**ECC3860
Integrated economic modelling**

Unit Guide

Semester 2, 2012

Last updated: 23 Jul 2012

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ECC3860 Integrated economic modelling - Semester 2, 2012

The aim of this unit is to enable students to understand some of the complexities of interdisciplinary policy problems, particularly in the areas of sustainable development, and to enable them to design and undertake integrated modelling exercises for themselves. A complex systems science perspective will be adopted, introducing Agent-Based Modelling (ABM) as a flexible and powerful tool for exploring solutions to complex real-world problems. The ABM approach will be demonstrated and critically assessed through several interdisciplinary, integrated economy/sustainability models. Additionally, a flexible ABM modelling platform (NetLogo) will be introduced and demonstrated.

Mode of Delivery

Clayton (Day)

Workload

6 points, SCA Band 3, 0.125 EFTSL

Unit Relationships

Prerequisites

Students must have passed ETC1000 before undertaking this unit

Co-requisites

It is recommended that students study ECC2800 Prosperity, poverty and sustainability in a globalised world

Chief Examiner

Dr Simon Angus

Campus Lecturer

Clayton

Dr Simon Angus
Contact hours: Tuesday 10am-12pm, 11.E962

Dr Brett Parris
Contact hours: Thursday 1.30-3.30 PM, 11.E660

Tutors

Clayton

Mr Behrooz Hassani-M
Contact hours: Monday 2:30 - 3:30 PM, Thursday 1 - 2 PM, 11.E755

Academic Overview

Learning Objectives

The learning goals associated with this unit are for students to:

1. understand some of the complexities of interdisciplinary policy problems, particularly in the areas of sustainable development
2. comprehend and critically assess the complex systems perspective
3. critically evaluate agent-based models and their outputs
4. develop and analyse an agent-based model of an integrated modelling problem
5. undertake verification, validation, evaluation and assessment of integrated modelling outputs
6. apply integrated modelling approaches to real-world interdisciplinary economic problems.

Graduate Attributes

Monash prepares its graduates to be:

1. responsible and effective global citizens who:

   a. engage in an internationalised world
   b. exhibit cross-cultural competence
   c. demonstrate ethical values
2. critical and creative scholars who:

   a. produce innovative solutions to problems
   b. apply research skills to a range of challenges
   c. communicate perceptively and effectively

Assessment Summary

Second marking

Where an assessment task is given a fail grade by an examiner, that piece of work will be marked again by a second examiner who will independently evaluate the work, and consult with the first marker. No student will be awarded a fail grade for an assessment task or unit without a second examiner confirming the result.

Note: Exceptions to this are individual pieces of assessment contributing 10% or less of the final mark, unless the total of such pieces exceeds 30% of the final mark.

Return of final marks

Faculty policy states that 'the final mark that a student receives for a unit will be determined by the Board of Examiners on the recommendation of the Chief Examiner taking into account all aspects of assessment'.

The final mark for this unit will be released by the Board of Examiners on the date nominated in the Faculty Calendar. Student results will be accessible through the my.monash portal.

Assessment criteria

Assessment Criteria Grading Descriptors available at:
http://www.buseco.monash.edu.au/esg/agu/policies/assessment.html.

Assessment Task	Value	Due Date
Complexity Assignment	10%	(To MUSO) 11:59pm, Sunday 19th August (Week 4)
NetLogo skills tests	Each test will be worth 3% of your grade, 9% in total.	(To MUSO) End of weeks (i.e. Sundays 11.59 PM) week 2 (5 August), week 4 (19 August), and week 6 (2 September) of the Semester, however, you may submit any test early.
Reading Log	8% total made up of 3% + 5%. NB: the Reading Log will be marked individually.	The log will be available all semester online, but will close to submissions at 11:59pm, Sunday 28th October
Major Project	Check-in 3%, Final submission 30%, 33% in total	The Check-in Assessment will be due by the end of week 8 (11.59 PM, Sunday 16th September), the final project will be due end of week 12 (11.59 PM Sunday 21st October).
Examination 1	40%	To be advised

Teaching Approach

- **Lecture and tutorials or problem classes**
  Lectures are used to develop the content of the course, starting with basic building block material in different areas such as core complex systems concepts and real world policy challenges. As the unit progresses, agent-based modelling is introduced and some themes from earlier lectures are revisited in more detail as the threads are woven together. Meanwhile, the free agent-based modelling platform NetLogo is taught in the tutorial stream. There is often not a direct connection between a particular week's lectures and that week's tute. Instead they develop in parallel. But as you will see, it all comes together in the end.
- **Peer assisted learning**
  Online group-based discussion logs are an essential component of the unit. The reading list for this unit is large. Since this is the only unit covering these topics, there is a whole world to introduce you to! You are not expected to read them all by any means - they are provided as a resource for later if particular topics spark your interest. To make these topics more accessible, we provide all readings as pdfs in a separate folder for download. Core readings are noted by a double asterisk in the reading guide. You are expected to divide these up among yourselves within the group and summarise their main points and discuss them.
- **Problem-based learning**
  The assignments, and particularly the major project, require you to take what you have learned in lectures and tutes and apply it to a simpified, but still fairly realistic real-world complex problem.

Feedback

Our feedback to You

Types of feedback you can expect to receive in this unit are:

- Informal feedback on progress in labs/tutes
- Graded assignments with comments
- Test results and feedback
- Quiz results

Your feedback to Us

Monash is committed to excellence in education and regularly seeks feedback from students, employers and staff. One of the key formal ways students have to provide feedback is through SETU, Student Evaluation of Teacher and Unit. The University's student evaluation policy requires that every unit is evaluated each year. Students are strongly encouraged to complete the surveys. The feedback is anonymous and provides the Faculty with evidence of aspects that students are satisfied and areas for improvement.

For more information on Monash's educational strategy, and on student evaluations, see:
http://www.monash.edu.au/about/monash-directions/directions.html
http://www.policy.monash.edu/policy-bank/academic/education/quality/student-evaluation-policy.html

Previous Student Evaluations of this unit

If you wish to view how previous students rated this unit, please go to
https://emuapps.monash.edu.au/unitevaluations/index.jsp

Required Resources

Prescribed textbook

Gilbert, N., (2008) *Agent-Based Models,* Quantitative Applications in the Social Sciences No. 153; SAGE Publications, Los Angeles & London, xiii + 98 pp.

Recommended books

Miller, J.H. and Page, S.E., (2007) *Complex Adaptive Systems: An Introduction to Computational Models of Social Life,* Princeton University Press, Princeton, NJ & Oxford, xix + 263 pp.

North, M.J. and Macal, C.M., (2007) *Managing Business Complexity: Discovering Strategic Solutions with Agent-Based Modeling and Simulation,* Oxford University Press, Oxford & New York, xi + 313 pp.

Railsback, S.F. and Grimm, V., (2012) *Agent-Based and Individual-Based Modeling: A Practical Introduction,* Princeton University Press, Princeton NJ, xviii + 329 pp.

Recommended Resources

Key online resources and websites:

Software

Academic Overview

GraphViz   http://www.graphviz.org/

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

NetLogo R Extension   http://r-ext.sourceforge.net/

Pajek   http://pajek.imfm.si/doku.php?id=pajek

R   http://www.r-project.org/

RStudio   http://rstudio.org/

Visual Paradigm for UML http://www.visual-paradigm.com/product/vpuml/

People - Monash

Simon Angus   http://users.monash.edu.au/~sangus/cgi-bin/moinres.cgi/sangus

Behrooz Hassani-M. http://users.monash.edu.au/~behroozh/

Brett Parris   http://www.brettparris.com

People - Non-Monash

Andrew Crooks http://gisagents.blogspot.com/

David Earnest http://www.odu.edu/~dearnest/research_abm.htm

Leigh Tesfatsion's ABM portal   http://www.econ.iastate.edu/tesfatsi/ace.htm

Jose M. Vidal   http://jmvidal.cse.sc.edu/

Gabriel Wurzer, NetLogo lessons http://www.youtube.com/user/gabrielwurzer/videos

Other

A Course in Individual and Agent-Based Modeling   http://www.railsback-grimm-abm-book.com/

Agent-based Models http://www.agent-based-models.com/blog/

Complex Systems & ABMs at Sydney Uni http://sydney.edu.au/business/research/complexity

Complexity Digest http://comdig.unam.mx/index.html

CosNet – The ARC Complex Open Systems Research Network   http://www.complexsystems.net.au/

Journal of Artificial Societies and Social Simulation   http://jasss.soc.surrey.ac.uk/JASSS.html

NetLogo Bag of Tricks http://backspaces.net/wiki/NetLogo_Bag_of_Tricks

NetLogo Modeling Commons http://modelingcommons.org/

Open Agent-Based Modelling Consortium   http://www.openabm.org/site/

Academic Overview

Santa Fe Institute http://www.santafe.edu/

TurtleZero (Netlogo) http://www.turtlezero.com/index.php

VLab - Virtual Complexity Lab at Monash University   http://vlab.infotech.monash.edu.au/

Unit Schedule

Week	Activities	Assessment
0		No formal assessment or activities are undertaken in week 0
1	Introduction to Integrated Economic Modelling	
2	The Complex Adaptive Systems perspective	NetLogo Quiz 1 due 11:59pm Sunday 5th August
3	A Tour of Complex Policy problems	
4	Introduction to Agent-Based Models (ABMs)	Complexity Assignment AND NetLogo Quiz 2 due 11:59pm Sunday 19th August
5	The Art of ABM	First assessment of Reading Logs on discussion up to 11.59pm Sunday 26th August. 3% allocated.
6	Simulation & Gaming	NetLogo Quiz 3 due 11:59pm Sunday 2nd September
7	Overview of CAS Modelling	
8	CAS Examples	Major Project 'check-in' assessment due 11:59pm Sunday 16th September
9	Data Acquisition	
10	Calibration, Verification	
11	Research Examples	
12	Analysis & Interpretation of Outputs	Major Project due 11:59pm Sunday 21st October
	SWOT VAC	Reading Log closes 11:59pm Sunday 28th October. Remaining 5% for the logs allocated.
	Examination period	LINK to Assessment Policy: http://policy.monash.edu.au/policy-bank/academic/education/assessment/assessment-in-coursework-policy.html

Assessment Requirements

Assessment Tasks

• Assessment task 1

Title:
Complexity Assignment
Due date:
(To MUSO) 11:59pm, Sunday 19th August (Week 4)
Details of task:
Part A. Find an example from everyday life that operates as a complex system

- ♦ Identify the elements of the system, and the feedbacks between the elements.
- ♦ Are the feedbacks non-linear in nature? Why?
- ♦ Does the system demonstrate emergence? If so, how?

Part B. Sketch (using UML, pseudo-code, feedback network) how you might model this system using NetLogo.

- ♦ What agents would you need?
- ♦ What attributes would each agent need to possess?
- ♦ What behaviours would each agent need to be able to exhibit?
- ♦ What context (e.g. spatial landscape, network, abstract) would the agents inhabit?

Word limit:
No more than 5 pages (including figures).
Weighting/Value:
10%
Presentation requirements:
The assginment should be typed clearly. Text answers should be as concise, clear and informative as possible. The UML/pseudo-code component should follow the guidelines given in the tutorials.
Estimated return date:

• Assessment task 2

Title:
NetLogo skills tests
Due date:
(To MUSO) End of weeks (i.e. Sundays 11.59 PM) week 2 (5 August), week 4 (19 August), and week 6 (2 September) of the Semester, however, you may submit any test early.
Details of task:
You will need to demonstrate your ability in fundamental aspects of NetLogo. Each test will be outlined in your tutorials. You will need to submit a working NetLogo (.nlogo) file in each submission that demonstrates the required skills.
Weighting/Value:
Each test will be worth 3% of your grade, 9% in total.
Estimated return date:

- # Assessment task 3

Title:

Reading Log

Due date:

The log will be available all semester online, but will close to submissions at 11:59pm, Sunday 28th October

Details of task:

You will be placed in a small Discussion Log (online) group to discuss the prescribed weekly readings..

- ♦ *Group formation*: You must fill out the Online Group Formation Form (accessible via MUSO > Admin) by the **end of week 1** of semester. You will receive notification of your group assignment by the end of week 2.
- ♦ *Assessment*: You will be assessed individually on how active you have been in the discussion log. As a guide, each student should aim to summarise at least 1 prescribed reading article for each week, and respond to other group member's posts each week to pass this assessment. Your activity on the Discussion Log should take no more than 30min each week.
- ♦ There will be two phases of assessment: 3 marks allocated at the end of week 5 (Sunday 26 August) and the remaining 5 marks at the close of the logs on Sunday 28 October.

Weighting/Value:

8% total made up of 3% + 5%. NB: the Reading Log will be marked individually.

Estimated return date:

- # Assessment task 4

Title:

Major Project

Due date:

The Check-in Assessment will be due by the end of week 8 (11.59 PM, Sunday 16th September), the final project will be due end of week 12 (11.59 PM Sunday 21st October).

Details of task:

You are required to either replicate and extend, or design and build, an agent-based model that explores an integrated economic / complex-adaptive-system problem from a list of projects given out later in the unit.

Note: This is an individual assignment. Of course, we expect some discussion between you and your tutorial members. However, you must turn in your own assignment work. Evidence of plagiarism between your assignment and another will incur severe penalties.

Intermediate 'Check-in':

You are required to submit to MUSO a 30 word statement of the 'research problem', or the research problem that you think the replicate paper is addressing. You must also outline the key agents and interactions in the model. Your check-in submission should be no longer than 1 A4 page.

Final project submission:

Your final submission **must include** your **.nlogo file** (and any input data attachments), and a **report (no more than 5 pages,** .doc, .docx, .pdf) file that addresses item 5. in the marking guide below. Late submissions will attract a **5% (raw) deduction** for every day

(or part thereof) that it is late.

Your project will be marked as follows:

For a novel project:

1. [3%] The **assumptions** of the model (are these realistic/intuitive? do they allow for straight-forward analysis?)
2. [5%] The **behaviour** of the model (does it give realistic behaviour? does it shed light on the research question?)
3. [5%] The **coding** of the model (in the 'Procedures Tab': is the code easy to follow and commented throughout? does the code make appropriate use of NetLogo procedures? is the code modular?)
4. [4%] The **explanation** of the model (in the Info Tab: does the explanation of the model fit with what has been modelled? are there interesting extensions to the model?)
5. [8%] The **analysis and interpretation** of your model (what does it show? does it answer the research question? what policy implications (if any) does this analysis suggest?)

For a replication project:

1. [3%] The **assumptions** of the model (are these realistic/intuitive? do they allow for straight-forward analysis?)
2. [5%] The **behaviour** of the model (does it replicate the reported behaviour?);
3. [5%] The **coding** of the model (in the 'Procedures Tab': is the code easy to follow and well commented throughout? does the code make appropriate use of NetLogo procedures? is the code modular?);
4. [4%] The **explanation** of the model (in the Info Tab: does the explanation of the model fit with what has been modelled? are extensions well motivated and documented?)
5. [8%] The **analysis, interpretation & extensions to the model:** what replication challenges did you encounter? was the model well described and easy to follow in the paper? what extensions did you try? what additional impact/insight did these extensions add to the model?

Weighting/Value:
Check-in 3%, Final submission 30%, 33% in total
Estimated return date:

Examinations

- **Examination 1**

Weighting:
40%
Length:
Type (open/closed book):
Electronic devices allowed in the exam:
None
Remarks:
Aim: to test overall understanding of integrated modelling problems and tools used to analyse them.

Task: 2 hour end-of-semester examination requiring students to answer a number of

short-answer and long-answer questions on material from the unit.

Assessment: emphasis on comprehension and overall synthesis of ideas and examples presented in the unit.

Assignment submission

Online submission

If Electronic Submission has been approved for your unit, please submit your work via the VLE site for this unit, which you can access via links in the my.monash portal.

Other Information

Policies

Monash has educational policies, procedures and guidelines, which are designed to ensure that staff and students are aware of the University's academic standards, and to provide advice on how they might uphold them. You can find Monash's Education Policies at:
http://policy.monash.edu.au/policy-bank/academic/education/index.html

Key educational policies include:

- Plagiarism
  (http://www.policy.monash.edu/policy-bank/academic/education/conduct/plagiarism-policy.html)
- Assessment
  (http://www.policy.monash.edu/policy-bank/academic/education/assessment/assessment-in-coursework-po
- Special Consideration
  (http://www.policy.monash.edu/policy-bank/academic/education/assessment/special-consideration-policy.h
- Grading Scale
  (http://www.policy.monash.edu/policy-bank/academic/education/assessment/grading-scale-policy.html)
- Discipline: Student Policy
  (http://www.policy.monash.edu/policy-bank/academic/education/conduct/student-discipline-policy.html)
- Academic Calendar and Semesters (http://www.monash.edu.au/students/key-dates/);
- Orientation and Transition (http://www.infotech.monash.edu.au/resources/student/orientation/);
  and
- Academic and Administrative Complaints and Grievances Policy
  (http://www.policy.monash.edu/policy-bank/academic/education/management/complaints-grievance-policy.

Student services

The University provides many different kinds of support services for you. Contact your tutor if you need advice and see the range of services available at www.monash.edu.au/students

The Monash University Library provides a range of services and resources that enable you to save time and be more effective in your learning and research. Go to http://www.lib.monash.edu.au or the library tab in my.monash portal for more information.

Students who have a disability or medical condition are welcome to contact the Disability Liaison Unit to discuss academic support services. Disability Liaison Officers (DLOs) visit all Victorian campuses on a regular basis

- Website: http://adm.monash.edu/sss/equity-diversity/disability-liaison/index.html;
- Telephone: 03 9905 5704 to book an appointment with a DLO;
- Email: dlu@monash.edu
- Drop In: Equity and Diversity Centre, Level 1 Gallery Building (Building 55), Monash University, Clayton Campus.

Moodle 2

All unit and lecture materials, plus other information of importance to students, are available through the virtual learning environment Moodle site. You can access Moodle via the my.monash portal.

Other Information

Where to go for help

If you're stuck, confused or simply not sure how to approach Moodle, there are a number of <u>Moodle resources</u> that you can tap into.

Prescribed text(s) and readings

Gilbert, N., (2008) *Agent-Based Models,* Quantitative Applications in the Social Sciences No. 153; SAGE Publications, Los Angeles & London, xiii + 98 pp.

Recommended text(s) and readings

Miller, J.H. and Page, S.E., (2007) *Complex Adaptive Systems: An Introduction to Computational Models of Social Life,* Princeton University Press, Princeton, NJ & Oxford, xix + 263 pp.

North, M.J. and Macal, C.M., (2007) *Managing Business Complexity: Discovering Strategic Solutions with Agent-Based Modeling and Simulation,* Oxford University Press, Oxford & New York, xi + 313 pp.

Railsback, S.F. and Grimm, V., (2012) *Agent-Based and Individual-Based Modeling: A Practical Introduction,* Princeton University Press, Princeton NJ, xviii + 329 pp.

Introduction to ETC/ECC 3860 *Integrated Economic Modelling*

Don't be alarmed by the number of readings listed on the following pages - we don't expect you to read them all. Required readings are marked with **. The other readings are ones you may find useful or interesting. Since there's only one unit covering complex systems approaches to integrated economic modelling, we thought it best to give you an idea of the breadth of material being produced and the amazing work being done in this exciting and rapidly expanding field. You won't have to go hunting either - all readings are provided as pdfs in a zip folder under IEM Library on MUSO.

Lecture 1: Simon Angus, Brett Parris & Behrooz-Hassani M.

Part 1: Introductions to Integrated Modelling (Motivation)

1.1: Economic Conundrums and the Complex Adaptive Systems Perspective

Lectures 2 & 3: Brett Parris

Ackerman, F., (2002) "Still Dead after All These Years: Interpreting the Failure of General Equilibrium Theory", *Journal of Economic Methodology,* Vol. 9, No. 2, June, pp. 119-139.

Anderson, P.W., (1972) "More is Different", *Science,* Vol. 177, No. 4047, 4 August, pp. 393-396.

Arthur, W.B., (1990) "Positive Feedbacks in the Economy", *Scientific American,* Vol. 262, No. 2, February, pp. 92-95 & 98-99.

** Arthur, W.B., (1999) "Complexity and the Economy", *Science,* Vol. 284, No. 5411, 2 April, pp. 107-109.

Ayres, R.U., (2007) "On the Practical Limits to Substitution", *Ecological Economics,* Vol. 61, No. 1, 15 February, pp. 115-128.

Bak, P. and Chen, K., (1991) "Self-Organized Criticality", *Scientific American,* Vol. 264, No. 1, January, pp. 46-53.

Other Information

Clower, R.W., (1995) "Axiomatics in Economics", *Southern Economic Journal,* Vol. 62, No. 2, October, pp. 307-319.

Cohen, A.J. and Harcourt, G.C., (2003) "Whatever Happened to the Cambridge Capital Theory Controversies?" *Journal of Economic Perspectives,* Vol. 17, No. 1, Winter, pp. 199-214.

Colander, D., Howitt, P., Kirman, A., Leijonhufvud, A. and Mehrling, P., (2008) "Beyond DSGE Models: Toward an Empirically Based Macroeconomics", *American Economic Review,* Vol. 98, No. 2, May, pp. 236-240.

Colander, D. and Rothschild, C., (2010) "Sins of the Sons of Samuelson: Vision, Pedagogy, and the Zig-Zag Windings of Complex Dynamics", *Journal of Economic Behavior & Organization,* Vol. 74, No. 3, June, pp. 277-290.

Conlisk, J., (1996) "Why Bounded Rationality?" *Journal of Economic Literature,* Vol. 34, No. 2, June, pp. 669-700.

Crutchfield, J.P., Farmer, J.D., Packard, N.H. and Shaw, R.S., (1986) "Chaos", *Scientific American,* Vol. 255, No. 6, December, pp. 38-49.

Cucker, F. and Smale, S., (2007) "On the Mathematics of Emergence", *Japanese Journal of Mathematics,* Vol. 2, No. 1, March, pp. 197-227.

Dillard, D., (1988) "The Barter Illusion in Classical and Neoclassical Economics", *Eastern Economic Journal,* Vol. 14, No. 4, October-December, pp. 299-318.

Felipe, J. and Fisher, F.M., (2003) "Aggregation in Production Functions: What Applied Economists Should Know", *Metroeconomica,* Vol. 54, No. 2-3, May-September, pp. 208-262.

Fontana, M., (2010) "Can Neoclassical Economics Handle Complexity? The Fallacy of the Oil Spot Dynamic", *Journal of Economic Behavior & Organization,* Vol. 76, No. 3, December, pp. 584-596.

** Foster, J., (2005) "From Simplistic to Complex Systems in Economics", *Cambridge Journal of Economics,* Vol. 29, No. 6, November, pp. 873-892.

Foster, J. and Metcalfe, J.S., (2012) "Economic Emergence: An Evolutionary Economic Perspective", *Journal of Economic Behavior & Organization,* Vol. 82, No. 2–3, May, pp. 420-432.

Gu, M., Weedbrook, C., Perales, Á. and Nielsen, M.A., (2009) "More Really is Different", *Physica D,* Vol. 238, No. 9-10, 15 May, pp. 835-839.

Harper, D.A. and Endres, A.M., (2010) "Capital as a Layer Cake: A Systems Approach to Capital and its Multi-Level Structure", *Journal of Economic Behavior & Organization,* Vol. 74, No. 1-2, May, pp. 30-41.

Helbing, D., (2009) "Managing Complexity in Socio-Economic Systems", *European Review,* Vol. 17, No. 2, pp. 423-438.

Holt, R.P.F., Rosser, J.B. and Colander, D., (2011) "The Complexity Era in Economics", *Review of Political Economy,* Vol. 23, No. 3, pp. 357-369.

Jones, H., (2011) "Taking Responsibility for Complexity: How implementation can achieve results in the face of complex problems", London, Overseas Development Institute, Working Paper 330, June, x + 60 pp. http://www.odi.org.uk/resources/download/5275.pdf

Other Information

Kirman, A.P., (1989) "The Intrinsic Limits of Modern Economic Theory: The Emperor Has No Clothes", *Economic Journal,* Vol. 99, No. 395, Supplement, pp. 126-139.

** Kirman, A.P., (1992) "Whom or What Does the Representative Individual Represent?" *Journal of Economic Perspectives,* Vol. 6, No. 2, Spring, pp. 117-136.

** Kirman, A.P., (2008) "Economy as a Complex System", In *The New Palgrave Dictionary of Economics Online* ed. Durlauf, S.N. and Blume, L.E.; 2nd Edition; Palgrave Macmillan. http://www.dictionaryofeconomics.com/article?id=pde2008_E000246

Miller & Page, (2007) *Complex Adaptive Systems*, Chapter 2: Complexity in Social Worlds, pp. 9-31.

Neumayer, E., (1999) "Global Warming: Discounting is not the Issue, but Substitutability is", *Energy Policy,* Vol. 27, No. 1, January, pp. 33-43.

North & Macal, (2007) *Managing Business Complexity,* Chapter 4. The Roots of ABMS, pp. 45-58.

Oxley, L. and George, D.A.R., (2007) "Economics on the Edge of Chaos: Some Pitfalls of Linearizing Complex Systems", *Environmental Modelling & Software,* Vol. 22, No. 5, May, pp. 580-589.

** Ramalingam, B., Jones, H., Reba, T. and Young, J., (2008) "Exploring the Science of Complexity: Ideas and Implications for Development and Humanitarian Efforts", London, Overseas Development Institute, Working Paper 285, October, 75 pp.

Rizvi, S.A.T., (1994) "The Microfoundations Project in General Equilibrium Theory", *Cambridge Journal of Economics,* Vol. 18, No. 4, August, pp. 357-377.

Rosser, J.B., Jr., (1999) "On the Complexities of Complex Economic Dynamics", *Journal of Economic Perspectives,* Vol. 13, No. 4, Fall, pp. 169-192.

Rosser, J.B., Jr., (2010) "Is a Transdisciplinary Perspective on Economic Complexity Possible?" *Journal of Economic Behavior & Organization,* Vol. 75, No. 1, July, pp. 3-11.

Saari, D.G., (1995) "Mathematical Complexity of Simple Economics", *Notices of the American Mathematical Society,* Vol. 42, No. 2, February, pp. 222-230.
http://www.ams.org/notices/199502/saari.pdf

Saari, D.G., (1996) "The Ease of Generating Chaotic Behavior in Economics", *Chaos, Solitons & Fractals,* Vol. 7, No. 12, December, pp. 2267-2278.

Scheffer, M., Bascompte, J., Brock, W.A., Brovkin, V., Carpenter, S.R., Dakos, V., Held, H., van Nes, E.H., Rietkerk, M. and Sugihara, G., (2009) "Early-Warning Signals for Critical Transitions", *Nature,* Vol. 461, No. 7260, 3 September, pp. 53-59.

Vicsek, T., (2002) "The Bigger Picture", *Nature,* Vol. 418, No. 6894, 11 July, p. 131.

Velupillai, K.V., (2005) "The Unreasonable Ineffectiveness of Mathematics in Economics", *Cambridge Journal of Economics,* Vol. 29, No. 6, November, pp. 849-872.

Velupillai, K.V., (2007) "Variations on the Theme of *Conning* in *Mathematical Economics*", *Journal of Economic Surveys,* Vol. 21, No. 3, July, pp. 466-505.

1.2: A Tour of Complex Policy Problems: Climate-change, economic development, energy, sustainability, finance, conflict, innovation

Other Information

Lectures 4 & 5: Brett Parris

Ayres, R.U., (2008) "Sustainability Economics: Where do we Stand?" *Ecological Economics,* Vol. 67, No. 2, September, pp. 281-310.

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Part 2: The Agent-Based Modelling Approach (Method)

2.1: Introduction to Agent-Based Modelling

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2.3 What can we learn from the overlap between simulation modelling and gaming?

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2.4: Overview of ABM Platforms

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2.5 Examples 1: spatial-interactions, cellular automata, networks, soup-models

Lectures 11 & 12: Simon Angus

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2.6 Examples 2: Learning, innovation, market design, evolutionary programming, genetic algorithms, simulated annealing

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Part III: ABMS and the Real World (Verification & Interpretation)

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3.3 Examples: economics, energy, development, drugs, epidemics, conflict

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