Complexity Economics - Theory and Computational Methods

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1 Motivation: Economics and complexity

Complexity Economics emphasizes the dynamic and systemic nature of economic systems. They are conjectured to consist of a massive number of interdependent entities including individuals, firms, and institutions. If interdependence and interaction structure among components matter, any attempts to abstract from the systemic level and reduce the system to a simple model focused on a few representative entities are doomed to fail. Convenient mathematical properties such as universal structural stability and definite equilibrium convergence are unlikely, and attempts to build such properties into models of the system are bound to produce incomplete and unreliable results.

Complexity economics is not an established part of mainstream economics, but it is more readily accepted today than it was before the subprime mortgage crisis and the following global financial crisis. It was the collapse of Lehman Brothers that convinced the last skeptics that the "Great Moderation", the conjectured end of business cycles, economic crises, and recessions, was at an end. Several economists taking complexity seriously had warned early on that something catastrophic was going to happen as the subprime bubble would entail systemic effects in the banking system. But as long as economic indicators such as employment and inflation looked good, they were dismissed as overly gloomy and alarmist.

While financial markets and financial crises may be the most colorful example of complexity in economics, they are certainly not the only one. Complexity is equally crucial for industrial organization, for technological change, for international trade, for development economics, for the mechanisms behind inequality, for urban economics and infrastructure, and for many other questions not only in the field of economics but all over the social sciences and beyond.

2 Contents of the course

This course offers a concise introduction to Complexity Economics. We will cover both theoretical and methodological concepts. The lecture consists of 15 sessions in total, with three sessions each day. Two sessions introduce selected concepts of complexity economics. We start by discussing the history of complexity economics and its roots in different disciplines. Then we discuss its meta-theoretical foundations and the relation to the philosophical concept of systemism. We also introduce common definitions of "complexity" and their meanings in the social sciences.

We will introduce the participants to basic modeling approaches of complexity economics: game theory, evolutionary dynamics, nonlinear dynamical systems, and basic network theory. When discussing the empirical aspects of complexity economics we focus on the importance of heavy tailed distributions such as power laws, and how to work with them.

Every day, the third session consists of an interactive introduction to the open-source programming language Python. Students learn about fundamental programming concepts, how to simulate nonlinear

equations, and the basics of object-oriented agent-based modeling. Students should find their own programming project that they may continue working on after the course.

At the end of the course, the participants will not be experts in any of the methods discussed during the course. But they should be able to continue their own programming project and to deepen their knowledge in the various methodologies through self-study.

For students who want to get an idea about the contents of the course we suggest them to have a look at the following conceptual readings:

> Mitchell, M., 2009. *Complexity. A Guided Tour*, Oxford and New York: Oxford University Press.
>
> Elsner, W., Heinrich, T. & Schwardt, H., 2015. *The Microeconomics of Complex Economies: Evolutionary, Institutional, Neoclassical, and Complexity Perspectives*, Amsterdam et al.: Elsevier/Academic Press.
>
> Arthur, W.B., 2010. Complexity, the Santa Fe Approach, and Non-Equilibrium Economics. *History of Economic Ideas*, 18(2).

With regard to agent-based modeling we recommend:

> Tesfatsion, L., 2017, Modeling Economic Systems as Locally-Constructive Sequential Games, *IA State Economics Working Paper No. 17022*, available online.

3 Topics covered in the lectures

- Historical roots of complexity economics
- Meta-Theoretical foundations and systemist thinking
- Nonlinear dynamical systems: difference and differential equations (theory and simulation)
- Game theory
- Evolutionary dynamics
- Fundamental concepts of network theory
- Heavy-tailed distributions: theory and empirics
- Agent based computational economics: theory and simple models

4 Prerequisites for the course

There are no formal prerequisites but we suggest students to review some basic mathematics as outlined in a separate document.

Participants are asked to complete a survey about their interests and prior knowledge some weeks before the course starts. Participation in the survey is important because we aim to adjust contents to the audience.

There is no prior programming experience required. Students need, however, a laptop with Python 3.X (and supplementary modules numpy, scipy, Jupyter, and matplotlib) installed. A manual with installation instructions will be distributed on the course main page. Claudius offers an optional troubleshooting session the day before the regular course takes place. It is essential that your Python environment is fully operational the first day of the workshop.