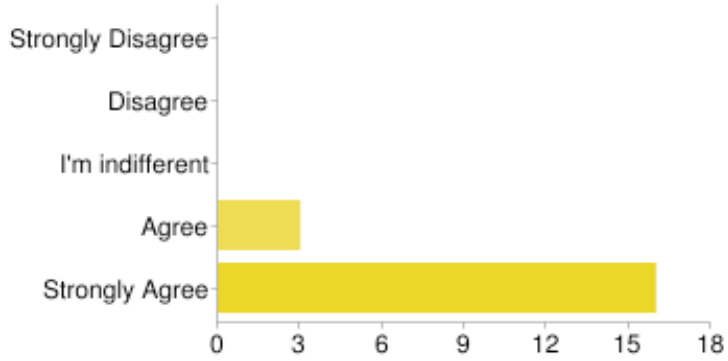


See the full exhibit at: `http://tinyurl.com/MonIEMProjectGallery2010`

Did the unit change perceptions of Economics?

Post-Unit

"After being a part of ECC/ETC 3860 ... The way I think about Economic Analysis has been significantly changed."



This was my favourite class in my economics major (so far). Very intellectually stimulating, and refreshing compared to the standard economics perspective found in the core units of economics. I think this subject, or one very similar, should be compulsory as part of the economics major as it challenges many standard assumptions and highlights weaknesses in classical modelling.

This was the most amazing unit I have ever done. It blew my mind (numerous times), changed my world, infiltrated (and dominated) every part of my life, and left me hopelessly craving more. Absolutely loved it!!

I would also strongly recommend this unit to friends. ... I hope you lobby for aspects of this unit to be introduced in first and second year units, and perhaps lobby for it to be spread to other institutions.

If I was able to study this subject gradually throughout my degree I think I would have enjoyed it even more.

What did we learn?

- Students really 'got' complexity

  e.g. Complexity project (ants, bikes, harmonies, ...)
- The coding assessments (El Farol + Major Project) were too demanding
- Students have a huge appetite for non-linear/complexity thinking in the undergrad Economics studies ...

"The minor and major projects were far too time consuming. In addition what we had to learn in the short amount of time was unreasonable, especially for students with absolutely no coding/programming background whatsoever. ..."

"I found the final assignment extremely dificult, and extremely time consuming with little reward..."

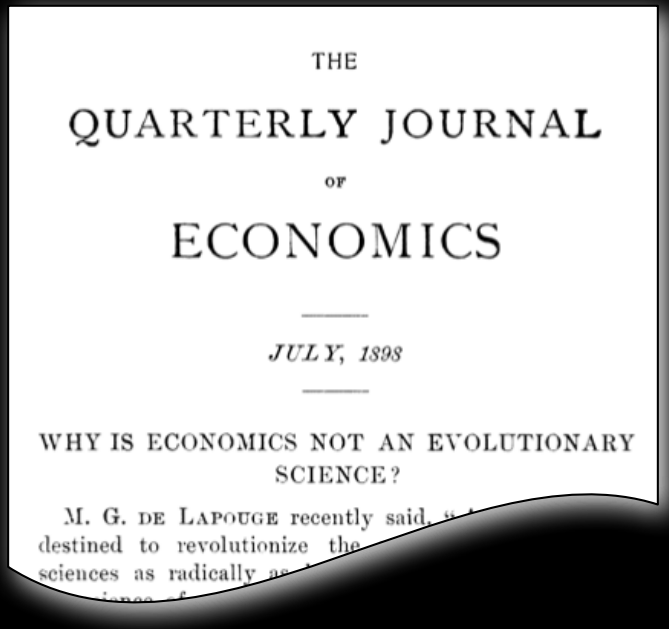
"Why is Economics not [taught as] an Evolutionary Science?"

The economic life history of the individual is a cumulative process of adaptation of means to ends that cumulatively change as the process goes on, both the agent and his environment being at any point the outcome of the past process.

Thorstein Veblen, *QJE*, 1898, pp. 390-391

... Like other men, the economist is an individual with but one intelligence. He is a creature of habits and propensities given through the antecedents, hereditary and cultural, of which he is an outcome; and the habits of thought formed in any one line of experience affect his thinking in any other.

Thorstein Veblen, *QJE*, 1898, pp. 395



THE

QUARTERLY JOURNAL

OF

ECONOMICS

JULY, 1898

WHY IS ECONOMICS NOT AN EVOLUTIONARY SCIENCE?

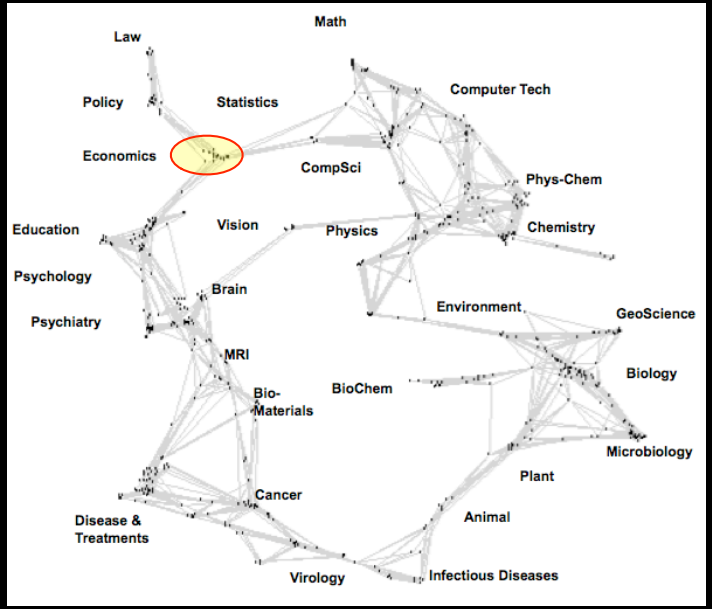
M. G. DE LAPOUGE recently said, "[illegible] destined to revolutionize the [illegible] sciences as radically as [illegible]

Hurdles for Systems Thinking

There's a hole in ... the middle of science

However, despite the upsurge in ABM research witnessed in the past 15 years, the methodology is still left aside in a standard economist's toolbox. ***Among the top 20 economic journals we were able to find only eight articles based on ABM****. This number is to be compared with the 26,698 articles that were published since the seminal work of Arthur (1988) in the top 20 journals considered.* ***Agent-based modeling thus counts for less than 0.03% of top economic research****. It seems to be confined only in specialized journals like the Journal of Economic Dynamics and Control, ranking 23rd, the Journal of Artificial Societies and Social Simulation, and Computational Economics, which are not even ranked. A notable exception is the Journal of Economic Behavior and Organization, ranked 32, which sometimes publishes research in ABM.*

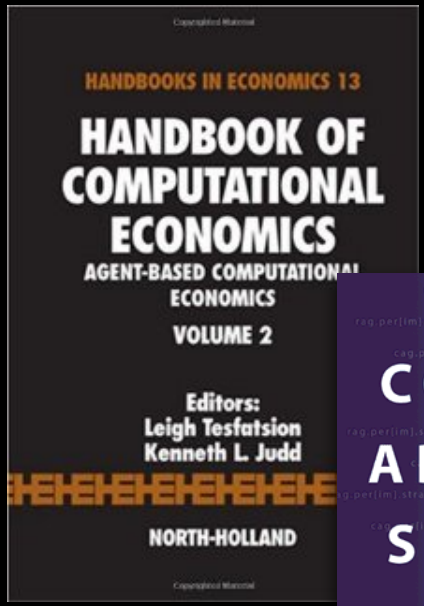
Roberto Leombruni, Matteo Richiardi, Physica A, 2005, v355, p.104

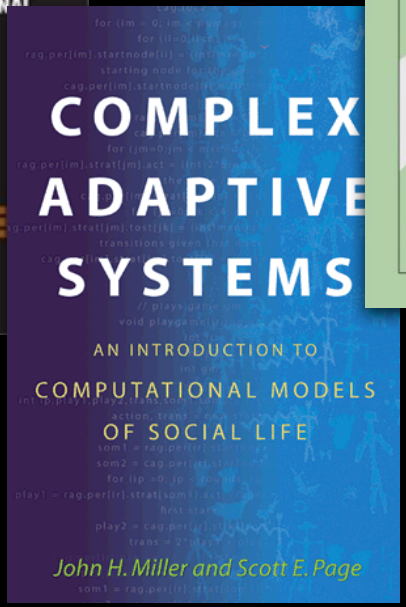


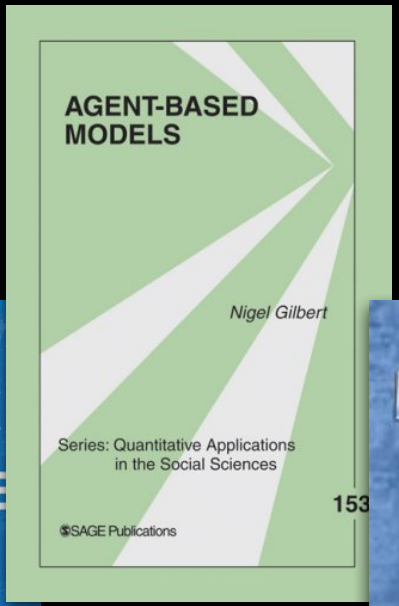
Combind Science CI + Social-Science CI: 1.07M papers, 24.5M references, 7,300 journals, Clustering -- 671 clusters

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007). Mapping the Structure and Evolution of Chemistry Research. 11th International Conference on Scientometrics and Informetrics. pp. 112-123.

Textbooks?


HANDBOOKS IN ECONOMICS 13
HANDBOOK OF COMPUTATIONAL ECONOMICS
AGENT-BASED COMPUTATIONAL ECONOMICS
VOLUME 2
Editors:
Leigh Tesfatsion
Kenneth L. Judd
NORTH-HOLLAND


COMPLEX ADAPTIVE SYSTEMS
AN INTRODUCTION TO
COMPUTATIONAL MODELS
OF SOCIAL LIFE
John H. Miller and Scott E. Page


AGENT-BASED MODELS
Nigel Gilbert
Series: Quantitative Applications in the Social Sciences
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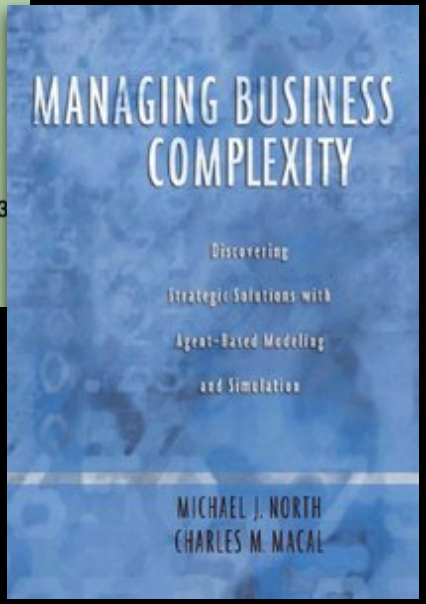
MANAGING BUSINESS COMPLEXITY
Discovering
Strategic Solutions with
Agent-Based Modeling
and Simulation
MICHAEL J. NORTH
CHARLES M. MACAL