# Complexity theory, systems thinking and international relations

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# Beyond models and metaphors: complexity theory, systems thinking and international relations

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**Abstract** *The concepts, language and methods of complexity theory have been slowly making their way into international relations (IR), as scholars explore their potential for extending our understanding of the dynamics of international politics. In this article we examine the progress made so far and map the existing debates within IR that are liable to being significantly reconfigured by the conceptual resources of complexity. We consider the various ontological, epistemological and methodological questions raised by complexity theory and its attendant worldview. The article concludes that, beyond metaphor and computational models, the greatest promise of complexity is a reinvigoration of systems thinking that eschews the flaws and limitations of previous instantiations of systems theory and offers an array of conceptual tools apposite to analysing international politics in the twenty-first century.*

## Introduction

> If things were simple, word would have gotten around.
>
> Jacques Derrida

It has long been a staple of social science to borrow paradigms, conceptual language and tools from the study of the natural world in the hope of emulating some of the successes achieved in that area. The last two decades has seen social scientists gradually beginning to apply insights derived from a new scientific field that has its origins in the study of the mathematical properties of non-linear dynamical systems in the 1960s. With theoretical foundations in cybernetics,

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catastrophe theory and chaos theory, the set of concepts and methods that have come to be identified under the label of 'complexity theory' has in this period garnered increasing attention within international relations (IR).

Initial attempts to apply concepts from complexity to the field emerged in the 1990s, when James Rosenau's *Turbulence in world politics* represented a path-breaking effort (Rosenau 1990; 2003; Axelrod 1997; Jervis 1997). Yet despite repeated attempts to build upon these early contributions and place complexity theory at the centre of the discipline (Hoffman and Riley 2002; Harrison 2006; Ma 2007), including recent calls for a 'fifth debate' (Kavalski 2007), it continues to stubbornly remain on the margins. The only area to have arguably generated a coherent and cumulative research agenda is that of agent-based modelling (Axelrod 1997; Cederman 1997; 2003; Cioffi-Revilla 2002; Epstein 2007), but this, despite dominating complexity research in IR to date, to our mind does not in any way exhaust the potential of complexity thinking and presents its own limitations. There have, however, been a number of disparate studies applying specific aspects of complexity theory to problems and debates in IR, as well as a wide range of scholarly output in which conceptual language developed to a sophisticated degree within complexity is employed but a full appreciation of that underlying sophistication is absent or left unstated. Furthermore, a number of rich ontological debates have emerged within IR over the past decade that resonate with many of the characteristics of a complexity ontology, although so far these connections have been insufficiently drawn out. In this article we will provide an account of where and how complexity can extend important debates within IR, and draw out many of the connections between IR and complexity that have remained either implicit or overlooked. We will also survey some of the growing interest in complexity and IR and assess where the most interesting contributions are being made, before outlining our own view of the way in which we hope the application of these ideas can still develop.

The article proceeds in three stages. Section one presents a necessarily brief overview and exposition of some of the key concepts of complexity theory, which will purposefully eschew overly technical descriptions for the benefit of a non-specialist audience.[1] Particular attention will be paid to the concepts of non-linearity, open systems, self-organization and emergence. Section two draws out the value that complexity can add to some of the debates that have been at the core of IR in recent years. It considers four such areas in detail: relational or anti-essentialist ontologies within IR, theories of the international system, the agent–structure problem and the nature of global networks. Complexity will be shown to offer the potential for furthering these debates and extending them in new directions. In the final section, we will offer some reflection on the full philosophical import of extending complexity to the social world and make a case for a 'generalized complexity' that goes beyond its metaphorical and modelling applications. We conclude that complexity offers an opportune means to reinvigorate systems thinking which can overcome the limitations and flaws of previous systems theories and is today necessary, even if it comes at the cost of some old certainties.

[1] Readers with a non-technical background who are interested in the genesis of complexity theory are encouraged to turn to Prigogine and Stengers (1984), Lewin (1992), Gleick (1998), Waldrop (1993) and Capra (1996).

**The conceptual toolkit of complexity theory**

As Walby (2007, 456) has aptly pointed out, 'complexity theory is not a unified body of theory; it is an emerging approach or framework … it is a set of theoretical and conceptual tools; not a single theory to be adopted holistically'. As such, complexity is less a definitive theoretical corpus than a conceptual toolkit, even though there is a definite coherence and complementarity between all its elements, as we will strive to make clear.

All these concepts nonetheless emerged in a particular context within the natural sciences in response to specific problems or puzzles, progressively accumulating and diffusing until they collectively mounted a powerful challenge to the dominant scientific paradigm associated with Descartes, Newton and the Scientific Revolution. This paradigm was concerned with discreet elements acting upon each other within self-enclosed systems. Newton's world was associated with the metaphor of a giant machine, the mechanism of which could be taken apart and subjected to analysis. In this way, a complex whole could be broken up into its constituent pieces and understood in its entirety by analysing the function of each in turn. This reductionist method could be used to explain the workings of whole systems as no more than the sum of their parts. A formal scientific framework was built upon this basis, emphasizing measurable behaviours and forces operating under exact mathematical laws that, once known, offered a predictive capacity. Beginning with the destabilizing shock of relativity and quantum mechanics in the early decades of the twentieth century, this framework has been subject to sustained revision. The concepts associated with complexity may justifiably be seen as the latest of these challenges.

Complexity is particularly sensitive to systemic properties and relationships, rejecting the reductionist assertion that complex systems can be wholly understood through the analysis of their constituent parts. Since many systemic properties are emergent, arising from the relationships and interaction of the parts over time, the whole can be said to be 'greater than the sum of its parts' and thus the dissection of a system into its components, either physically or theoretically, destroys that system and precludes a full understanding of its dynamics and properties (Capra 1996, 29). Yet complexity neither denies an autonomous existence to the parts composing a system nor seeks to dissolve them into an overarching determining structure. As Morin (1977; 2005) points out, a systemic arrangement can bring out emergent properties latent in the parts just as it can inhibit other properties. Furthermore, entities that are systemic wholes at one scale will be the parts of a different whole at another scale, and vice versa. Parts and whole thus co-constitute one another with a relationship of 'reciprocal causality' between local and global levels (Thompson and Varela 2001, 421).

Complexity thus promotes a relational and processual style of thinking, stressing organizational patterns, networked relationships and historical context. Gell-Mann (1995/1996) points to the word's etymology: *plexus* means 'braided' or 'entwined', from which is derived *complexus*, meaning 'braided together'. Hence complexity suggests the 'intricate intertwining or interconnectivity of elements within a system, and between a system and its environment' (Mitleton-Kelly 2000). Although processual and relational perspectives have a very long history (Rescher 1996), complexity draws upon mathematical, theoretical and technological developments of the latter half of the twentieth century. Its genealogy

includes cybernetics and general systems theory, which first formulated the concepts of feedback and self-organization, and argued for the possibility of applying general principles of organization to all sorts of social and natural systems. It also draws upon chaos theory and catastrophe theory, two special branches of dynamical systems theory that emerged in the 1960s with the work of Edward Lorenz and Rene Thom. These theories investigate the mathematical properties of non-linear, unstable or non-equilibrium systems (Gleick 1998). Non-linear phenomena or systems are those which do not display proportionality between input and output, and in which small influences can result in large effects, most famously encapsulated in the metaphor of the 'butterfly effect', according to which a butterfly flapping its wings in Brazil results in a hurricane in Florida. The non-linear equations describing these systems are particularly resistant to analysis and consequently were largely ignored and poorly understood until the development of the electronic computer. It is through the iteration of calculations made possible by the latter's processing power that the complex behaviour of such systems was revealed and with it a subtle order and structure in phenomena previously believed to be completely devoid of recognizable patterns, such as the turbulence of fluids or the movements of plate tectonics. However, due to the practical and theoretical impossibility of gaining enough information about the initial conditions of a system to offset the issue of disproportionality between cause and effect, accurate prediction of the long-term behaviour of a complex system is highly constrained, leading to a move from the quantitative to the qualitative analysis of systems and the identification of patterns of behaviour over precise point prediction.



Of the concepts associated with complexity introduced so far, we would highlight four that hold possibilities for reorienting or refocusing debates within IR: non-linearity, open systems, self-organization and emergence. These concepts are all intricately connected. We have just highlighted the importance of non-linearity, and the origins of complexity theory in the mathematical study of non-linear dynamical systems. Of particular importance to non-linear phenomena are positive feedback loops, whereby a system amplifies any perturbation or new input through cycles of recursion or iteration. This leads to runaway processes that take a system away from its present state and can even cause its dissolution (this is in contrast to negative feedback loops, which counter perturbations and preserve the stability of the system). As Capra (1996, 82) makes clear, non-linear relationships are networked relationships:

> The first and most obvious property of any network is its non-linearity—it goes in all directions. Thus the relationships in a network pattern are non-linear relationships. In particular, an influence, or message, may travel along a cyclical path, which may become a feedback loop. The concept of feedback is intimately connected with the network pattern.

Indeed the notion of the network as the abstract organizational pattern linking the different elements of a system is key to complexity thinking and the mapping of the interactions of entities studied.

The notion of an open system moves decisively away from Newtonian understandings, which stressed the homeostatic closure of the system under study to new sources of information and energy. Closed systems are simple systems with few interacting parts, whereas complex systems are open systems.

Open systems have boundaries that are porous and shifting, and exchange information and energy with their environment. This allows for the entry of contingency and evolution, and thus the introduction of the 'arrow of time', into systemic theorizing (Bertalanffy 1968; Prigogine and Stengers 1984). A special case of complex systems is that of the 'complex adaptive system', which demonstrates the ability to learn from, adapt to and co-evolve with its environment over time, especially when this environment also consists of other such systems (Holland 1995). As a feature of the natural world but particularly relevant to the social realm, work on understanding the general principles underlying all complex adaptive systems is seen as a cross-disciplinary endeavour (Finkenthal 2008).

Self-organization is a key property of open systems. 'Self-organization' refers to the process by which the autonomous interaction of individual entities results in the bottom-up emergence of complex systems. In the absence of centralized authority, the spontaneous appearance of patterned order results from the interaction of the parts of the system as they react to the flow of resources through the system. Self-organization is thus closely related to the concepts of feedback, learning and self-regulation. Such patterned order, and the organizational relationships that give rise to it, can be mapped, and computer-based simulation of the interaction of elements in systems has become a key methodological innovation of complexity. It is such patterns of organization that are destroyed by the reductionist or analytical approach. This is because patterns of organization arising from the interaction of the components at a lower level of the system are emergent. Emergence is the phenomenon or process by which complex structures or patterns arise on the basis of simple interactions. As Stephen Wolfram puts it:

> Whenever you look at very complicated systems in physics or in biology, you generally find that the basic components and the basic laws are quite simple; the complexity arises because you have a great many of these simple components interacting simultaneously. The complexity is actually in the organisation—the myriad possible ways that the components can interact. (Waldrop 1993, 86)

At each different level of complexity within a system a new set of patterns or properties emerge that are specific to that domain of interaction and that generally cannot be deduced from the individual behaviour or character of its constituent parts but may subsequently come to act back upon these parts.

These four concepts outlined here will be essential in the following discussion of the value of complexity for thinking through key issues in international politics. However, it is useful to first consider the wider cultural context in which complexity concepts are to be situated.

## Complexity, social ontology and IR theory

The concepts of complexity are tied, in many ways, to their cultural context. In this sense, they cannot be viewed unproblematically as simply the result of objective attempts to understand the natural and social world. As we have seen, their development has been dependent upon the technology of high-power computers, and technological developments are always embedded in social and cultural contexts (MacKenzie and Wajcman 1999). As Manuel Castells (1996) has argued, the advent of the internet and proliferation of telecommunication devices have facilitated the formation of new networked forms of social organization and

heightened our awareness of the role such dynamics play in human societies. Similarly, Mark C Taylor's (2001) investigation of the 'moment of complexity', encompassing architectural, literary and artistic developments, is concerned to outline the emergence of a 'network culture'. The turn towards complexity in the social sciences has thus been partly driven by the growing realization that non-linear and networked social relationships characterize much of the contemporary world. In this sense, complexity offers the conceptual language and methodological tools for an age characterized by patterned global flows and the interpenetration of non-contiguous societies. At the same time, complexity also speaks to the earlier post-structuralist debates of the 1960s and 1970s, and may be seen to derive some of its philosophical impetus from the outcome of these debates, an important point we will return to in the final section.

The rise of complexity in the social sciences can thus be viewed as linked to concerns over globalization, particularly in the wake of the end of the Cold War's bipolar stability. Rosenau's work in applying complexity to international politics, which draws on the metaphors of turbulence and the international as a global dynamical system, first appeared in 1990. The sense that methodological nationalism and notions of states as bounded societies were no longer adequate drove many to consider the global system level, and those familiar with complexity found within it a set of resources appropriate to the task. John Urry has sketched an outline of the potential for complexity to reorient sociological approaches to globalization which draws on the power of metaphor while at the same time expressing concern that 'the enormously open character of global systems might mean that they are currently beyond systemic analysis' (2003, 38). His proposal is that the complexity paradigm can at the very least help analysts to begin asking the right questions about politics and society in a highly interconnected and non-linear world.

A further development that adds to the attraction of complexity is the recent turn towards reconsidering social ontology and the movement away from essentialist conceptions of physical and social objects towards relational and processual ontologies. Ontological issues have been squarely on the agenda of IR in recent years (Wight 2006), and in the next sections we will investigate the overlap between complexity and IR's own turn to relationalism, as one of four promising avenues for complexity concepts to open up core IR debates. We argue that one of the core features of complexity is its ability to refocus attention onto processes and social relations, offering a very different social ontology to those which see social entities, such as states for example, as having pre-theoretical characteristics or dispositional interests, a view shared by structural realism and liberal institutionalism alike.

We begin our discussion with a consideration of the commonalities between complexity and relational theory, and follow this strand through into the linked debates about the nature of the international system and the agent–structure problem in social and IR theory. Finally we outline how complexity informs the rise of the analysis of networked social forms, and how the study of networks has become an important aspect of theorizing about world politics.

### *Relational and anti-essentialist ontologies*

The concepts and ontology of complexity share a number of strong resemblances to what has come to be described as the 'relational turn' in the social sciences

and IR. Relationalism represents an attempt to recast social ontology in a way that rejects essentialist notions of social units (Emirbayer 1997) and sees social transactions and processes as the fundamental constituents of social reality. Particular social entities, agents or sites are viewed as historically situated and potentially transient bundles of social processes. So, for example, in applying such a perspective to IR theory, Jackson and Nexon (1999) have argued that social relations come before states, thus problematizing those theories that take the modern state-system as their starting point and states as ontologically primitive units. A relational and processual approach would rather view both the state and the state-system as phenomena that have a particular origin in time, a specific history and most likely an endpoint. In this sense, relational ontology gravitates towards historical sociology, which has shown recent signs of recovery after the dominance of state-centric approaches to IR (Hobson and Hobden 2002).

Relational and complexity-inspired approaches share a common processual ontology that privileges 'becoming' over 'being', dynamic flux over stable essences (Rescher 1996). Patrick Jackson has argued that ultimately what separates complexity and relational social theory in IR is their different disciplinary histories (Abbott 2001). For Jackson, the dominant strand of complexity in IR, which has tended to focus on computational methodologies and simulations, derives from a lineage in the natural sciences that includes physics, biology, engineering, informational theory and computational science. By contrast, relational theory looks to origins in philosophical pragmatism, process metaphysics, social studies of science and the post-structuralist critique of structural functionalism in social theory. Thus, according to Jackson, complexity and relational theory share a common scientific ontology, but this ontology is methodologically neutral: computer simulation, discourse analysis or social network theory may all be considered to be justifiable methodological tools to investigate this common ontological commitment.[2]

We would nonetheless argue that a necessary methodological requisite is a shift away from the search for general covering laws in favour of the identification of specific mechanisms and processes, as advocated by Tilly (2008):

> Covering-law, necessary-sufficient condition, and system accounts generally resist history as they deny the influence of particular times and places … Mechanism-process accounts, in contrast, positively welcome history, because their explanatory program searches for mechanisms of very general scope with arguments that initial conditions, sequences, and combinations of mechanisms concatenate into processes having explicable but variable overall outcomes. Mechanism-process accounts reject covering-law regularities for large structures such as international systems and for sequences such as democratisation. Instead, they lend themselves to 'local theory,' in which the explanatory mechanisms and processes operate quite broadly by combining locally as a function of initial conditions and adjacent processes to produce distinctive trajectories and outcomes.

The benefit of such an approach is that it avoids the pitfalls of various forms of methodological and phenomenological individualism, on the one side, and

[2] Jackson outlined this argument in a panel entitled 'Complexity science meets the relational turn' at the annual International Studies Association conference in New York, held on 17 February 2009.

holistic and structuralist accounts, on the other, by focusing on the interactions and processes that bind and reconfigure individual entities. Complexity is particularly suited to this task, as it offers a rigorous and well-defined set of operative concepts that may be used to formulate and describe such local and historically sensitive explanatory mechanisms.

### *Theories of international systems*

Complexity can offer new perspectives on a problem that has been central to IR theory: how to conceptualize the international system. Complexity certainly shares some common foundations with some of the earliest attempts to found IR on scientific principles, in which a set of American scholars introduced insights from general systems theory into IR (Kaplan 1957; Singer 1971; Waltz 1979). It does, however, break with significant postulates of these previous approaches and thereby permits a broadening of the taxonomy of systemic theorizing in IR (Harrison with Singer 2006) through its novel battery of concepts, including emergence and non-linearity, and by radically extending the notion of open systems.

Scholars such as Singer and Waltz, in importing general systems theory ideas into the study of world politics, argued that IR should be a discipline founded upon scientific principles.[3] They had in mind a particular philosophy of science, positivism, relying upon observable and measurable material phenomena to conceptualize the international system. A case can be made that the 'great debates' in IR have all hinged upon challenges to this positivist assumption about the nature and content of science. In particular, the now orthodox challenge of the social constructivism of Alexander Wendt (1999) explicitly contests Waltz's conception of the international system by drawing upon a scientific realist philosophy of science, albeit maintaining a state-centric approach. Complexity, although not in itself a philosophy of science, does bring with it an established and proven set of concepts honed in the natural sciences, which are accompanied by new forms of scientific methodology and a set of more or less explicitly stated ontological and epistemological commitments.

Systemic theorizing in mainstream IR that has derived from Waltz's seminal 'structural realist' contribution has, with assumptions about theoretical parsimony and a desire for predictability in mind, tended to conceptualize the international system as a simple and closed system—simple in terms of the number and type of actors involved and closed in terms of the scope for transformation. Such systems are conceptualized as containing a small number of actors with simple characteristics (such as state actors motivated by survival), as tending towards equilibrium with movements that are cyclical and predictable (the self-reproducing nature of the balance of power). A further assumption about

[3] These thinkers diverged from the work of Karl Deutsch (1966), which specifically drew upon cybernetics to develop a theory of world politics based upon learning in social systems via feedback loops and which Albert and Cederman (2009, 4–5) argue may be seen as a forerunner to later theories of global governance. As the Waltzian structural approach to systems thinking came to dominate, Deutsch's alternative faded away. Our arguments point towards the recovery of these kinds of alternatives to structural functionalist systems theories.

simple systems has been the classical notion of the role of the analyst, standing objectively outside the system being observed, classifying and imposing order, predicting outcomes. A complexity perspective finds the distortions inherent in such simplifying assumptions too high a price to pay, but offers alternative paths.

Operating on the premise that natural and social systems are open to their environments and to new inputs of energy and information, complexity opens up new space for exploring conceptualizations of the international system. Complex systems are composed of multiple actors, at a variety of spatial scales, that engage in complex interactions according to non-linear and networked patterns. This non-linearity of interaction severely circumscribes the kind of predictability that structural realists argue is offered by the operation of the balance-of-power mechanism under anarchy. Instead, complexity holds out the promise of identifying underlying patterns that give rise to order from the multiple individual interactions of diverse actors. The issue of sensitivity to initial conditions that complexity draws attention to highlights a very different understanding of the role of history to that displayed by structural realism, which has tended to develop ahistorical accounts of the international system. Complexity approaches take into account path-dependency and systemic history, focusing upon the evolution of systems and institutions over time.

Complexity copes with the difficulty of incorporating structure and transformation, stability and change, and the interactions of multiple actors operating at a variety of systemic levels, through the concepts of emergence and complex adaptive system. In general systems theory, a system is commonly seen as *no more than the sum of its parts* and the patterns of interactions and relationships among them, thus ruling out emergence (Singer 1971, 19). This characterization may be applied to most orthodox positions on the international system in IR that view it as constituted by the interaction of states in an anarchical environment. The concept of emergence allows for much greater flexibility in characterizing the international system, linking micro and macro elements of the system together and showing how causes at the lower levels of a system can have effects at higher levels (Jervis 1997). At the same time, the theory of complex adaptive systems investigates how the elements of a system can (co-)evolve through interaction over time. Intrinsically linked to this question of how the international system is conceptualized is the agent–structure debate in social and IR theory, and it is to this debate that we will now turn in the light of complexity.

## *Agents and structures*

The agent–structure debate has been a central preoccupation in IR in recent decades, having been imported from social theory to interrogate the nature of the state (Dessler 1989; Wendt 1989; Wight 2006). All theoretical positions on social life must stake out a position on the ontological status and relative weight of structural and agential factors, whether this is done explicitly or left implicit within the theory (Hay 2002, 91). In this sense, the agent–structure debate is relevant to ontological considerations regarding relations and essences and questions over the nature of the international system that have been outlined above. Positioning the concepts and insights of complexity within this debate offers a way to outline its most promising potential contributions to IR theory.

At the heart of the agent–structure debate is the relation between social actors, that do not have a free hand to implement their plans or achieve their goals, and the structured contexts in which they find themselves. Agency is the source of qualities that can introduce change and indeterminacy into social life: without space for the possibility of agency, theories must fall into predetermination or teleology. There remains, however, the question of how we conceptualize agents. To argue that only individual human beings can be agents is to accept the reductionism of ontological individualism. Many social theories argue that agents should be conceptualized as collective social wholes that, nonetheless, can be theorized as corporate individuals (this is predominantly the case with the state in IR: Wendt, for example, views the state quite literally as a person). Taking a longer historical view reveals the importance of other forms of historically specific collective agents that are 'sufficiently cohesive to have actor quality', such as tribal bands, city-states, empires and transnational firms (Buzan and Little 2000, 101). Others would argue for even more radical reconceptualizations of agency that would extend this attribute beyond humans and their institutions to non-human objects (Latour 2005).



However, the need to incorporate agency into social theory does not mean that actors can modify the world as they wish. Structures play constraining roles. Structures can be material phenomena, such as underlying economic structures that shape social and cultural activity, as much as they can be recurring patterns of behaviour, symbolic orders, internal rules or institutional arrangements. Indeed, Giddens (1984) has argued that structures should be thought of not simply as restraining actors, but as providing the materials and resources that make agency possible. Gidden's structuration theory represents one of a number of attempts to mediate between the two theoretical poles of structuralism and intentionalism by highlighting the role of praxis in shaping both structures and agents over time (Archer 1995; Bhaskar 1979).

The contribution of complexity to this intractable problem of social theory promises to be one of both social ontology and methodology. Complexity offers new avenues to conceptualize the relationships between individuals and emergent social formations without reducing one to the other. It may also offer new ways to bridge the divide between materialist and social constructivist positions, a divide that has separated theorists of the international system in particular. We will highlight here two interesting avenues that have been developed; firstly, complexity-inspired social ontology and, secondly, the contribution of complex adaptive systems (CAS) approaches and methodologies.

That complexity derives its origins from the natural sciences does not rule out its application to the social world in ways that are faithful to its ontological principles. A key exemplar of this approach is Manuel DeLanda (2007), who has developed a theory of social complexity that leans on the philosophical legacy of Gilles Deleuze. DeLanda's version of 'assemblage theory' draws on the concept of emergence in order to show how a variety of social entities may be characterized as concrete individuals operating at different sociospatial scales. The social ontology Delanda develops is flat, in the sense that each concrete individual that is assembled has the same ontological status *as an individual*, regardless of its spatial size or scale. In this way, starting at the sub-personal scale and moving up through nested systems, individual persons, groups and networks, organizations, governments, cities and states may all be viewed as emergent individuals composed of, but

not reducible to, populations of individuals existing at lower levels of social complexity. The component parts of an emergent whole (or social assemblage) retain a level of autonomy and may, in the right historical circumstances, be detached and plugged into a different assemblage. This allows for the possibility that historically constituted social entities may be decomposed or restructured into new forms, something that Saskia Sassen (2006) has explored in relation to the modern state in recent work that assesses the nature of global social assemblages.

A primary attraction of this approach is its ability to move beyond forms of social theory that rely on essences or totalities while at the same time providing a means to transcend the reduction of the social to individual persons. Assemblage theory sets itself the task of accounting for 'the synthesis of the properties of a whole not reducible to its parts' and, in this sense, attempts to overcome the divide between analytic reductionism and holism. The effort to move beyond essences is clear in the emphasis placed upon historical processes: each concrete social assemblage is the result of a set of historical processes that have worked to construct a synthesis of organic, non-organic and social elements into a whole. The endurance of this whole may be accounted for by further historical processes of identity stabilization, or the whole may eventually be destabilized by 'deterritorializing' social mechanisms that work to undermine its coherence. Through the incorporation of organic and non-organic components into the theory, DeLanda aims at a synthetic account of both the material and socially constructed elements of entities. The reassertion of materialism in a sophisticated social theory may be seen in part as a reaction against the excesses of the linguistic turn embodied in post-structuralist and social-constructivist accounts, and thus as an aspect of the re-evaluation of systems theories that complexity can be seen to be a part of.

Another important contribution derives from the development of the theory of CAS and the computational methodologies designed to explore such systems. CAS approaches were developed by pioneers in computing simulation at the Sante Fe Institute in California, particularly through the work of John Holland (1995) and Murray Gell-Mann (1994). CAS has cross-disciplinary application, constituting a theory and methodology appropriate to comprehending the dynamics of complex systems in both the natural and social worlds and operating at a variety of scales. The central insight of CAS is that the dynamics of systems exhibiting highly complex behaviours may be modelled or described in terms of a limited number of simple rules governing the interactions of individual agents. These rules are open to adaptation through learning, as the agents accumulate experience from their interactions with their environment. This environment is formed in large part from other adaptive agents, and so both system and agents *co-evolve* over time. Again, the stress on the historical evolution of the system highlights the importance of sensitivity to initial conditions and path-dependency. The theory allows for the computer simulation of such systems, where the analyst specifies the rules for agents and can model the potential evolutionary systemic histories such rules can give rise to.

One of the key benefits of CAS is that they incorporate the interaction of agents and structures over time, focusing attention on the meso-level of praxis, where both are continuously co-constituted through dynamic evolution. In this sense there are clear parallels with those relational approaches outlined earlier that argue that social transactions should be made the central unit of analysis.

However, the question remains of how to operationalize CAS in relation to world politics. One suggested starting point is postulated by Kim Holloman (2008), who argues that CAS can be wedded to a social constructivist approach to account for the evolution and internalization of ideational norms by actors in world politics. Holloman argues for competition over rules to be placed at the centre of a CAS approach to the international system: successful rules are internalized by agents and become effective through self-regulation and further stabilized through material power relations. Unsuccessful rules and norms are selected out of the system over time. World politics may accordingly be viewed as a CAS in which dynamic nonlinear interactions between agents at different scales (individuals, states, firms, international governmental organizations) produce continually evolving changes in both agents and structures.



*Global networks*

One of the most notable trends in social theorizing over the last two decades has been the turn towards the notion of the network to describe and analyse specific forms of organization and social relations. In the context of accelerating economic globalization, the rapid development and diffusion of information and telecommunications technologies, and the seeming decline in the authority and power of hierarchical state structures, decentralized and flexible modes of organization have proliferated (or perhaps only been made more visible) and increasingly become the focus of social science research (Watts 1999; Nexon 2009). In many instances, the social dynamics charted in such studies and the claims made about the properties and behaviours of the broad range of social networks examined strongly echo the findings of complexity theory, and a number of scholars have grounded their findings in its terminology and conceptual framework.

Manuel Castells' *Information age* trilogy remains here a major milestone. Although Castells has not made explicit the influence of complexity on his work, Stalder (2006, 170–175) has persuasively argued that the concepts deployed display a clear intellectual kinship: 'a network-based social structure is a highly dynamic, open system, susceptible to innovating without threatening its balance' (Castells 1996, 470). Throughout the work, Castells tracks such social structures across the social field to account for the changing organization of states, enterprises, modes of economic production and consumption, civil society and social movements, and the global criminal economy.

In their influential work *Empire*, Hardt and Negri (2000) argue that the centralized territorial power of the state is being supplanted by a diffuse deterritorialized 'society of control' in which corporations, international organizations and global civil society constitute networked systems of human management, regulation and subjectification. Power therefore no longer has a centre but is capillary and distributed. Strikingly, for these authors as well as for many members of the so-called 'anti-globalization' movement, resistance to global governance therefore passes through decentralized self-organization and open networks, in contrast to the more rigid and hierarchical party structures that dominated previous internationalisms. One finds here a conceptual resonance with complexity, sometimes expressed in the very language of the non-linear sciences, as when Chesters and Welsh (2006, 126) describe the World Social Forum as 'a system that instantiates the phase space of global civil society composed of

competing attractors that maintain the system at a point of self-organized criticality, where collective action at the edge of chaos becomes possible'. More generally, much research has been conducted into the dynamics of social movements through the prism of the network form (Diani and McAdam 2003; Della Porta et al 2006).

Studies of organized crime and street gangs have also witnessed a critical reassessment of previous assumptions about the hierarchical nature of such groups and recognition of the loose networks and decentralized dynamics behind their emergence and operation (Klein and Maxson 2006; Williams 2001; Wright 2006). Even where relatively formal and centralized criminal organizations have in the past prevailed (although the extent to which these conventional characterizations need to be revisited is itself debated), a trend towards more horizontal structures has been observed. The emergence of a loose confederation of organizations pursuing illicit activities in the post-Soviet Russia of the 1990s perhaps heralded this development (Shelley 1995). Since then similar tendencies have been reported in the Latin American cocaine trade, where the fall of the Cali and Medellín cartels has left in their wake a denser network of smaller but no less effective groups (Kenney 2007; 2008). In Italy, a power shift has seen the Sicilian Cosa Nostra, weakened by the arrest of many of its key leaders, relinquish its control over the drug trade to the looser 'Ndrangheta criminal organization from Calabria (Gnosis 2007).

For Duffield (2002, 161), 'the new security terrain in general is characterized by the trend toward networking' and the thriving of complex adaptive systems, evidenced by both the 'new wars' in the global South (Kaldor 1999; Duffield 2001) and the 'network-centric' doctrinal and organizational developments of state militaries (Bousquet 2009; Dillon and Reid 2009). The 'War on Terror' has focused particular attention on violent Islamist networks, from those which have been assigned the 'al-Qaeda' moniker to those which make up the wider nebulous jihadist movement. The bottom-up processes of emergence and self-organization of these networks, along with their highly distributed modes of operation that have so frustrated state efforts to eradicate them, have been noted by a number of writers (Marion and Uhl-Bien 2003; Burke 2004; Sageman 2004; 2008; Bousquet forthcoming). Sageman has notably presented 'leaderless jihad' as the 'natural outcome of a bottom-up mechanism of group formation in a specific environment shaped by top-down counterterrorist strategy' (Sageman 2008, 143).

## Beyond models and metaphors: towards generalized complexity

The above discussion has shown how complexity is already enriching our insights into many of the central concerns in the study of global politics, and has outlined some of the further benefits that might accrue from a wider engagement with these ideas. However, it will also have become clear that an array of different approaches is in evidence, the respective appeals of which will differ significantly according to the audience. While plurality is on the whole something to be celebrated rather than lamented, this also largely accounts for the still limited impact of complexity on the disciplinary mainstream. This section will therefore seek to further sharpen our understanding of complexity as a reinvigoration of systems thinking which has to be located within broader intellectual history and

whose full philosophical implications preclude a return to discredited scientistic approaches to IR.

The earliest attempts to bring complexity into the study of international politics may be characterized as qualitative and predominantly metaphorical. These took concepts and language emerging from the science of complexity and examined how they might recast the way in which the international system is perceived (Rosenau 1990; Jervis 1997; Urry 2003). Although the use of complexity concepts is by no means limited to metaphorical applications, the importance and philosophical implications of metaphors should not be underestimated. While such approaches are often seen as a 'soft' way to apply complexity to international politics by those using quantitative methodological tools, it is possible to argue that the creation of metaphors must precede such activity and is indeed equally important to theorizing in the natural sciences (Arbib and Hesse 1986). The metaphorical application of complexity to the study of IR has been driven by the desire to transform dominant theories, destabilize established knowledge and open up new space for debate, and as such remains useful and insightful. While this topic deserves greater attention than we can afford here, we simply wish to note that recognition of the important role of metaphors does not in itself preclude a scientific realist stance towards complex social systems (Lewis 1996).

As has been already noted, computer simulations and models have been among the core methodological tools that complexity theorists have developed to interrogate the behaviour and dynamics of complex systems. This has in turn become an increasingly popular way of bringing complexity to bear on the study of the social world, notably through agent-based modelling that studies the outcome of the interaction of autonomous rule-based actors (Cederman 1997). While there are certainly some insights to be gained from simulations, their use and interpretation need to be clearly circumscribed if they are not to lead to the same disappointments and dashed hopes that previous modelling efforts experienced. The biggest error in our view would be to see in models accurate representations of specific real-world social systems and reliable tools to predict their behaviour, except in the most constrained and bounded cases, and certainly not in the case of anything as large and complex as international or national politics.

There are several reasons for this position, some of which pertain to complex systems, others being of a more general nature. Sensitivity to initial conditions, non-linearity and feedback preclude any reliable prediction of a given social system beyond the shortest timescales, in the same way that the weather still eludes trustworthy forecasts beyond a few weeks. The study of social systems is further complicated by the reflexivity of actors capable of absorbing and adjusting to the very knowledge produced about them. Furthermore, any model requires the drawing of system boundaries that complexity has shown to be highly porous, along with necessarily arbitrary choices in the scale of analysis. Finally, models of real-world social systems frequently rely on implicit, unexamined or unacknowledged epistemological and ontological assumptions. Pepinsky (2005) has thus argued that those which have used modelling in IR import into their models assumptions that inevitably draw upon the modeller's particular disciplinary inclination. The majority of modellers in IR have tended to draw upon the ontology of IR realism, with all the assumptions about state-centrism, systemic-level interactions and behavioural preferences that this so often implies being built into the models from the outset.

Notwithstanding these significant reservations, computer simulations can make valuable contributions in allowing experimentation with dynamic models and the acquisition of insights and intuitions about the general processes and patterns of behaviour governing social systems. Where possible, modelling may also permit fruitful ontological explorations by speculatively experimenting with various presuppositions about the agents and structures that matter in the social realm. What modelling should not be is a fig leaf for scientific methodologies no longer tenable under the complexity paradigm.

Thus Edgar Morin draws an important distinction between 'restricted' and 'generalized' complexity: between attempts to harness complexity to established modes of scientific enquiry, and the full embrace of its profound implications for the acquisition of knowledge of the world and our actions within it:

> Restricted complexity made possible important advances in formalisation, in the possibilities of modelling, which themselves favour interdisciplinary potentialities. But one still remains within the epistemology of classical science. When one searches for the 'laws of complexity', one still attaches complexity as a kind of wagon behind the truth locomotive, that which produces laws. (2005, 10)

Generalized complexity, on the other hand, demands an engagement with the full philosophical consequences of emergence, sensitivity to initial conditions, and open systems and the consequent blows delivered to previous scientific ambitions for predictability and control. General covering laws may become unavailable (or at least severely restricted in their applications) and knowledge primarily situational, the outcome of our interaction with the world being uncertain.

This insistence on the limitations and situatedness of knowledge will for some readers no doubt echo the post-positivist or post-structuralist critique that has gained increasing traction within IR in recent decades, and certainly the philosophical approach to complexity we are advocating is one that takes on board the most valuable theoretical contributions made within this literature. However, we simultaneously wish to argue that complexity offers a way to reinvigorate systems thinking, the previous incarnations of which had been severely critiqued by post-structuralists (see also Albert and Cederman 2009). Indeed we find within the writings of several of the pre-eminent thinkers placed under this broad label philosophical resonances with complex systems thinking as well as, in some cases, common references.

Post-structuralism gathers under its heading a range of theorists seeking to resist and critique totalizing systems and structures that repress or negate difference. Coming in the wake of the post-war dominance of structuralism in the human sciences, figures such as Foucault, Derrida and Lyotard sought in their own respective ways to undermine attempts to identify universal ahistorical invariants underneath the apparent diversity and contingency in the manifestations of human society, culture, language or psyche. The success of these attacks has resulted in greater attention being paid to the fragmented, plural, marginal and constructed aspects of social life, along with breeding a strong scepticism towards all-encompassing frameworks of interpretation, 'grand narratives', and claims of natural givens.

However, as Taylor (2001, 47–65) argues, what post-structuralists like Derrida cannot imagine is 'a non-totalising system that nonetheless acts as a whole'. Indeed philosophers of social science have increasingly been arguing that

'abandoning conceptions of systems has imposed a high price on the social sciences: a lack of ontologies and methodologies that are both philosophically profound and methodologically defensible' (Pickel 2007, 392). The emphasis that complexity places upon the open nature of systems and their self-organization, these thinkers argue, can overcome the post-structuralist suspicion of systems. Drawing upon the thought of Morin, Paul Cilliers (1998) in fact claims that postmodernism and complexity actually share many similar characteristics, especially a sensitivity to the inherent complexity of the social, and a refusal to reduce or essentialize that complexity within simple one-dimensional theories. In this sense, complexity internalizes the post-structuralist critique and offers the possibility of ways forward, one of which we outlined earlier in DeLanda's Deleuzian-inspired social ontology.

Indeed, the work of Deleuze and Guattari offers the most obvious case of cross-pollination between complexity theory and post-structuralism. Drawing direct inspiration from the work of scientists who were laying the foundation of complexity in the 1970s, such as Ilya Prigogine or Benoît Mandelbrot, the philosophy they developed through the concepts of rhizome and assemblage broke with structuralist postulates while not abandoning the principle of system (Deleuze and Guattari 1987). As Deleuze put it himself in an interview:

> Systems have not lost any of their vital forces. There is today in science or in logic the complete beginnings of a theory of the so-called open systems based on various interactions. They repudiate purely linear series of causes and they transform the notion of time … What Guattari and I call a 'rhizome,' is precisely a case of open system. (*Liberation*, 23 October 1980)[4]

These systems are not the all-encompassing totalizing structures from which all meanings and properties of the elements they encapsulate are derived and that post-structuralists have rightly sought to critique. Rather they are fluid and open-ended assemblages, the properties of which emerge from the interaction of their components while being nonetheless irreducible to them. These are systems without any necessary propensity to equilibrium or stasis; they are instead open to transformative change and metamorphosis and within them we find the openings and interstices that constitute the very space of politics.

The identification and analysis of such systems in IR remains ultimately an empirical question to be answered by the painstaking mapping of the connections and interactions between the different entities that inhabit our world. Bruno Latour's work on actor–network theory (2005) is here particularly salutary in reminding us of the necessity of avoiding both prejudging the identity or relative importance of the actors in any system and taking any analytical shortcuts that invoke underdetermined social forces such as 'capitalism', 'globalization' or the 'balance of power' as explanatory in the final instance.[5] Complexity is particularly

[4] Several authors have since sought to combine Deleuze and Guattari's philosophy and more recent developments in complexity to propose new social ontologies and methodological orientations (DeLanda 2002; 2007; Bonta and Protevi 2004). Bonta and Protevi define an assemblage as 'an intensive network or rhizome displaying "consistency" or emergent effects by tapping into the ability of self-organising forces of heterogeneous material to mesh together' (2004, 54).

[5] See Srnicek (2010) for an application of actor–network theory to the study of conflict.

apposite to the task at hand in offering a coherent ontological framework alongside a battery of concepts that can be fruitfully combined and applied to capture the different mechanisms and processes that generate and sustain these systems, whether they be circular feedback loops, non-linear dynamics, self-organization, emergence or complex adaptive systems. There is no reason why this conceptual toolkit cannot be further enriched in the future by new concepts developed in the course of the study of specific problems, just as it was originally assembled in a piecemeal fashion from the disparate research projects of natural scientists. Complexity theory is after all no less of an open system than those it purports to account for and is as such liable to continue being developed and supplemented as needed.



## Conclusion

We have argued here that the application of the conceptual framework and methodological resources of complexity to core debates in IR has the potential to offer fresh insights and extend those debates in interesting new directions. Some of the conceptual language of complexity simply did not exist more than a few decades ago, and its ability to reinvigorate debates in world politics has barely begun to be tested. The application of complexity to world politics should be seen as encompassing far more than just computer modelling and suggestive metaphors: as we have shown, complexity also offers the resources for a significant reworking of social ontology and is related to a range of new approaches to the study of the social that have been gaining ground in recent years. Above all, we have highlighted how complexity can be part of a return to systems thinking that is sensitive to and internalizes the post-structuralist critique of the totalizing nature of systems. Complexity develops an anti-essentialist, processual ontology that can conceptualize non-totalizing systems as wholes whose parts can retain their autonomy and leave room for agency and transformative change. In an increasingly interconnected global world that is ever challenging our understandings of it, the capacity to think systemically remains an ever more pressing need, both as an analytical lens and as a practical guide to political action.

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