The adoption of "complexity" in economics as a contribution to resolving dilemmas in the Anthropocene

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Introduction

Anthropogenic climate change and ecological breakdown are now major threats to human life and other species. It is widely acknowledged that mainstream economic theory and especially neoclassical theory lack adequate concepts to address these problems and arguably have contributed to them through misdirection and delay. "Complexity" sciences, however, are now widely adopted but have as yet made little impact on economics. In this short article I advocate the widespread adoption of "complexity" in the field of economics. Complexity means more than just acknowledgement that "it's complicated". Its greatest attraction in our current "climate emergency" is that it is capable of dealing with the interconnection and interdependence between the biosphere and economic systems. I draw attention to several significant aspects of complex systems for economics:

a) The lack of homogeneity among the elements of the system in terms of the characterization of agents (attributes, rules of behaviour, cognitive rules, strategies, learning capacity) and the environment where patterns of interaction occur;
b) The adaptive nature of an agent's behaviour in interaction with their environment;
c) The concept of emergence as the property of novelty, change, and innovation of complex systems that exhibit a wide range of aggregate patterns.

Theory and policy that fail to consider a) to c) in the context of the impacts of economic systems on the biosphere are deficient and as Winkelman et al argue, there is a need to "close this loop" (Winkelmann et al., 2017)

1. The incorporation of complex economic and biophysical systems in Eco 100

While founding economists such as the physiocrats and John Stuart Mill had some concept of the material impact of economic activity, mainstream economics has since become divorced from the physical world. Its main focus is exchange valuations and at the macroeconomic level, national accounting, circular income flows and trade balances (for discussion of issues see Naredo, 2012; Green 2012). Mainstream economics exemplifies a mechanistic cause-and-effect perspective prevalent in the 19th century. Simple linear cause-effect and recourse to ceteris paribus clauses don´t allow for realistic representation of the economic system (Madi, 2020). The mainstream has attempted to adapt itself through "environmental economics", but as "ecological economists" argue, this remains incapable of appropriately incorporating material flows and energy use in ways liable to lead to a rational conception of "biophysical limits". Moreover, Econ 100 courses and textbooks still treat the environment as a specialist issue rather than a basic concern. This state of affairs reflects a deeper problem of unrealistic knowledge, mainly predicated on homo economicus (with a few modifications) and Cartesian reductionism (Fullbrook, 2016). Worse, a mainstream economics education imposes implicit norms that prevent students cultivating a critical mindset. In a time of "climate emergency" this is a major problem (Reardon and Madi, 2020).

Earth systems scientists have developed a "planetary boundaries" framework which seeks to model the interactions between human activity and different systems – of which climate is only one (Steffen et al. 2015a, 2015b). Earth system scientists work with a concept of "safe operating space" and report that multiple systems have now exceeded this (Steffen and Morgan, 2021). It is partly because of such changes that Earth systems scientists have also coined the term "Anthropocene" (though others, such as Jason Moore, prefer the term "capitalocene") (Donges et al., 2017).

It seems clear that economics needs to adopt an appropriate variation of the kind of complex systems approaches that are now available (though it is also important to distinguish these from the simple models advocated by William Nordhaus and others, which ecological economists argue have resulted in deeply unrealistic work). Appropriate complexity allows for greater realism of relations and impacts in time and space.

Recognition of the need for greater realism in terms of time is, of course, not new. John Maynard Keynes, for example, placed specific emphasis on the uncertainty inherent to a monetary economy of production, wherein money serves as the bridge connecting the present and the future (Madi, 2020). Space, on the other hand, has not been a significant or enduring aspect of mainstream economic thought – though economic geographers have long recognised the need to spatialise theory. In terms of ecological economics, the need for a better theorisation of space and time are basic to the work of Nicholas Georgescu-Roegen. Mainstream economics, however, has resisted taking such work seriously.

2. Complexity and Econ 100

Complexity is characteristic of a system that preserves the differentiation among its constituent elements while also preserving their identity. Complexity also implies dynamic systems, that is to say, open totalities of interrelated parts constantly changing in spacetime. The complexity of a system is related to the coexistence of intertwined parts in spacetime and complexity is intrinsic to real-world natural, economic and social processes (Almeida Filho, 1998). If we are to address contemporary problems of the kind referred to in the introduction both the natural world and human society need to be understood as complex systems, where the latter is nested in the former and interdependencies of different kinds arise.

An economy, similar to other systems, consists of complex networks of agents engaged in ongoing interactions, characterised by competition and cooperation. These agents constitute heterogenous components and are in a constant state of learning, adaptation, coevolution, and potential transformation or elimination, as part of an uninterrupted dynamic process (see Arthur, 1988; Arthur et al., 1997). In an economic system, different agents must work to find solutions to challenges they encounter, act in accordance with what is expected of them by others, and collaborate with one another to construct economic, legal, and social structures.

Clearly, the standard circular flow model found in mainstream economics differs markedly from a complex system. Within this model, the interacting agents in the economy (households and firms) are typically homogenous, solve problems with more or less all relevant information and according to clear and simple decision rules founded on rationality, and activity tends towards equilibrium states (see Mankiw, 2015).

If represented as a complex system the circular flow would be replaced by dynamic interactions among heterogenous agents, subject to endogenous causal effects in time and space. Nonlinear causality is extensively employed in complex systems and emphasises indeterminacy, equifinality, feedback loops, disproportionality, multiple causes, and downward-upward causation as crucial characteristics (Van 't Hof, 2018):

- Indeterminism: events may not invariably be caused by antecedent actions;
- Equifinality argues that a single event might have numerous consequences that alter a given circumstance;
- Disproportionality examines the discrepancies between cause and effect;
- Feedback loops refers to the way in which events produce reinforcing influences;
- Downward-upward causation investigates the reciprocal influence of actions.

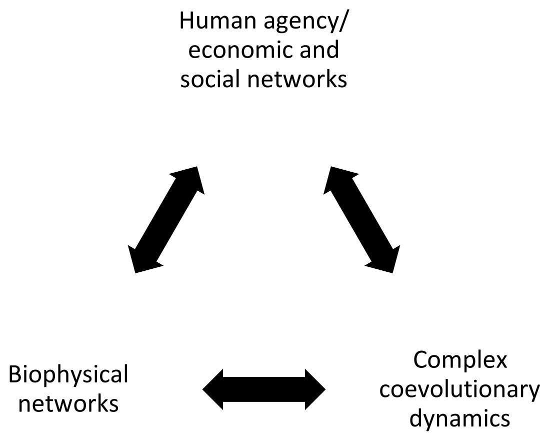
Clearly, any such representation must also incorporate interdependencies with the biosphere based on such concepts as metabolic flow and intrinsic interconnections with the biophysical environment (García and Ivarola, 2022). It is also imperative that this representation incorporates fundamental characteristics that set the Anthropocene apart from previous epochs (Donges et al., 2017):

a) The existence of human agency on a planetary scale;
b) The interconnectedness of global economic and social systems;
c) Substantial interactions between human systems and planetary processes.

With a) to c) in mind, the goal of Econ 100 should be to introduce the conceptualization of the economy as a complex evolutive system with individual components that are connected and interdependent. Action of one part may trigger reactions of other parts, and these also have the potential for adaptation, reaction, innovation or collapse. Evolution is an irrevocable and unrepeatable process of unfolding, transformation, self-organisation entailing oscillation in time and space (Miroslav, 2020).

If considered in terms of epistemology, economic complexity deals with the actions, reactions, expectations, and strategies of economic actors with bounded rationality in an always changing picture. Understanding and modelling tightly intertwined economic-social-environmental systems requires addressing human agency, system-level effects of networks and complex coevolutionary dynamics. Figure 1 summarises this:

Figure 1. The open coevolutionary interactions of complex economic and biophysical systems.



Ultimately, in complex systems, there is a permanent tension between stability and change. Crucially, coevolution in the form of material impacts on the biosphere gives rise to discontinuities that increase uncertainty at the economic and social levels and these should be a matter of concern.

3. An examination of the impact of climate shocks on economic outcomes via the business cycle

The 21st century will be marked by a crucial debate: can we make economic growth compatible with the preservation of our natural environment? (Reardon and Madi, 2020). An enduring myth of neoclassical economics is that the economy has a growth path from which it may deviate in the short term, possibly requiring macroeconomic stabilization policy, but to which it will return in the long term.

Complex systems in contrast provide a more appropriate way to reconnect biophysical and economic phenomena. This can be briefly illustrated.

It is possible to conceive of business cycles which endogenously link biophysical and economic variables. It is already the case that study of finance requires consideration of climate-related risks at the micro and macroeconomic levels. Although such risks are currently underrepresented in the macroeconomic literature, they can more adequately be connected with biophysical disruptions. Such disruption can propagate through economic interconnections, increasing the likelihood of macroeconomic instability. For example, the expansion of decarbonising green investments can produce multiple systemic outcomes. A micro-macro dynamics can be applied that take account of non-linear causation, and which can examine reciprocal relationships between micro-level process components and larger-scale processes. Here, a macroeconomic approach can facilitate the organisation of the framework in which a network of micro-interactions occurs (see García and Ivarola, 2022).

In simple terms, there are clear possible counterproductive effects. After a period of expansion of green investments, and in the aftermath of a climatic shock, property damage may lead to an increase of climate physical risks that have a heterogeneous impact on banks´ assets and liabilities. Non-performing loans, increasing financing costs, and falling asset values can all have an effect on the interaction between credit, liquidity, and market risks that affect the balance sheet of banks and thus their subsequent lending strategies. It may be that indebted firms cannot fulfil their financial obligations. As a direct result of this, the levels of credit, green investment, production, employment, and income may all reduce. Furthermore, when profits and asset prices begin to decline, a credit constraint may also restrict external financing to firms and households, in turn creating a severe demand for liquidity.

I could go on, but it should be clear that complexity allows for multiple consequences and it is likely these would multiply. Over time, climate-related risks could dampen the level of green investment and delay the transition to a low-carbon economy. This, of course, means emissions would continue at higher levels for longer, with further impacts and feedbacks on climate systems, putting more pressure on planetary boundaries. As this brief illustration indicates it is only via complexity that we achieve a sense of dynamic interdependencies. This can be extended to more specific coupling approaches to structural change and economic stability in a theoretical setting that highlights emergence, non-linear causalities, and irreversibility.

Final considerations

If we are now living in the Anthropocene and the Holocene is behind us then it is incumbent on us to take responsibility for the world we are making. Climate emergency requires we take seriously the problem of "biophysical limits", but in order to adequately assess what these are in relation to economies, the widespread introduction of complexity science would seem to be imperative.

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