Embracing Complexity in Economics Education
Experiences from a new unit in complex adaptive systems and agent-based modelling

Simon Angus
Department of Economics
Monash University

Brett Parris
Behrooz Hassani
'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.

Marginal Economics vs. Thresholds/Criticality/Phase-Changes

What 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.
'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 significant elements of novelty, so that the actors should be regarded as searching for a best action, as contrasted 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 system is.

Complexity ... everywhere (but nowhere)
Another look at the role of 'mathematical analogies'

<table>
<thead>
<tr>
<th>Type of Equations</th>
<th>Linear</th>
<th>Nonlinear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One equation</td>
<td>One equation</td>
</tr>
<tr>
<td>Equations</td>
<td>Several equations</td>
<td>Several equations</td>
</tr>
<tr>
<td>Algebraic</td>
<td>Trivial</td>
<td>Very difficult</td>
</tr>
<tr>
<td></td>
<td>Easy</td>
<td>Very difficult</td>
</tr>
<tr>
<td>Ordinary Differential</td>
<td>Difficult</td>
<td>Impossible</td>
</tr>
<tr>
<td></td>
<td>Essentially impossible</td>
<td>Impossible</td>
</tr>
<tr>
<td>Partial Differential</td>
<td>Difficult</td>
<td>Impossible</td>
</tr>
<tr>
<td></td>
<td>Essentially impossible</td>
<td>Impossible</td>
</tr>
</tbody>
</table>

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'

<table>
<thead>
<tr>
<th>Type of Equations</th>
<th>Linear</th>
<th>Nonlinear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equations</td>
<td>One equation</td>
<td>Several equations</td>
</tr>
<tr>
<td></td>
<td>Several equations</td>
<td>Many equations</td>
</tr>
<tr>
<td></td>
<td>One equation</td>
<td>Several equations</td>
</tr>
<tr>
<td></td>
<td>Several equations</td>
<td>Many equations</td>
</tr>
</tbody>
</table>

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

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:"

- Strongly Agree: 6
- Agree: 10
- Disagree: 0
- Strongly Disagree: 0
- Not Applicable: 1

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

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?

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
- Defining 'Agents'
- Heterogeneity
- Realistic Economic Networks
- The 'Interest in between' (Interplay)
- Verification, Validation and Calibration

**Learning vs. Optimisation**
- Co-evolution
- Genetic Algorithms, Evolutionary updating
- Data Sampling

Angus, Parris & Hassani: Embracing Complexity in Economics Education
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

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?

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

http://users.monash.edu.au/~sangus/Malthus/
Could students handle learning an ABM computer language?

**Pre-Unit**

"How much do you know about computer programming?"

- Nothing: 12
- 1: 10
- 2: 5
- 3: 2
- 4: 1
- 5: 0

**Post-Unit**

"Before taking this unit, I answered the question, 'How much do you know about computer programming?'"

- Nothing: 8
- 1: 2
- 2: 1
- 3: 3
- 4: 2
- 5: 0

If you have done any programming 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)

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

Angus, Parris & Hassani: Embracing Complexity in Economics Education
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 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.

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.
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 difficult, 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
Hurdles for Systems Thinking

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.


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

Textbooks?