Cambridge Journal of Economics 2023, 1 of 18
https://doi.org/10.1093/cje/bead002

Complexity defying macroeconomics

Pablo Paniagua[*]

This article contributes to the literature on complexity and macroeconomic models by exploring the analytical relationship and tensions between complex phenomena and macroeconomics. By evaluating the properties of organised complexity, this article suggests alternative strategies for analysing the macroeconomy. Drawing on F. A. Hayek's notion of organised complexity, I examine how its causal properties relate to the analytical criteria and assumptions that contemporary macroeconomic models use. The purpose is twofold: first, I associate the properties of complexity to the idea of the macroeconomy as an emergent totality arising from the causal interplay between individuals and the organising structure. This conceptually challenges modern macro and frames analytical tensions between complexity and macroeconomic analysis. Second, introducing complexity facilitates breaking away from current analytical and conceptual straitjackets in macroeconomics. Economic inquiry requires looking for alternative ways beyond standard models to analyse the macroeconomy as an emergent totality. This suggests stepping away from current formalistic methods and radical reductionism, in favour of unconventional strategies and approaches that are sensitive to rules, structures, and the causal properties of organised complexity.

Key words: Complexity, Macroeconomics, Economic models, Ontology, Emergence
JEL classifications: B4, D02, D08

Too large a proportion of recent 'mathematical' economics are mere concoctions, as imprecise as the initial assumptions they rest on, which allow the author to lose sight of the complexities and interdependencies of the real world in a maze of pretentious and unhelpful symbols.
J. M. Keynes, 1936, p. 272

1. Introduction

Economic thinking has entered a new era of unprecedented pluralism (Ostrom, 2010; Holt *et al.*, 2011). There are two major research agendas that have driven economic analysis toward more pluralism: complexity economics and heterodox economics (Hodgson, 2019; Lawson, 2019). One characteristic of this new period is accepting

Manuscript received 7 August 2020; final version received 17 October 2022
Address for correspondence: Research Fellow, Centre for the Study of Governance and Society, Bush House, North East Wing, 30 Aldwych, WC2B 4BG, UK; email: pablo.paniagua_prieto@kcl.ac.uk
[*]Research Fellow at the Centre for the Study of Governance and Society, King's College London, Bush House North East Wing, 30 Aldwych, WC2B 4BG, UK, and Professor of Political Economy at Universidad del Desarrollo, Santiago, Chile (Faro UDD) (PP). I would like to thank Victoria Finn and Harry David for their generous support and editing assistance. Special thanks to Alexander Salter, Geoffrey Hodgson, Pete Boettke, Richard Wagner, and Mark Pennington for their encouragement and support while drafting this essay. The feedback of CJE Managing Editor Jacqui Lagrue and the three anonymous reviewers is greatly appreciated. The usual caveats apply.

that the economy is inherently complex: the economy is being portrayed as a complex system (Dosi and Roventini, 2019).[1] Instead of conceptualising the economy as a well-ordered machine reaching equilibrium, some economists are now interpreting it as a complex evolving system emerging from interactions (Wagner, 2020; Hommes, 2021).

While it holds true that 'modern economics is more willing to accept that the formal part of economics has limited applicability' (Holt *et al.*, 2011, p. 363), despite the recent advancements made in bringing complexity and ontological ideas into economics, the complexity vision has not yet permeated macroeconomic thinking (Lawson, 1997; Kirman, 2010; Romer, 2016). Macroeconomics seems to be moving ever further away from complexity since it embraces an 'analytic macro theory based on abstract, representative agent models that rely heavily on the assumptions of equilibrium', thus 'it is less clear what this work has added to our understanding of the macroeconomy' (Holt *et al.*, 2011, p. 365).

The analytical tension between emergent macroeconomic phenomena and the formal methods and ways of thinking used in macro have long been identified by Hayek (1973), Keynes (1936) and other heterodox economists (Hodgson, 2019; Wagner, 2020). While the concepts of emergence and complexity have made their way back into the social sciences (Lawson, 1997, 2019; Hodgson, 2000), few attempts have been made to try to incorporate them into macroeconomic thinking (Lewis and Wagner, 2017; Wagner, 2020). Therefore, macroeconomics has been seriously impoverished (Romer, 2016).

Lawson (2019, p. 22) has argued that economics is facing 'an inability to avoid reliance upon unrealistic assumptions'; and thus 'a continuous failure to achieve explanatory insight have been features of academic economics for the last 60 years'. This situation disregards social ontology,[2] thus neglecting 'the functioning of social reality' which has led to retain economic 'methods that carry inconsistent ontological presuppositions or "preconceptions"' (*ibid.*, pp: 9–15). Neglecting to engage explicitly in ontological reasoning has led to promoting techniques which carry 'ontological commitments that do not fit the nature of social material' (*ibid.*, p. 9).

Echoing Lawson's (2016, 2019) concerns, the scope of this paper is to follow Ostrom's (1982, 1990) advice on understanding the *proper limits* of the methods in economics, once we grasp the nature of the phenomena we seek to explore. In Ostrom's (1990, p. 24) words, 'scientific knowledge is as much an understanding of the diversity of situations for which a theory or its models are relevant as an understanding of its limits'. The present analysis focuses on the implications these ideas could bring to formal methods and frameworks used in macroeconomics, challenging the standard way of thinking about macro.

This article suggests that the leading literature and current formalist methods in macroeconomics are unable to represent the macroeconomy as organised complexity and to represent its causal properties (Axtell, 2014). Because of reductionist and debatable assumptions throughout their methods, they inherently overlook causal features of complexity and social reality (Romer, 2016; Lawson, 2019). This situation in macroeconomics has been recently addressed by Wagner (2020), who argues that

[1] See H. Simon (1962, p. 267): 'Roughly by a complex system I mean one made up of a large number of parts that interact in a non-simple way. In such systems, the whole is more than the sum of the parts, not in an ultimate metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole'.

[2] Ontology 'is investigation into the nature, basic constitution and modes of being of stuff, of all phenomena' (Lawson, 2019, p. 21).

conventional macro presents the economy as a collection of aggregated variables and the relationships that develop among them. In contrast, Wagner (2020) depicts 'macroeconomics as system theory', meaning an analytical framework enriched by theories of complex systems (Hayek, 2014 [1964]) and systems theory (Pryor, 2008).[3] This vision results in a departure in analytical perspective: the 'macro level' of society *cannot* be pursued through aggregation over micro level entities, but rather via an 'open-ended evolutionary framework' (Devereaux and Wagner, 2020).[4]

These contrasting visions toward macro theory, alongside the recent critiques put forth by some of their own practitioners (e.g., Caballero, 2010; Kirman, 2010; Trichet, 2010; Calvo, 2013; Romer, 2016), clearly evidence analytical tensions and intellectual difficulties in macroeconomics. The 2018 special issue on 'Rebuilding Macroeconomic Theory' in the *Oxford Review of Economic Policy* gathers several discussions concerning the current tensions and qualms in macroeconomic thinking (e.g. Stiglitz, 2018; see also Hommes, 2021). Given the identified tensions within macroeconomics, this article contributes to the literature on complex phenomena, macroeconomics, and the relationship between them (see also Paniagua, 2016a, 2016b).[5] It explores the theory of complex phenomena and its causal properties in order to show the relevance of heterodox strategies for studying the macroeconomy. It also provides arguments as to why heterodox approaches might be more suitable for representing the macroeconomy as a complex system. Section 2 briefly explores arguments about statistics' limitations in dealing with complex phenomena and emergence. Section 3 examines the four properties that define both organised complexity and the macroeconomic order. Section 4 reviews three conceptual criteria and assumptions currently employed in macroeconomics—and how they are incompatible with the properties of complexity. Section 5 suggests an ontological and heterodox framework of macro analysis that avoids current reductionism, analytical incompatibilities and the shortcomings of formal models. Section 6 concludes.

2. Social systems and the limitations of statistical modelling

In recognising the complexity vision in economics, Hayek (2014 [1964], p. 264) and Pryor (2008) argue that, as a form of analysis, statistical linear models (i.e. statistical methods used to analyse linear causation) are analytically incapable of dealing with patterns of complexity based on systems of relations. For Hayek (2014 [1964]), and

[3] Systems theory focuses on relationships between parts and wholes in which the system has relevant properties irreducible to and distinct from the properties held at the level of the parts that constitute the system (Bertalanffy, 1968). My approach to macro resonates strongly with systems theory. Pryor (2008, p. 545) argued that macro systems could be treated as 'causal forces'—that is, as 'systemic causation'. Systemic causation 'focuses not on the relationship of individual variables with each other, but on the grouping of characteristics into systems within the various domains' (*ibid.*, p. 546).

[4] The themes explored by Wagner (2020) and Devereaux and Wagner (2020), reflect a similar orientation toward macro as developed here. This approach to macro resonates also with—and can be enriched by—systems theory (Bertalanffy, 1968; Pryor, 2008).

[5] Some mainstream economists have pointed to some problematical features of the current dynamic stochastic general equilibrium (DSGE) approach. For instance, Kirman (1992, 2010) has undertaken a critical analysis of representative agent modelling. Janssen (1993) and Stiglitz (2018) have provided critical assessments of DSGE models, leading Stiglitz (2018, p. 73) to recognise that 'the core DSGE models is not good theory'. Paul Romer (2016, p.1) has even described macro theory as 'macroeconomic pseudoscience'. Korinek (2015) concluded that the 'scientific rigor of this [macro] method is questionable'. Macroeconomic practitioners such as Caballero (2010), Trichet (2010), Howitt (2012), and Calvo (2013) have also presented misgivings on the current state of macroeconomics.

also for Weaver (1948) and Ostrom (1982), statistics as a method is unfit to deal with social phenomena that display the essential features of organised complexity.[6] Hayek (2014 [1964], pp. 264–265) argues that statistical models are unable to illuminate the workings of complex and highly organised phenomena because its methods deliberately ignore the relative positions of elements within the whole. Furthermore, statistical models also turn a blind eye regarding how those elements connect with each other (see also Lawson, 1997).

This suggests that statistical methods used to analyse linear causation, and other formal approaches, face analytical and methodological limits, preventing them from explaining and representing organised complex phenomena since complexity arises from rule-guided interactions between orderly and systematically connected parts (Hayek, 2014 [1964], p. 265). Lawson (2019, pp. 6–7) argues that statistical and formal models applied to social systems and economic reality in general lead to 'analytical incoherence' since they carry inadequate ontological presuppositions: a 'prevalence of *closed systems*, namely configurations in which event regularities or correlations occur'. Thus, these models are committed to the view that 'social reality consists of a ubiquity of closed systems of isolated atoms'. Most modelling and statistical attempts of economics are ultimately 'manifestations of this atomistic ontology' (*ibid.*, p. 7; see also Ostrom, 1982). Hence, statistical assumptions generally assume away the properties of complexity and the open-ended nature of social reality (Lawson, 1997; Pryor, 2008; Lewis, 2021).

For simplicity, social systems are here conceived as emergent totalities or social 'wholes' which result from the causal interplay between the individuals (i.e. the parts) that compose the system and its organising structure (Ostrom, 2005; Lewis, 2021).[7] Social systems are therefore 'complex' since they display relevant properties irreducible to, and distinct from, the properties held at the level of the parts that constitute them (Bertalanffy, 1968; Wagner, 2012). As Herbert Simon (1962, p. 267) noticed, 'a complex system' is 'made up of a large number of parts that interact in a non-simple way'. Furthermore, an *organised* complex system, according to Weaver (1948), is a type of regular order arising from the social relations among the elements.[8] Thus, it is a special type of order (or regularity) that occurs when elements are organised and 'interrelated in a complicated, but nevertheless not in helter-skelter, fashion' (*ibid.*, p. 539).

[6] A problem of 'organised complexity' shows the features of an organisation, meaning that the arrangement of the variables generates an order—an organisational property that possesses emergent features (Simon, 1962). Thus, they are 'problems which involve dealing simultaneously with a sizable number of factors which are interrelated into an organic whole' (Weaver, 1948, p. 539). Organised complexity displays a type of interconnectedness among the elements so that they are 'all interrelated in a complicated, but nevertheless not in helter-skelter, fashion' (*ibid.*, p. 539).

[7] Organising social structure means: 'merely a category that collects together the collective practices, acceptances, [social] positions, rules, rights, obligations and suchlike that are emergent features of human actions and interactions and which relationally organise the individuals as communities' (Lawson, 2019, p. 61). The important point for Lawson (2022) is that we are not dealing with a long list of different things (organisation, social relations, positions, rights, and obligation), but looking at the same things under different descriptions (Slade-Caffarel, 2020).

[8] To clarify, social relations are here conceived as 'to express the manner of connection of social positions … a social relation just is (or is first and foremost) and accepted set of rights and obligations holding between, and connecting, two or more positions or occupants of positions. Social interaction can be understood as the contingent actualisations of such social relations' (Lawson, 2019, pp. 56–57). In addition, a social 'position or rather position occupancy is an accepted status that confers a social identity; to be allocated to a specific position is to acquire the social identity of being so positioned. … a position is essentially a locus of a set of specific rights and obligations' (*ibid.*, p. 55).

Accordingly, the social and economic reality are marked by 'specific processes of emergence. These are processes whereby various elements in existence … become *relationally organised* to form components of some novel or "emergent" totality' (Lawson, 2019, p. 12).[9] Recently, Lawson (2019, 2022) and the Cambridge Social Ontology group have made important contributions into understanding the relevance of organisation for understanding how social phenomena are constituted (Slade-Caffarel, 2020). Thus, using certain formal methods that exclude or negate the existence of complexity and emergence would not only be a misapplication of methods but also a potential waste of intellectual resources that deter social scientists' efforts from understanding such organised phenomena (Ostrom, 1982).[10] Alas, macro analysis has not undertaken the path suggested by Pryor (2008) since they focus on linear causation models, presuming a 'closed system' of related variables that allow to 'deduce specific predictions about likely outcomes of highly simplified structures' (Ostrom, 2005, p. 29).

Consequently, statistics as commonly practiced (i.e. linear causation models) proceeds under the reductionist assumption that the numerical information about the isolated parts, the randomly distributed numerical frequencies of their properties, and the repetition of the classes of behavior of the different elements are sufficient to explain complex phenomena (Ostrom, 1982). Pryor (2008, p. 548) recognises that 'the statistical methods used in analysing lineal causation are no longer satisfactory, and we must supplement this approach with different methods'. Standard models attempt to engage in a form of reductionism, or rather a type of conceptual and linear simplification of the whole (Pryor, 2008). Using such a reductionist stance while studying complexity is a grave inaccuracy since emergent properties cannot—even in theory—be deduced from the knowledge of the components, neither separately nor partially combined (Hodgson, 2000; Lewis, 2015).

3. The four features of complexity

The analytical and methodological limitations of both statistics and modern macroeconomic models attempting to illuminate complex phenomena are broadly derived from the presence of four features of organised complexity. The four properties drive the existence of complex social systems (Lewis, 2015; Wagner, 2020), yet are

[9] Lawson (2019, 2022) has tried to clarify and further advance his position into the nature and properties of social reality. For a thorough account of the evolution of Lawson's thought and of the Cambridge Social Ontology project consult Slade-Caffarel (2020). In a nutshell, it is vital not to treat structure, organisation, social relations, positions, rights and obligations as though they are different; these are basically the same things at different levels of abstractions. Lawson's (2022) basic argument is that: (i) basic elements (human beings and various objects) are (ii) relationally organised to form (iii) components of social totalities, the latter taking the form of human communities. There, the elements come to occupy positions and are thereby formed into relational components, where positions are essentially packages or sets of rights and obligations.

[10] Despite the fact this paper borrows heavily from Lawson's (1997, 2016) ideas on emergence, organisation and social structures, due to space constraints, this paper will not delve deeper into Lawson's (2019, 2022) theory of social positioning. A good account of Lawson's recent position can be found in Slade-Caffarel (2020), Lewis (2021) and Lawson (2022). Importantly, for Lawson (2022), rules are not an important category: rules, for Lawson, are less ontological than epistemological, as they are codified representations of obligations. Lawson (2019, 2022) departs from institutionalists since they seemed to lack a developed ontology. Institutional economics tends to use the term 'rule' as if it were ontological and use it to cover most social phenomena. This is a key difference between Lawson's position and the one developed in this paper. For a possible reconciliation on these matters using the work of Elinor Ostrom and Tony Lawson see Lewis (2021).

deeply incompatible with modern macro's methodological criteria and reductionist assumptions.

First, systems that display organised complexity comprise a large number of elements that are related to each other and interact in particular ways (Hayek, 2014 [1964]). Organised complexity is characterised by the existence of elements that establish purposeful and interconnected ways of behaviour among them (Hayek, 1952). All the parts are interrelated in a complicated fashion—but *not* in individually erratic or unknown helter-skelter ways—forming an organic whole, or an organised system of relations (Weaver, 1948). An organised system is 'a coherent structure of causally connected… parts' and as such, 'only certain kinds of regular arrangements' can produce an order (Hayek, 2014 [1964], p. 258).

Second, the specific and orderly interactions between the parts—organised by the structure—are what constitute the system's core elements; they comprise the generative mechanism that produces a complex order and its emergent properties (Colander and Kupers, 2014; Lewis, 2021). Given the myriad of intricate and dynamic interconnections, the interactions cannot be entirely understood or fully represented in detail. However, they can be *indirectly* explained and described in general terms, by either the system of rules or the organising framework configuring them (Ostrom, 2010; Lewis, 2015). Thus, while it is impossible to know, model and completely detail the myriad of interconnections, they can nonetheless be described in terms of the sets of rules and organisational structures that define the positions, rights and obligations 'which relationally organise the individuals as communities' (Lawson, 2019, p. 61). These are the general principles guiding the parts' interactions (Lewis and Wagner, 2017).

Consequently, the key feature in analysing orderly interactions—while bypassing the intractability of formalising the whole dynamic network and the impossibility of accounting for all the interactions generating the whole—is by being able to identify their specific governing rules and organising structures (Ostrom, 2005; Wagner, 2020). Sets of governing rules that define relations are the fundamental aspect generating 'persistent structures of relationships' (Hayek, 1952, p. 142). Complex wholes are 'defined in terms of certain general properties of their structure' and rules (Hayek, 2014 [1964], p. 262). In other words, a complex order must have a set of rules, an organising or a physically guided structure governing the general principles, and properties of interactions (Lewis, 2015). Specific sets of rules define and allow the individual parts to interact with each other *only* in certain orderly ways while proscribing others, in turn, producing an order (Hayek, 2014 [1964], p. 285).

The third property of complexity is that the orderly system generates new emergent properties that are ontologically and causally *irreducible* to the basic elements, if the latter is considered separately from being organised and arranged (Lawson, 2019). Emergent properties are ontologically and qualitatively distinct from the aggregation of all the intrinsic properties that the parts possessed before engaging in the system of relations (Wagner, 2012). A social entity and its properties 'are said to be *emergent* from some lower (or different) level where they arise through the relational organising of lower-level elements, and the emergent properties in question are not possessed by any of the (lower-level) elements that get to be organised' (Lawson, 2019, p. 34). Emergence is 'ultimately a compositional term, and one that involves components being organised rather than aggregated' (*ibid.*, p. 197).

Fourth, emergent properties of complex systems form a constant, endogenous, and unpredictable source of novelty and radical uncertainty (Lewis and Wagner, 2017).

Complex systems exhibit 'perpetual novelty in the system as mutations lead it to evolve new ecological niches' (Rosser, 2004, p. 47). Once we conceptualise the macroeconomy along these lines, it becomes clear that system or macro variables do not act directly on one another, since those variables are the product of emergence via the interactions among micro-level entities within the system (Wagner, 2020). Therefore, 'the injection of novelty is continuous as against being discrete' (Devereaux and Wagner, 2020, p. 33). The fourth property of complexity is a fundamental lack of steadiness within these systems—meaning the absence of any general equilibrium state or endogenous tendencies toward one (Axtell, 2014).

The presence of emergence and the endogenous recurrence of novel properties indicate that complex systems cannot be meaningfully conceptualised as static equilibrium outcomes (Lawson, 1997; Lewis, 2015). Equilibrium precludes the idea that higher-level patterns and ontological transformations of the parts to the whole are generated by constant change and dynamic interaction among the parts (Wagner, 2012). Based on these four properties, we can distinguish that the macroeconomy and complex macroeconomic wholes that arise from market settings—based on similar kinds of (monetary) relations established by purposeful agents—are much more than the mere aggregation of their parts (Keynes, 1936; Wagner, 2020). It becomes clear that the macroeconomy resembles a complex system or an emergent social totality.

The recent literature (e.g. Kirman, 2010; Holt *et al.*, 2011; Howitt, 2012; Wagner, 2012; Dosi and Roventini, 2019) recognises that the macroeconomy possesses the features of complex systems: causally connected parts, (monetary) interactions defined in general terms by systems of monetary rules and banking frameworks, emergent properties separate from the parts' initial properties, and out-of-equilibrium dynamics (Axtell, 2014; Wagner, 2020). The macroeconomy thus resembles an ecology of monetary interactions *organised* by a monetary and banking structure (Wagner, 2012). The aforementioned properties pose severe problems for both linear causation models and standard macroeconomic theory that treat the macro economy or social systems as a collection of aggregated variables seeking to establish mere linear relationships among them (i.e. act as if the aggregated variables directly relate to one another in a causal manner) (Pryor, 2008; Devereaux and Wagner, 2020).

3.1 Macroeconomic complexity: acknowledged but not yet applied

By extrapolating and by considering the four properties of complexity in economic analysis, it seems clear that the macroeconomy resembles a complex system much more than a linear and mechanical one, and thus displays the four reviewed features (Holt *et al.*, 2011; Dosi and Roventini, 2019; Hommes, 2021). Indeed, as Ostrom states, 'we need to recognise that not only are humans complex systems; so are the [economic] structures they build' (Ostrom, 2005, p. 125). Following Keynes (1936) and Hayek (1973), if the macroeconomy resembles a complex system, then it must be treated analytically and conceptually as such; otherwise, the analysis will miss important causal elements (Colander, 2000; Wagner, 2020). Based on that recognition of complexity, both Keynes and Hayek advocated a heterodox and pluralist position in economics and a broad complexity vision of what constitutes the aggregate economy (Lewis, 2015).

This vision concerning the complexity of economic reality indicates that the macroeconomy can no longer be represented as if it were displaying the same types of nature,

phenomena and properties that occur at the level of its parts (Wagner, 2012). The notions of layered ontology, emergence and irreducibility in economics suggest that it is incoherent—and thus a critical conceptual mistake—to treat the relationship between micro and macro as one of either linearity or ontological and complex homogeneity, meaning a mere matter of 'scalability' among similar phenomena (Hodgson, 2000; Lawson, 2019).

The presence of the explored features defining complexity in the macroeconomy make it analytically difficult and methodologically challenging for scientists to coherently apply statistical and formalistic methods to shed light on such systems, without at least also falling into questionable assumptions about the lack of emergence and the radical reducibility of macro phenomena to their isolated parts (Wagner, 2012; Axtell, 2014). Yet, when social scientists use such assumptions, they are precluding those very same crucial properties that need to be considered to make the phenomena coherent, distinguishable and separate from the parts. This suggests a kind of analytical paradox or dilemma in social sciences aiming to study complex phenomena (Lewis, 2021). A critical dilemma arises, between relying on mathematical refinement, formalistic simplicity and statistical tractability—with their unavoidable and reductionist assumptions—versus relying on non-formalist scientific ways to analytically and seriously account for complexity.

This echoes what Caballero (2010) has identified as a fundamental tension in macroeconomics: 'the tension between a type of answer to which we aspire but that has limited connection with reality (the core) and more sensible but incomplete answers (the periphery)' (Caballero, 2010, p. 86). The core being modern macro models, given its limited connection with reality (Romer, 2016). This conceptual trade-off seems to plague most scientific attempts to formalise and study complex systems (Hayek, 1952; Axtell, 2014).

Accordingly, inappropriate assumptions could manage to slip into the social sciences' formal applications, undermining the social analysis with an inappropriate set of assumptions (Ostrom, 1982; Hayek, 2014 [1964]). It is wrong to equate science with formal methods. The method of science is to use tools appropriate to the object of analysis *given* its nature (Ostrom, 1990). Thus, attempting to use mathematical and statistical methods, when not suitable is not science; it is simply a form of what Hayek (1952) denominated 'scientism' (see also Ostrom, 2010; Lawson, 2019). Complex phenomena—such as the macroeconomy—are today being fitted to economists' preferred methods, rather than choosing the appropriate method based on the nature of the phenomenon we are seeking to explain.

4. Macroeconomic models: incongruent with complexity

The reviewed properties of complex systems help to shed light on the key shortcomings and analytical limits of using general equilibrium models, statistical analysis, and dynamic stochastic general equilibrium (DSGE) models to understand the macroeconomy as an emergent complex reality. By surveying the aforementioned properties of complex phenomena, this section pinpoints where the conceptual and analytical shortcomings and intellectual blind spots reside in current macroeconomic models.[11]

[11] For mathematical details of DSGE models, consult De Grauwe (2010), Korinek (2015), and Christiano *et al.* (2018).

Recently, some economists have pointed to some problematical features of the DSGE approach, for instance, Kirman (1992) undertakes a critical analysis of representative agent modelling, Janssen (1993) and Stiglitz (2018) provide critical assessments of the shortcomings to erect macroeconomics on sound microfoundations, and Romer (2016) even describes contemporary macro as 'macroeconomic pseudoscience'. Some other renowned economists are now recognising that mainstream models fall short of depicting some essential components of macroeconomic reality and are, therefore, problematic at best (Caballero, 2010; Kirman, 2010; Trichet, 2010; Howitt, 2012; Calvo, 2013; Korinek, 2015).

Building from these concerns and critiques to the current state of macroeconomic theory (see also footnote 5), the focus here is on the underlying criteria and core assumptions contained within macro DSGE models, which central banks extensively use and position as the most prominent tools 'for projection and policy analysis' (Howitt, 2012, p. 14; see also De Grauwe, 2010 and Christiano *et al.*, 2018). Essentially, DSGE models and modern macroeconomics in general are unable to recognise that macroeconomic phenomena are *rules-conditioned* emergent totalities generated by monetary interactions within a particular societal and organising framework (a set of monetary and banking rules) that define the monetary networks, positions and interactions (Wagner, 2012).

Macroeconomic models face three critical methodological and analytical shortcomings in properly dealing with macro reality and the main causal features of complexity. Examining the analytical incongruences and shortcomings of macro models reveals that DSGE and formal models are incompatible with understanding economic reality and with treating the macroeconomy as a complex system. The literature (e.g. De Grauwe, 2010; Korinek, 2015; Stiglitz, 2018) has developed important critiques of DSGE models. Despite these technical critiques, macroeconomists have largely ignored a more basic point: are these methods and frameworks compatible with the nature and properties of the phenomena they seek to study? The following provide some answers to this essential question.

4.1 Steady state assumptions: incompatible with higher-level orders

First, neo-Walrasian conceptualisations of the economy and DSGE models overly rely on conceptualising systemic equilibrium and constant effortless adjustments toward general equilibrium (assumed tendencies to always *revert back* toward its steady state), which were originally derived from general equilibrium theory (Axtell, 2014; Stiglitz, 2018). These static or 'steady state' conceptualisations are ultimately incompatible with the properties of complexity regarding emergent phenomena and endogenous change (the third and fourth properties explored in the previous section) (Korinek, 2015). After all, the DSGE model 'is an applied general equilibrium model that is considered as more scientific than earlier models since it is based on microeconomic foundations' (Kirman, 2010, p. 500).[12]

Thus, despite DSGE models possibly being grounded on 'more scientific' and highly formal microfoundations, they nonetheless firmly rely on Walrasian general

[12] The representative agent is a mythical character whose choices supposedly reflect all the choices that society makes (Kirman, 1992, 2010). The agent's choices are taken to be illustrative—a direct representation—of the aggregation of the choices made throughout the entire economy. Under such an idealised 'single representative household' model, there is no trade or interactions and therefore no need for mechanisms of social relations, such as language or money (Howitt, 2012).

equilibrium and systemic-static notions (Kirman, 2010; Stiglitz, 2018). The problem is that such notions conflict with the ideas of dynamic agents' interactions and of an emergent order being sustained through constant processes of change and dynamic relations among the parts (Axtell, 2014). Hence, it is still 'a strange micro foundation—a micro foundation based on assumptions of no heterogeneous agent interaction, when, for many people, it is precisely the heterogeneous agent interaction that leads to central characteristics of the macro economy' (Holt *et al.*, 2011, p. 365; see also Janssen, 1993).

Moreover, the modern modelling approach encompasses strong conceptual biases toward assuming infinite time horizons with a 'well-behaved ergodic steady state' (Korinek, 2015, p. 3). The models are not contingent on notions of order, internally generated structures, or organisations *derived from* changes among parts. In other words, the models are unable to convey the idea that an overall 'order can be preserved throughout a process of [endogenous] change' (Hayek, 2014 [1968], p. 308). Also, these 'steady state' assumptions are problematic because there are many real-world processes that cannot be assumed to always revert back toward steady states (Korinek, 2015; Stiglitz, 2018). Macroeconomists found a way around such problems by assuming the presence of a single representative agent for the whole economy, which can attain a single and stable equilibrium (Smithin, 2004; Kirman, 2010). But such an equilibrium also ignores the fundamental issue of how macro states are generated, as well as how dynamic processes at lower levels of reality constantly sustain them (Lawson, 1997; Lewis, 2015). In other words, the problem with the DSGE vision is that 'resources cannot allocate themselves, for only people can do that. But people do not act within the DSGE model, they merely respond to the allocative imperatives of the equilibrium model' (Devereaux and Wagner, 2020, p. 31).

Thus, assuming a single-equilibrium end state contrasts with both ontological and complexity transformations that rest upon processes of interaction, as well as with the notion of endogenously generated order that define complexity (Hayek, 1973; Lewis, 2015). Consequently, the assumptions of equilibrium, static orders and end states are profoundly incompatible with the notion of a higher-level order sustained by the parts' constant dynamic changes and interactions—which is complexity's fourth property, as reviewed in Section 3.

The second and third shortcomings of macro models jointly stem from their unrealistic and highly reductionist approaches: their atomistic (radically isolated) individual basis is used to construct models of simple aggregative behaviour (Trichet, 2010; Wagner, 2012). They adopt the unwarranted assumption that the aggregates correspond linearly to the hypothetical choices made by a single and isolated representative individual, and that the aggregates would behave similarly (Janssen, 1993; Korinek, 2015).[13] Estimating macro parameters based on microfoundations 'may be a reasonable estimate for an individual agent facing a specific micro decision, but what does it have to do with the aggregate?… why do we call this strategy microfoundations rather than reduced-form?' (Caballero, 2010, p. 89).

[13] The 'microfoundations quest' is 'the pure theory of individual choice, essentially divorced from the institutional or social context in which the choice is supposed to take place. The insistence on microfoundations… is therefore the insistence that an explanation of macroeconomic phenomena should be based on the logic of the outcomes of the… atomistic agents, without reference to any higher-level social structure' (Smithin, 2004, p. 3).

4.2 Microfoundations: conflicting with emergence and layered ontology

Concerning the second shortcoming, DSGE 'models are based on the same fundamental building blocks. The most important of these is the idea that individuals act in isolation… All that we have to do, to deduce the behaviour of the economy at the aggregate, or macro level, is to add up the behavior of the individuals who make it up' (Kirman, 2010, p. 501). Moreover, 'the theoretically unjustified assumption is made that the behavior' of the aggregate can be assimilated to that of an individual' (*ibid.*, p. 501). Hence macroeconomics maintains the impression of scientific rigor by following the reductionist microfoundations program and, in turn, restricting the analysis to closed-system types of optimisation problems, which only the representative agent solves (Janssen 1993; Korinek, 2015).

Such analysis ignores agents' heterogeneity, social positioning, systems of relations, and the organising social structures that bind them (Trichet, 2010; Howitt, 2012; Lawson, 2019; see also footnote 8). As Devereaux and Wagner (2020, p. 32) acknowledge, 'information about the individuals who constitute a macro economy is irrelevant to the DSGE framework, for such information can only clutter the model without offsetting advantage because plans are stipulated as being pre-coordinated without any action having taken place'.

The assumption of representing the whole macroeconomic order by a single, highly rational representative agent shows how far macro models have drifted from reality (Romer, 2016). As reviewed in previous sections, social wholes or totalities are formed by causally connected parts, interactions and systems of relations so, 'the idea that the entire household sector of say the US economy is just a blown-up version of a single person is on the face of it about as bold and unlikely a hypothesis as one could imagine' (Howitt, 2012, p. 14). Furthermore, by disregarding interactions, the microfoundations dictum fall into an unjustified reductionism that hinders the possibility to consider the existence of emergence or novelty, therefore also blocks considering nested complex systems and layered ontology (Lawson, 1997; Kirman, 2010; Wagner, 2020).

Further, the representative agent and DSGE modelling questionably assume that aggregated outcomes and macro variables are linear, scaled-up and magnified versions of the original variables that constitute the isolated agent's optimisation problem (Kirman, 1992; Wagner, 2012; Korinek, 2015). Accordingly, such formal models illegitimately assume that the macro variables and representative agent's constrained-optimisation variables are ontologically and qualitatively equal and thus homogenous and analogous in complexity (Janssen, 1993). In turn, they negate the role of interactions, money, systems of relations, and emergence that can profoundly affect the economic and ontological reality and the *nonlinear* relation between micro and macro phenomena (Howitt, 2012; Lewis, 2015).

Put differently, the microfoundations framework of modern macro follows an unsuitable form of 'causal reduction'; it presupposes that 'the causal powers of an emergent totality or system are held to be reducible to the causal powers of its components' (Lawson, 2019, p. 199). This situation problematically implies that the micro and macro domains possess similar and reducible properties and that they face the same ontology and degree of complexity (Janssen, 1993). This misleads social scientists about what they can know, manage and predict about aggregated, complex and self-organising systems (Caballero, 2010; Ostrom, 2010; Calvo, 2013; Hayek, 2014 [1964]).

Additionally, once we recognise that in all economic systems the *organisational structure* is an essential and causal component of the emergent totality, and that this structure is also 'extrinsic, and so additional, to the powers of any individual components', then it becomes easier to acknowledge that the microfoundations of macroeconomics and the representative agent theorising are inappropriate and unjustifiable forms of casual reduction, making them a method that 'is quite untenable' (Lawson, 2019, p. 199; see also Janssen 1993). Thus, 'once we take note of organising structure, an ontological reduction is usually proscribed' (Lawson, 2019, p. 201). Yet, as Paul Romer (2016, p. 1) has recognised, this is exactly the sort of untenable 'pseudoscience' that macro theory has been pursuing.

In sum, these strong assumptions negate the existence of complexity's first and third reviewed features: they are incompatible with the notions of a coherent structure of causally connected parts and the novel properties of emergence.

4.3 Do rules and organising structures play a relevant role?

The third analytical shortcoming of DSGE models is that they severely disregard the social structures and rules that frame and enable particular sets of orderly interactions, while proscribing others (Hodgson, 2000). Essentially, resorting to the isolated representative agent for formal modelling—implicitly suggesting that the interactions among agents *are irrelevant* in producing macro phenomena—correspondingly also assumes away the role of the social structure and the organising framework that define and guide the organisation, positioning and *kind* of interactions in place (Smithin, 2004; Kirman, 2010; Lawson, 2019).

This one-dimensional way of treating the relation between micro and macroeconomic phenomena has profound implications for how macroeconomists analytically disregard the role of monetary and organising structures, as well as banking rules, in determining macroeconomic phenomena. Contemporary models presume a coherent, simple and direct link at the same level of complexity and ontology, connecting the micro and macro socioeconomic realms (Lewis and Wagner, 2017). Such assumptions in macro models wrongly force the two entirely distinct socioeconomic realms to be ontologically and qualitatively indistinguishable (Wagner, 2012).

Assuming such homogenous properties is inappropriate since, as argued in previous sections, micro and macro phenomena are entirely different ontologically because of the existence of *rule-guided* interactions, organisational structures and emergence (Lewis, 2015; Lawson, 2019). By assuming away social relations, and by treating reality in a one-dimensional fashion, they also preclude any theoretical necessity to concentrate on, and explore the properties of, the organising structures and banking rules, as the 'complexity link' between the two ontologically and qualitatively *distinct* micro and macro realms (Hodgson, 2000). An unfortunate but predictable result is that 'few institutions play important roles in models today' (Axtell, 2014, p. 38). This is problematic in macro theorising because 'in most cases factors entirely extrinsic to lower-level components and their interactions are necessarily involved, preventing causal reductions' (Lawson, 2019, p. 202).

Consequently, recognising (i) the above arguments concerning macro models' inherent limitations and their severe analytical and philosophical incongruity with complexity, and (ii) the unavoidable presence of the four features of complex phenomena in macroeconomic reality, leads to acknowledging that most macro models, particularly

DSGE ones, are ill-suited analytical and descriptive tools for macro analysis. As such, they represent questionable intellectual pursuits for understanding the relevant aspects that generate a macroeconomic complex reality as *distinct* from its parts (Romer, 2016). The severe incongruity between formal frameworks of macro analysis and complex economic reality suggests that current macro modelling is unsuitable for macroeconomic research, when the scientific goal is to shed light on the features that make the macroeconomy irreducible to, and distinct from, both microeconomic phenomena and the parts composing it.

To conclude, the critical problem can be summarised as, 'in order to make the DSGE model tractable, they had to assume away almost all elements of complexity' (Colander and Kupers, 2014, pp. 105–106). In turn, macroeconomists have also negated the existence of the four properties that generates the subject matter (Lewis, 2015). The core issue is that mathematical and linear statistical modelling disregard the fundamental nature and the causal properties of macroeconomic reality, thus becoming ill-suited methods given the 'open-ended' nature of the social reality at hand (Axtell, 2014; Lawson, 2019).

A difficulty going forward lies in which aspects of the real economy are disregarded or concealed by employing certain types of mathematics, formal models and assumptions that ultimately negate the nature of the phenomena under study (Ostrom, 2010). Hubris and analytical problems arise whenever we use abstraction not to simplify things along *inessential* dimensions, but as a way to negate reality itself, disregarding its causal elements (Caballero, 2010). The deep incompatibilities between modern macro models and complexity have shown why these methods will remain irreconcilable with the features of complex phenomena and therefore intrinsically unable to illuminate macroeconomic reality.

5. Towards the organising structures of economic complexity

Much beyond a mere ontological point about economics or an abstract exercise in philosophical reasoning, the discussion so far contains serious repercussions that should challenge the ways of thinking and practicing economics as a science. Understanding the enormous differences between how things really are in the macroeconomic reality (see Sections 2 and 3) and how things are assumed to be in current macroeconomic thinking (see Section 4) has profound implications on how macroeconomics as a discipline is practiced and how scientifically valuable it ultimately becomes (Romer, 2016).

Exploring these incompatibilities has suggested a change of vision and practice, and, perhaps even, adopting alternative heterodox frameworks to more realistically and accurately engage in macroeconomics, as a social science dealing with complexity (Paniagua, 2016a, 2016b). This article has highlighted the analytical and conceptual limits of how far formalistic approaches and current mathematics can be coherently extended and applied to the realms of complexity and macro (Rosser, 2004). Hence, the time has come to acknowledge that 'today there is no mathematics capable of describing such an economy' (Axtell, 2014, p. 42).

At the level of formal modelling, the properties of complexity represent problematic aspects for standard models, systems of equations and microfoundations (Kirman, 2010). As Romer (2016, p. 19) recognises, 'macroeconomists should admit that the

wreckage runs so deep that they should abandon the quest for the sacred simultaneous equation model'. Plausibly, incorporating alternative and heterodox methods in economics could be more suitable for engaging with macro phenomena and their properties.

To overcome, or at least bypass, the explored impasses, analytical inconsistencies, and radical reductionism, what seems to be needed in macroeconomics, as Smithin (2004) argues, a theory of social ontology in monetary economics (see also Lawson, 2016). Macroeconomics needs a broader theory from which we can affirm the importance of organising social structures and monetary relations that form the 'monetary-ecosystem,' which determines economic complexity (Wagner, 2012).

To grasp complexity in macro, it might be helpful to engage in forms of ontological and social analysis exploring and making explicit the relevant organising structures—such as monetary rules, social and debt positioning, banking rights and obligations (Lawson, 2016; Paniagua, 2018)—and their effects on monetary relations, the production of money and emergent totalities (Wagner, 2020). This requires: first, focussing on the nature of money, systems of banking rules, positioned debt and central banks, or on the 'features of the current monetary system' (Lawson, 2019, p. 162); and second, examining the ways they affect incentives and monetary interactions of the agents (Wagner, 2020).

Importantly, this requires avoiding any analytical conflation of the macroeconomic emergent totality with the organising banking and monetary structure. As argued in this article, the three levels of social reality suggest that we should reject the notions of economic foundations: both the 'microfoundations of macroeconomics' and the 'macrofoundations of microeconomics' (Janssen, 1993; Lawson, 2019). The main reason is that we need to add analytical emphasis to the organising banking and monetary structure that causally interact with the individuals to produce the totality (Paniagua, 2018; Wagner, 2020). Therefore, as Smithin stated, the objective:

> would be to uncover those aspects of social structure… which are relatively enduring… and can therefore provide some type of theoretical explanation for the actual course of events… It establishes the crucial point the treatment of… institutions… The social institution or [organising] structure which is most in need of investigation is that of money… [which is] the entire social apparatus of banks, central banks, and other financial institutions, which are involved in the production of money. (Smithin, 2004, pp. 11–12)

Given the difficulties of dealing with complex phenomena, Smithin (2004) proposes moving the nature of the scientific inquiry toward both an organisational or structural focus on banking rules and the details and aspects of monetary rights and obligations and banking entities, which produce money and thus create a monetary constraint for agents and their exchanges (Paniagua, 2018). A sort of intellectual move in macroeconomics toward a 'realist orientation' in monetary and banking analysis would help to uncover the monetary-organising structures which help produce the macro totality (Paniagua, 2016a; Wagner, 2020).

Recently there have been various attempts to explore this intellectual move in macro theory and a 'realist orientation' in monetary and banking analysis (Smithin, 2004; Wagner, 2012; Lewis and Wagner, 2017). For instance, Boettke *et al.* (2021) and Paniagua (2016a, 2016b, 2017) use analytical narratives and political economy to undertake different comparative analyses of banking frameworks and rules. Salter and Tarko (2019) employ Elinor Ostrom's polycentric framework to assess the robustness of different banking structures. Lawson (2016) and Paniagua (2018) take a 'realist

orientation' on money and its role in society. Finally, Wagner (2020); Devereaux and Wagner (2020), and Dosi and Roventini (2019) set forth an open-ended evolutionary framework for macroeconomics by borrowing from systems theory and agent-based modelling. These works provide valuable ways forward for a more realist orientation in macroeconomics.

These arguments are *not* synonymous with advocating for 'downward causation' or 'top-down causation' in macroeconomics, if we conceive 'downward causation' as 'the concept that a system as a whole has a causal influence on its constitutive parts'; and thus, that 'higher level entities causally affect their lower-level constituents' (Lawson, 2019, p. 214). A macro entity cannot have a causal impact on its parts since the whole cannot be separated from its constituent elements—a 'whole cannot act; for the former is composed out of the latter'. However, the monetary and banking 'organising relations of the whole can and do make a difference to how the components interact' (*ibid.*, p. 216).

Analysing and assessing banking structures and organising relations could be a fruitful focus in macroeconomics going forward. Different banking structures 'can causally impact upon the component individuals, albeit only by way of providing the conditions or means of forms of individual activity' (*ibid.*, p. 218). The notion of an organising structure could also be fruitfully associated with Ostrom's (2005) conception of different social rules that structure interactions in each 'action situation' (Lewis, 2021). Different sets of rules define and organise the roles, positions, rights and obligations within the action situation, consequently, rules shape the structure of an 'action situation' (Ostrom, 2005, pp. 18–21).

In other words, this would mean scrutinising and comparing the enduring aspects and core features of actual banking rules, practices and monetary rights and obligations because they provide the framework that affects and constrains the interactions between agents, as well as the emergence stemming from those interactions (Smithin, 2004; Wagner, 2020). Crucially, this shift will also include critical assessments of the role of money in society, how it is constituted and produced, and its nature (Lawson, 2016; Paniagua, 2018, 2020).

To conclude, a plausible way to indirectly, yet scientifically, deal with economic complexity is to scrutinise and assess different banking rules and organisational properties, which define the rights and obligations of central banks, commercial banks and individuals, as well as the incentive structures and the epistemic generating mechanisms within different monetary arrangements (Lewis and Wagner, 2017). Subsequently, it is possible to study how those organising properties define the production of money, the social positions and the ways the parts interact to produce a totality (Lawson, 2016; Wagner, 2020). Monetary comparisons and historical banking scrutiny, through political economy, analytical narratives and other alternative methods, could help reveal which sets of banking rules and monetary structures are relatively robust and conducive to generating stable and wealth-enhancing orders (e.g. see Paniagua, 2017, 2020, 2021; Salter and Tarko, 2019; Boettke *et al.*, 2021).

6. Concluding remarks

This essay has argued that looking at the macroeconomy from a complexity perspective provides insights not only into emergence and the 'complexity vision' of macro

but also into what it should fundamentally be about: macro analysis should never become too detached from political economy, systems theory and the three basic levels of social reality. Incorporating the notion of complexity and recognising its core properties 'will be good news to Institutionalists, Post Keynesians, Austrians, and perhaps even Marxists, since they are the schools that have continued to explore complex phenomena such as market processes and comparative institutions despite the disapproval, and often intense opposition, of their colleagues within the mainstream' (Prasch, 2000, p. 223).

The analysis also suggests that reductionist and formal approaches in macro and DSGE models are flawed both conceptually and methodologically to handle the macroeconomy's fundamental features. Based on this article's explorations of complexity and their conceptual implications for macroeconomics, a challenging and unsettling conclusion arises: the realisation that the notion of macroeconomics might not necessarily mean what most economists think it means (Paniagua, 2020, 2021).

If the macroeconomy behaves much like a complex system, then macroeconomics would instead be defined as the organisational and rules-oriented study of money, its processes of production and social positioning (the apparatus of banks and central banks), and its rules-conditioned emergent phenomena. Such a redefinition could encourage macroeconomists to change frameworks and approaches toward heterodox approaches in macro analysis (Wagner, 2020). In order to scientifically study complex phenomena, it is necessary to apply methods of analysis that the nature and properties of the material under study *dictate* using, not vice versa (Hayek, 1952, p. 77).

The study of economics needs to be 'guided in the choice of its methods in the main by the nature of the problem it [has] to face' (Hayek, 1952, p. 77), rather than the other way around, which is scientifically unsound (Ostrom, 1982; Romer, 2016). Accordingly, it would be judicious to supersede current formal methods and frameworks that analytically and conceptually undermine the complex reality social scientists seek to study.

Finally, the radical and uncomfortable conclusion of this article is that in order to tackle economic complexity in a constructive and meaningful way, we might have to set aside most current models, techniques of thought and formalist ways of thinking about macroeconomics and money to instead embrace insights from both heterodox economics and systems theory (Lawson, 2016; Wagner, 2020). A heterodox and political-economic analysis of money and banking—one that sidesteps the current models' reductionist shortcomings and questionable assumptions—could convey the casual properties and essence of complex phenomena, which are, after all, our real subject matter (Paniagua, 2016a, 2016b, 2021).

Conflict of interest statement

None apply.

Funding information

None apply.

Bibliography

Axtell, R. 2014. Hayek Enriched by Complexity Enriched by Hayek, paper presented at Mercatus Center, George Mason University, October 2–5

Bertalanffy, L. 1968. *General System Theory*, New York, George Braziller

Boettke, P., Salter, A. and Smith, D. 2021. *Money and the Rule of Law: Generality and Predictability in Monetary Institutions*, Cambridge, Cambridge University Press

Caballero, R. 2010. Macroeconomics after the crisis: time to deal with the pretense-of-knowledge syndrome, *Journal of Economic Perspectives*, vol. 24, no. 4, 85–102

Calvo, G. 2013. Puzzling over the anatomy of crises: liquidity and the veil of finance, IMES discussion paper series, 13-E-09.

Christiano, L., Eichenbaum, M. and Trabandt, M. 2018. On DSGE models, *Journal of Economic Perspectives*, vol. 32, no. 3, 113–40

Colander, D. (ed.) 2000. *Complexity and the History of Economic Thought*, London, Routledge

Colander, D. and Kupers, R. 2014. *Complexity and the Art of Public Policy*, Princeton, Princeton University Press

De Grauwe, P. 2010. The scientific foundation of dynamic stochastic general equilibrium (DSGE) models, *Public Choice*, vol. 144, no. 3–4, 413–43

Devereaux, A. and Wagner, R. 2020. Contrasting visions for macroeconomic theory: DSGE and OEE, *The American Economist*, vol. 65, no. 1, 28–50

Dosi, G. and Roventini, A. 2019. More is different... and complex! The case for agent-based macroeconomics, *Journal of Evolutionary Economics*, vol. 29, 1–37

Hayek, F. A. 1952. *The Counter-Revolution of Science: Studies in the Abuse of Reason*, Indianapolis, Liberty Fund

Hayek, F. A. 1973. *Rules and Order. Vol. 1, Law, Legislation and Liberty: A New Statement of the Liberal Principles of Justice and Political Economy*, London, Routledge

Hayek, F. A. 2014 [1968]. Competition as a discovery procedure, in Caldwell B. (ed.), *The Market and Other Orders*, Chicago, University of Chicago Press

Hayek, F. A. 2014 [1964]. The theory of complex phenomena, in Caldwell B. (ed.), *The Market and Other Orders*, Chicago, University of Chicago Press

Hodgson, G. 2000. The concept of emergence in social science: its history and importance, *Emergence: Complexity and Organization*, vol. 2, no. 4, 65–77

Hodgson, G. 2019. *Is There a Future for Heterodox Economics?*, London, Routledge

Holt, R., Rosser, J. and Colander, D. 2011. The complexity era in economics, *Review of Political Economy*, vol. 23, no. 3, 357–269

Hommes, C. 2021. Behavioral and experimental macroeconomics and policy analysis: a complex systems approach, *Journal of Economic Literature*, vol. 59, no. 1, 149–219

Howitt, P. 2012. What have central bankers learned from modern macroeconomic theory?, *Journal of Macroeconomics*, vol. 34, 11–22

Janssen, M. C. 1993. *Microfoundations: A Critical Inquiry*, London, Routledge

Keynes, J. M. 1936. *The General Theory of Employment, Interest and Money*, London, Palgrave

Kirman, A. 1992. Whom or what does the representative individual represent?, *Journal of Economic Perspectives*, vol. 6, no. 2, 117–36

Kirman, A. 2010. The economic crisis is a crisis for economic theory, *CESifo Economic Studies*, vol. 56, no. 4, 498–535

Korinek, A. 2015. Thoughts on DSGE Macroeconomics: Matching the Moment, but Missing the Point?, Paper prepared for the 2015 Conference 'A Just Society' honouring Joseph Stiglitz's 50 years of teaching

Lawson, T. 1997. *Economics and Reality*, London, Routledge

Lawson, T. 2016. Social positioning and the nature of money, *Cambridge Journal of Economics*, vol. 40, no. 4, 961–96

Lawson, T. 2019. *The Nature of Social Reality: Issues in Social Ontology*, London, Routledge

Lawson, T. 2022. Social positioning theory, *Cambridge Journal of Economics*, vol. 46, no. 1, 1–39

Lewis, P. 2015. Notions of order and process in Hayek: the significance of emergence, *Cambridge Journal of Economics*, vol. 39, 1167–90

Lewis, P. 2021. Elinor Ostrom's 'Realist Orientation': an investigation of the ontological commitments of her analysis of the possibility of self-governance, *Journal of Economic Behavior and Organization*, vol. 189, 623–36

Lewis, P. and Wagner, R. 2017. New Austrian macro theory: a call for inquiry, *Review of Austrian Economics*, vol. 30, no. 1, 1–18
Ostrom, E. 1982. Beyond positivism: an introduction to this volume, pp. 11–28 in Ostrom, E. (ed.), *Strategies of Political Inquiry*, Beverly Hills, CA, Sage Publications
Ostrom, E. 1990. *Governing the Commons*, Cambridge, Cambridge University Press
Ostrom, E. 2005. *Understanding Institutional Diversity*, Princeton, NJ, Princeton
Ostrom, E. 2010. Beyond markets and states: polycentric governance of complex economic systems, *American Economic Review*, vol. 39, no. 1, 7–27
Paniagua, P. 2017. The institutional rationale of central banking reconsidered, *Constitutional Political Economy*, vol. 28, 231–56
Paniagua, P. 2018. Money and the emergence of knowledge in society, *Review of Social Economy*, vol. 76, no. 1, 95–118
Paniagua, P. 2016b. The robust political economy of central banking and free banking, *The Review of Austrian Economics*, vol. 29, no. 1, 15–32
Paniagua, P. 2016a. The stability properties of monetary constitutions, *Journal des Économistes et des Études Humaines*, vol. 22, no. 2, 113–38
Paniagua, P. 2020. Governing the (banking) commons: polycentric solutions to bank runs, pp. 115–144 in Boettke, P., Herzberg, R. and Kogelmann, B. (eds.), *Exploring the Political Economy and Social Philosophy of Vincent and Elinor Ostrom*, London, Rowman and Littlefield
Paniagua, P. 2021. The institutional evolution of central banks, *Journal of Evolutionary Economics*, vol. 32, no. 1, 1049–70. doi:10.1007/s00191-021-00759-y
Prasch, R. 2000. Complexity and economic method: an institutionalist perspective, in Colander, D. (ed.), *Complexity and the History of Economic Thought*, London, Routledge
Pryor, F. L. 2008. System as a causal force, *Journal of Economic Behavior and Organization*, vol. 67, 545–59
Romer, P. 2016. *The Trouble with Macroeconomics, Commons Memorial Lecture of the Omicron Delta Epsilon Society*, The American Economist, forthcoming
Rosser, J. B. 2004. On the epistemological implications of economic complexity, *Annals of the Japan Association for Philosophy of Science*, vol. 12, 45–57
Salter, A. and Tarko, V. 2019. Governing the banking system: an assessment of resilience based on Elinor Ostrom's design principles, *Journal of Institutional Economics*, vol. 15, no. 3, 505–19
Simon, H. 1962. The architecture of complexity, *Proceedings of the American Philosophical Society*, vol. 106, 467–82
Slade-Caffarel, Y. 2020. Organisation, emergence and Cambridge social ontology, *Journal for the Theory of Social Behaviour*, vol. 50, no. 3, 391–408
Smithin, J. 2004. Macroeconomic theory, (critical) realism, and capitalism, in Lewis, P. (ed.), *Transforming Economics: Perspectives on the Critical Realist Project*, London, Routledge
Stiglitz, J. 2018. Where modern macroeconomics went wrong, *Oxford Review of Economic Policy*, vol. 34, no. 1–2, 70–106
Trichet, J. C. 2010. Reflections on the nature of monetary policy, nonstandard measures, and finance theory, *Opening address at the ECB*. Central Banking Conference Frankfurt
Wagner, R. 2012. A macro economy as an ecology of plans, *Journal of Economic Behavior and Organization*, vol. 82, no. 2–3, 433–44
Wagner, R. 2020. *Macroeconomics as Systems Theory: Transcending the Micro-Macro Dichotomy*, London, Palgrave Macmillan
Weaver, W. 1948. Science and complexity, *American Scientist*, vol. 36, 536–44