We do complexity too! Sociology, chaos theory and complexity science

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Abstract

The 'new science' of complexity and chaos theory has grown rapidly in the last three decades aided enormously by the quantum expansion of computers and computing applications. Responding to the energy and enthusiasm of complexity scientists and publicists, social theorists have assimilated concepts of complexity and its potential impacts on sociological theory and social research. This paper examines the strategic projects of two landmark contributions to the growing literature on complexity theory in the social sciences; the work of David Byrne and Sylvia Walby. I sketch the historical development of complexity science/theory given by Byrne and Walby and identify a narrative around differences between chaos theory and complexity. I argue that both writers successfully translate scientific insights into an accessible complexity theory for sociology. They transfer its metaphors and concepts to concerns, debates and research in sociology and social theory. Each uses complexity thinking to address substantive issues in sociology. Byrnes incorporates chaos/ complexity theory into quantitative, survey-based programs for sociological research and theory formation. Walby works more directly with theoretical concepts. She revives, but fundamentally re-conceptualises, systems thinking for social theory. Both writers offer substantively grounded developments of complexity theory that fruitfully connect sociology and the new science of complexity.

Keywords: Social theory, Complexity science, Chaos theory, Quantitative data analysis, Systems theory, Interdisciplinarity

New science, complexity and sociology

The 'new science' of complexity developed as a self-conscious movement to shift scientific thinking and imagination beyond the reductionist and linear thinking of the 1970s. The Santa Fe Institute (SFI), the major US hub of complexity sciences, was founded in 1984. It has facilitated the development of new forms of non-linear mathematical modelling that explore phenomena too complex for older approaches. This work has been greatly facilitated by the quantum expansion of computers and computer power over these decades. The SFI has pursued a multidisciplinary program to apply these advances to all areas of science including the social sciences.

Much of the appeal of the new sciences of complexity has been the new metaphors and concepts it has introduced. Science writers and journalists have produced a significant literature of highly sophisticated and engaging discussions of complexity, its stories of discovery and its applications in many intriguing areas of human activity and life (Buchanan 2000; Waldrop 1993). This literature makes complexity and its ideas readily accessible to non-scientists.

One stream of this writing targets social science, and sociology in particular, as irrelevant to complexity thinking. This writing sees all social science as tainted by the excesses of postmodernist constructivism and its ontological solipsism. It also assumes that the model building and non-linear mathematical modelling essential to complexity theory is beyond the reach of sociologists (Buchanan 2007: 17-19).

This paper outlines two significant projects within sociology that make substantive contributions to complexity thinking in their own right. The first of these is David Byrne's (2002; 2007) re-affirmation of the validity of survey data and his re-interpretation of quantitative data 'analysis' as 'interpretation'. Byrne shows how the production and organisation of large-scale statistical information, which complexity scientists often use without thinking, is itself a complexity process and able to yield insight into the complexity of human societies. The second sociological project is the social theory of Sylvie Walby (2007; 2009) that total revises sociological systems theory to bring it into a framework compatible with the non-linear dynamical systems analysis of chaos and complexity theory.

I begin by considering the differences between complexity science, associated with the Santa Fe Institute (SFI), and chaos theory usually linked with the study of 'far from equilibric' (dynamical) systems initiated by Ilya Prigogine. I then outline Byrnes' active application of complexity thinking to quantitative data analysis, a move more in tune with chaos theory than SFI complexity modelling. Walby works from theory. She urges sociologists to totally re-conceptualize systems thinking in the light of complexity theory's concepts of complex adaptive systems. I sketch out the new concepts of 'system' she develops and examine the additional element of complexity that she introduces to complexity theory. Both writers provide, I argue, substantive and grounded connections between sociology and complexity science. They demonstrate that sociologists are indeed 'doing complexity theory too!'

What is complexity theory and how does it relate to social theory?

Complexity science is generally associated with the parallel efforts of physicists interested in chaos theory, with Ilya Prigogine as a lead figure, and the intellectual program of the SFI. Founded in 1984 the SFI set out to apply the new models and methods of modelling made available by computers to complex problems in the sciences. It had 'convening power', the ability to bring top people together for intensive discussions (Harvey 2001: 4) and set up multidisciplinary meetings to foster applications of these methods in biological and social sciences as well as natural sciences and physics.

Complexity scientists work with mathematically defined models. The signature of complexity sciences are complexity models based on non-linear, rather than the linear equations. (Non-linear equations contain terms with exponential functions – i.e. terms squared or raised to some power – so the graphs of these functions are curves rather than lines.) Only some of these models are pure 'mathematical' models in the sense that they are systems of solvable equations that allow predictions of outcomes once given parameters are estimated. Computer simulations extend non-linear modelling beyond the limits of mathematical solutions by providing millions of scenarios for a given set of starting conditions until models converge toward some outcome or outcomes. Another computer driven activity is Agent-Based Modelling (ABM). ABM produces models that simulate collective behaviour by establishing protocols of interaction among 'agents' and running random iterations of the model.

At the public level, however, complexity scientists and publicists use language, metaphor and analogies to package their ideas in terms that enable mathematically defined models developed in one context to be applied to other contexts. A prime example of this is the building of models of cellular automata or neural networks that are then presented as 'artificial life' - metaphors for all life processes. (There is an analogy here to established metaphor of artificial intelligence.) Social theorists have done much around the issues of using such analogies and metaphors Lopez (2003) but this is seldom considered seriously by these scientists.

Once packaged for internal communications and public consumption these models and concepts become a social theory. I will designate this theoretical discourse as complexity theory. Like all social theory complexity theory embeds an ontology, assumptions, statements about which elements of the model match entities and relations in empirical contexts. When describing human contexts, complexity theory tends to present a world of atomistic individuals and emergent social systems. This model has direct analogies to natural contexts; the atoms and molecules of natural materials, the molecules and cells of biology and the cells and organisms of living organisms. One of the strongest achievements of SFI type modelling are simulations of emergence and 'self-organising systems' – simple protocols governing the local activity of entities at a lower level of being can, of themselves, produce stable patterns that, in turn, constitute the materiality of the higher order emergent entity (Johnson 2002).

Emergence and similar sorts of images are familiar ground for social theory albeit that we specify them in terms of structure and agency, micro-macro interactions and issues of (social) system stability, disruption and change (Byrne 1998: 46: Kontopoulus 1993).

If complexity science is presenting a social theory social theorists can assess its frameworks and claims in the way they do other social theories. Walby does this by considering the parallel development of the concepts and frameworks in complexity and social theory to see what insights discussions within complexity sciences and complexity theory have for social theory. Byrne follows a more methods-based route. He considers the new approaches to data analysis and non-linear modelling that complexity science uses and incorporates them into discussion of the way data analysis relates to theory formation in sociology. These two efforts are a real, practice-level engagement of working social researchers and theorists with complexity science through the shared terrain of complexity theory interrogated as social theory.

Chaos theory versus SFI: Are the differences significant?

In outlining complexity theory both Byrne and Walby comment on differences of emphasis between the chaos theory of Ilya Prigogine, on the one hand, and the SFI and its programs on the other. Chaos theory presents a distinct view of systems.

Systems do not tend to equilibrium, rather they exist as dynamical entities (needing continual inputs of materials and expulsion of wastes), posed on a knife-edge between possible disintegration into chaos or ossification into deadly stasis. They are 'far from equilibric, dissipative structures'. More importantly once they fall away from the pattern and stability evident at one point in time they are in a chaotic state without any particular likelihood that they will return to their former stable state. On the contrary, in the transitional conditions of chaos any one of a host of different small conditions may turn out to be decisive to the emergence of a new pattern and ordering which is impossible to predict. This insight is encapsulated in the fanciful aphorism that the beating of a butterfly's wings in Mexico might, in theory, be the input that sets a weather system toward the positive feedbacks and clustering that become a hurricane in the Caribbean.

The mathematical models for 'far from equilibric' systems are deceptively simple equations where the predicted variable (x) changes as the values on the y side are iteratively fed in from the previous state of the equation (Gribbin 2004). Equations that model population numbers given birth and death rates that vary with nutrient supply are one example. A second set of examples are equations that model the incidence of a disease according to its rate of spread and the development of resistance among survivors. As the iterations progress these models show moments of rapid growth and troughs of quiescence. They also show the potential to hover or converge for substantial periods of time around particular solutions or, in the language of this modelling, 'strange attractors'. These characteristics ape the chaotic and hitherto unpredictable patterns of some diseases and other population dynamics. The dramatic shifts of balance are labelled as 'bifurcations' (not in the sense of a splitting but a shift from one state through a moment of chaos to a quite different state).

Scientists associated with the SFI tended to work with simulations of emergence, complex adaptive systems (CAS) and ‘self-organization’. These models owe much to statistical mechanics and have also developed rapidly in ABM. Scientists around the SFI “Searched for and found patterning [order] in phenomena others saw as merely chaotic” (Walby 2007: 456). Such models are believed to emulate the inner structure of life forms and provide the basis for studies of artificial life. An engaging set of applications are computer simulations of swarming, known as ‘boids’. Objects (birds) were programmed to move randomly but to moderate their movements according to the presence of other objects in their immediate vicinity. Set to run iteratively the objects form into temporary flocks and swarms that look like their real world natural counterparts (Waldrop 1993: 241-2).

David Harvey (2001) makes the assessment that differences between chaos theory and the SFI are not a significant difference within complexity theory. Chaos theory, he suggests, looks at the external patterning of complex systems whereas SFI complexity looks at the internal subsystems of complex systems. He acknowledges, however, that there are “profound differences in the scientific and social agendas they pursue, as well as the style of scientific praxis to which each is committed.” (Harvey 2001: 3).

The differences between chaos and SFI may not impede the development of complexity science nor significantly hinder communications among scientists from the two camps. However, for social theorists and other outsiders, they offer very different entry points and connections to complexity science and different strategies for connecting with complexity scientists. As Harvey notes, chaos theory presents its social project as “‘humanizing the physical sciences’ while the more or less technocratic credo of the Santa Fe Institute seeks a unified science by ‘scientizing the arts and humanities’” (Harvey 2001: 3).

Sociologists seeking to communicate with complexity scientists will find a significant prejudice against them from SFI inflected complexity theory. However its concepts of emergence and self-organising systems involve issues central to social theory. Chaos theory has no particular view of sociology however the models and applications it uses are much more unfamiliar and foreign to sociologists. The work of Byrne and Walby addresses these entry barriers.

David Byrne: Data analysis and complexity in social science

Byrne's application of complexity thinking to social research and analysis is more attuned to chaos theory than SFI approaches. Byrne interprets social science data, and survey data in particular, with analytic approaches that shift attention away from the linear regression modelling that is widespread in social sciences and psychology toward the alternate non-linear and combinatorial modelling used in complexity science. He presents a lucid exposition of how a complexity-inspired research programme could work in sociology.

Byrne (1998: Ch 3 and 4) argues that social surveys provide valid empirical information about the state of a social system. Longitudinal data, where it is accurate, tracks system change, including bifurcations to a new state. Like Catherine Marsh (1982) he defends sociological practice and its survey traditions against scientific prejudices toward sociological methods as well as the critiques of postmodernists (Byrne 1998: Ch 3). Understanding survey data as sets of measures about a social system at a point in time opens the way for 'a causal account founded in an understanding of the nature of a social system which is subject to deterministic chaos' (Byrne 1998: 56).

Byrne presents theory formation as integrally linked with data analysis. It is:

> a reflexive process in which the theory serves as a basis for the organisation of the model but the data itself is also used to generate ideas in an exploratory way which are then taken back for further review (1998: 67).

This description of theory formation is consistent with Marsh's (1998) exposition of exploratory data analysis and Nigel Gilbert's (1993) description of models and data analysis.

The final element of Byrne's argument is a discussion of the types of data analysis appropriate for the complexity-derived programme in sociology. He argues for a summative view of survey data in which every possible configuration of relevant variables and their values is identified and we make a count of cases within each one. As used in log-linear analysis, and advocated by Byrne, this procedure creates a model, a map of all possible outcome spaces. If we assume there is a uniform distribution of cases across each possible configuration we have a 'general mean' model. This is 'uniform probability' model is not, however, based on the assumption of a 'normal' (Gaussian) distribution of variation. A second step is to use theoretical claims and guidance from other research to modify and tweak the distribution away from the initial, 'uniform probability' and to test the resulting model against the data. If it produces a better fit it is a better model for this set of data (1998: 82). These are procedures derived from exploratory data analysis and advocated by Catherine Marsh (1988).

Byrne's program outlines a distinctive approach to modelling, data fitting and theory formation within sociology. It is not simply a translation of metaphors and concepts from complexity theory into sociology. It connects with established practices of quantitative data interpretation. Byrne's achievement is thus not only the domestication of complexity theory for social sciences, but, more importantly, the development of a genuine complexity programme within the social sciences. Its demands for thinking about data analysis break with the assumptions of case-by-variable analysis on the one hand and offer an alternative social ontology to the 'social atom' ontology of SFI thinking.

Walby: Complex 'systems theory'

Walby (2007) approaches complexity theory through concept elaboration. Walby engages with complexity theory on the premise that its metaphors and concepts will provide a new approach for understanding and re-orienting problems of social theory. Her vision is systemic, the de-stabilization and re-orientation of concepts in one area of social theory inevitably impacts on related concepts. The full project is a major book on conceptualizing inequality on a global scale (Walby 2009).

Walby's article (2007) presents an overview of complexity theory and its constituent elements and I have drawn on her accounts in my summaries above. She notes that complexity scientists maintained an intellectual engagement with concepts of systems, cybernetics and system theory while social theorists explicitly rejected these ideas from the 1970s onwards. Complexity theory, however, engenders an utterly new version of system theory.

Social theory's rejection of systems theory of the 60s and 70s was justified, Walby argues. The systems theory of that time was intellectually limiting. It drew on and embedded functionalist assumptions from the Parsonian tradition. In particular old system theory assumed that systems were necessarily equilibriating; negative feedback dealt with variation so that deviation was contained within system limits and tolerances. In old system theory systems were stable and self-maintaining and, as a consequence, there was no room for change, let alone the type of sudden and dramatic de-stabilization (bifurcations) adumbrated by chaos theory. The old systems theory tended also to be over-deterministic and circular. The system itself explained the functional differentiation of parts and their specialisation. Social institutions existed because they served a societal function. If institutions were not working others would develop to take their place (functional equivalence). Finally there was no 'bottom up' understanding of institutional development.

Walby (2007) highlights a particular problem of old systems theory. Old systems theory saw any system as standing alone in relation to a changeable but undifferentiated 'environment'. Systems were considered as bounded entities unconnected to other systems.

Although social theory eschewed the concepts and terminology of systems theory it uses a variety of other terms to designate the concept of system as social totalities or collectivities. Walby suggests that the following terms served as synonyms: 'social relations', 'regime', 'network' and 'discourse' (Walby 2007: 455) The conceptual need was there but the linguistic variety indicates a lack of agreement about acceptable and appropriate metaphors that could serve as the basis of concept development.

Complexity theory's concepts of complex adaptive systems (CAS) provide a totally different picture and metaphor of system from 'old' systems theory. These adaptive or dynamical systems, or 'dissipative structures', are not stable. They are in a state of constant transformation incorporating resources from outside themselves, transforming them for their own needs and expelling waste and toxins. System stability is highly contingent and fragile, a delicate balancing between chaos and frozen order (stasis). Positive feedback loops that amplify the effects of small divergences open the possibility of de-stabilization and bifurcation. Notions of emergence, a predominant concern of the SFI scientists, provide new metaphors for seeing how social contexts and networks become collective realities (institutions, organizations or 'networks') where the 'whole' is something beyond the aggregate sum of its elements.

Walby (2007) devotes much of her article to issues involved with systems and their 'environments', the last criticism of old systems theory noted above. Her interest is highlighted by a pre-existing social theory problem – the problem of intersectionality. Intersectionality refers to the compounded impacts of overlapping systems of discrimination ('intersections'), most obviously those of gender, race and class. Walby extends complexity theory toward the issues intersectionality raises. She makes the simple but powerful observation that we should not see systems as bounded and sitting within an undifferentiated 'environment'. The sociological perceptions of intersectionality require us to conceptualise systems as overlapping. The workings of any one system of discrimination mess with the workings of others. Secondly Walby suggests that we need to understand the 'environment' in which a system operates as populated by competing, overlapping systems.

Walby is bringing the insights of social theory to bear on the metaphors and images of complexity theory. However she adds an additional dimension of complexity. Her image of systems as overlapping competing entities draws from social theory and engagements with empirical social research, particularly the rich fields of feminist studies. It pushes the concept of complex adaptive systems in important directions. In complexity theory ecological modelling and concepts of co-evolution have only begun to accommodate the qualitative complexity that Walby has sketched out.

Walby's social theory has mapped an conceptual problem where social theory has already operated and complexity science is catching up.

Summation and comments

Like Byrne, Walby's achievement has been to develop a substantive connection between sociology and the practice of complexity scientists. At one level Byrne and Walby provide a bridge between the two worlds. They domesticate complexity science and complexity theory and make it understandable for sociology and amenable to adaptation and development within our discipline.

More significantly, however, both writers engage complexity theory with problems and issues already established within social research and social theory. Byrne shows how sensitive quantitative analysts are aware of the ontology dimensions of their models and the need to treat models as constructs. Complexity theory opens new horizons of interpreting quantitative data in terms of complex system dynamics in ways that complement this project. Walby engages with complexity at the metaphorical and conceptual level. Her careful analysis of system thinking builds complexity systems theory as a viable conceptual framework for social theory and analysis. Moreover she has defined the social theoretical issue of 'intersectionality' – the overlapping and interaction of systems upon one another with a 'system of systems' - with enough clarity for us to assess whether co-evolution and similar models of complexity science are sufficiently sensitive to the situations she envisages.

There are many problems and misunderstandings that will arise as sociologists attempt to communicate with complexity scientists. The most immediate one is that sociologists have to be familiar with (and intelligently sceptical) about the enormous array of models and modelling techniques complexity scientists are throwing up. Writing in the early 1990s Bryne is still uncertain about the implications for sociology of the different techniques of mathematical modelling, agent-based modelling and stochastic and statistical modelling. Re-orienting quantitative knowledge to take account of these developments within complexity poses a formidable challenge for sociology. The challenge is all the more difficult given that these new techniques need to be examined within frameworks that acknowledge and work with the considerable achievements of qualitative research methodology that consolidated over the same decades.

A second source of problems comes from the scientific embeddedness of complexity theory. Natural scientists are reluctant to accept the validity of issues generated by qualitative research or social theory. Misperceptions of all social science as caught in postmodernist circularities were given a popular aura of legitimacy by the Sokal affair. Byrne devotes a significant amount of effort to setting out a (critical) realist account of social research to counteract this prejudice. Walby's insights from social theory will be harder to sell to 'hard nosed' complexity scientists who are often rusted-on positivists.

Byrne and Walby connect the concerns of sociology and the practices of social research and theory with the applications and achievements of complexity scientists. Their pioneering efforts show the difficulties and pitfalls of this endeavour. However they also show that it is possible.

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