Sociology and Non-Equilibrium Social Science

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Abstract This chapter addresses the relationship between sociology and Non-Equilibrium Social Science (NESS). Sociology is a multiparadigmatic discipline with significant disagreement regarding its goals and status as a scientific discipline. Different theories and methods coexist temporally and geographically. However, it has always aimed at identifying the main factors that explain the temporal stability of norms, institutions and individuals' practices; and the dynamics of institutional change and the conflicts brought about by power relations, economic and cultural inequality and class struggle. Sociologists considered equilibrium could not sufficiently explain the constitutive, maintaining and dissolving dynamics of society as a whole. As a move from the formal apparatus for the study of equilibrium, NESS does not imply a major shift from traditional sociological theory. Complex features have long been articulated in sociological theorization, and sociology embraces the complexity principles of NESS through its growing attention to complex adaptive systems and non-equilibrium sciences, with human societies seen as highly complex, path-dependent, far-from equilibrium, and self-organising systems. In particular, Agent-Based Modelling provides a more coherent inclusion of NESS and complexity principles into sociology. Agent-based sociology uses data and statistics to gauge the 'generative sufficiency' of a given microspecification by testing the agreement between 'real-world' and computer generated macrostructures. When the model cannot generate the outcome to be explained, the microspecification is not a viable candidate explanation. The separation between the explanatory and pragmatic aspects of social science has led sociologists to be highly critical about the implementation of social science in policy. However, ABM allows systematic exploration of the consequences of modelling assumptions and makes it possible to model much more complex phenomena than previously. ABM has proved particularly useful in representing socio-technical and socio-ecological systems, with the potential to be of use in policy. ABM offers formalized knowledge

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that can appear familiar to policymakers versed in the methods and language of economics, with the prospect of sociology becoming more influential in policy.

1 Introduction

This chapter examines the connection between sociology and Non-Equilibrium Social Science (NESS). Sociology is one of the most general and diverse of the social science disciplines. This diversity has important implications when discussing the way new developments can have an impact on practices within the discipline. Moreover, there is no one definition of the principles of non-equilibrium thinking. Thus, as we show in this chapter, the potential links between sociology and NESS depend on what assumptions and goals are attributed to both of these traditions. The chapter is divided as follows: the first section provides a brief introduction to sociology. It focuses on the distinctive features of the discipline, in comparison with other social sciences. The second section discusses the links between sociology and non-equilibrium social science. It argues that NESS and sociology can be connected in two different ways, but only one of them has significant implications. The third section introduces agent-based modelling, a social science method that has strong links to NESS. The aim is to show how this method can help in articulating the principles of sociology and NESS. Finally, the fourth section addresses the connection between sociology and policymaking. It describes the way in which sociologists have linked the discipline with the public arena and the potential role agent-based modelling can play in policy-oriented sociology.

2 Sociology in a Nutshell

Giving a brief introduction to sociology is not an easy task. There is significant disagreement among practitioners regarding the goals and status of sociology as a scientific discipline. Sociology can be described, following Ritzer (1975, [28]), as a 'multiparadigmatic' discipline. The different paradigms underlie diverging conceptualizations of the subject matter of the discipline, resulting in the application and production of different methods and theories. However, of all the social sciences, it is sociology that has scrutinized stability and change, order and conflict in society as a whole most closely. Although different paradigms have populated sociology since its inception, the discipline has always aimed at identifying the main factors that explain, on the one hand, the temporal stability of norms, institutions and individuals' practices; on the other, the dynamics of institutional change and the conflicts brought about by power relations, economic and cultural inequality and class struggle.

At the same time as anthropologists were travelling around the globe observing and understanding exotic or foreign groups, sociology emerged as an attempt to make sense of the deep social transformations that were occurring between traditional and modern societies. The first sociologists lived in a transitional period, which they understood as the passing from one stage of social evolution to a new and completely different one: from mechanic to organic forms of social integration [9]; or from mainly communitarian, face-to-face interactions (Gemeinschaft) to more impersonal and indirect interactions (Gesselschaft) [34].

The distinctive lack of unification in sociology is partly due to the fact that the discipline has not achieved the overall level of formalization that is common in the natural sciences and other social sciences such as economics and psychology, but also to some interesting factors regarding the way knowledge is produced within the discipline. The first of these is that the process of knowledge production in sociology is highly contextual. Sociology was developed following a general concern with the impacts of the many socio-demographic changes of the nineteenth century, (e.g. population growth, the emergence of democracy, capitalism, industrialisation and urbanisation). Yet, these changes were approached differently, depending on the principles of diverse intellectual traditions. For example, German rationalism and idealism strongly influenced German Sociology. American sociology, in comparison, was more influenced by positivism and the analytical Anglo-Saxon tradition.

Sociology is also a discipline that has retained a strong connection with its founders. In other social sciences, the classics have mostly historical value; in sociology, many important discussions are still traced back to foundational thinkers. It is thought that these thinkers are a source of both insights and inspiration for contemporary social issues. The contemporary relevance of the classics is due in part to the overarching character of grand theory that characterizes sociology's early days, but also to the fact that the lack of formalization of sociological theory allows constant reformulation of classical social theory. This particular trait of sociological theorization, where prior literature and developments are constantly reinterpreted and reformulated, has led to a constant reshaping of the tradition. There is widespread agreement in contemporary sociology on the foundational role played by Marx, Durkheim and Weber. However, the value attached to these and other early sociological thinkers has changed significantly depending on the place and time. During the first decades of the twentieth century, American sociology, for example, paid more attention to Comte and Spencer than to the three founding fathers, which were introduced later in the century. Likewise, early textbooks and articles gave the role of founding father to a great diversity of authors such as Adam Smith, who are no longer taken into account in contemporary sociology [3].

Despite its multiparadigmatic nature, some common and permanent topics in sociology can be identified. One of them is 'complexity', since sociology has always dealt with the ever increasing complexity of Western Societies [6]. For instance, for Durkheim [9] the distinctive aspect of modern societies was its organic structure of interactions brought about by the increasing social division of labour. For him, as the functional specialisation of the constituent social units begins to increase, the frequency of social connections or interactions also increases (what he refers to as

the *moral density* of society). In his words: "The division of labour develops ... as there are more individuals sufficiently in contact to be able to act and react upon one another. If we agree to call this relation and the active commerce resulting from it dynamic or moral density, we can say that the progress of the division of labour is in direct ratio to the moral or dynamic density of society" [9, p. 257].

For this classic sociologist, the internal differentiation of society (i.e. division of labour) produces more and more inter-dependence among the differentiated units. The increasing division of labour and the resulting inter-dependence of the units are what hold modern societies together. Durkheim's understanding of modern societies is similar to what is known today as *functional complexity*, a concept deriving from biology and a revived systems theory [32]. This concept relates complexity to organisational transitions and the evolution of new properties from the interaction of more basic or lower level units. Coveney and Highfield [8, p. 6] claim that "complexity is the study of the behaviour of macroscopic collections of (basic but interacting units) that are endowed with the potential to evolve." Unsurprisingly, Durkheim's theory has been influential for several contemporary thinkers who have lead the complexity turn in sociology and connected sociology with non-equilibrium sciences [36].

3 Sociology and Sociology and Non/equilibrium Sciences

The notion of equilibrium has not played the same role in sociology that it has played in economics. In economics, it has been historically linked to the analysis of price fluctuations derived from the interaction between supply and demand. It has been conceptually constrained within the boundaries of market dynamics and has led to the formulation of a formal apparatus that focuses entirely on the economic factors related to these dynamics. Thus, the concept of equilibrium has led to the identification of a few crucial relevant factors, in both classical political economy and the neoclassical paradigm, which allowed for the articulation of a formal apparatus for its study. In recent decades, some authors have reacted against the assumptions underlying this conceptual and methodological apparatus and developed non-equilibrium economics (e.g. [25]).

In contrast, the domain of sociology is wider and the conceptual and formal apparatus of economics has not penetrated into it. Sociologists considered that this apparatus could not sufficiently explain the constitutive, maintaining and dissolving dynamics of society as a whole. Instead, the foundational role played by the idea of equilibrium in economics has been, to a certain extent, played by the notion of *order* in sociology [1]. However, there is a key difference between the two concepts.

In its most general formulation, the inquiry around order is a hypothetical question about the emergence of society as such. This general approach is visible, for example, in Parsons' *The Structure of Social Action* [26]. Yet, 'Order' has been more commonly used to describe particular aspects of social dynamics that allow for the existence of social life. Attention has been paid, to name a few cases, on

whether order depends on the existence of social institutions (e.g. [33]), on how order emerges from the dynamics of interaction (e.g. [22]) and to whether a state of sociality is achieved by conflict or consensus (e.g. [21]).

The diversity in the approaches to what order is and how it is achieved and maintained has led to a more complex conceptualization of the emergent character of social dynamics. The question of the transition from equilibrium to non-equilibrium thinking is not easily answerable as there is no dominant theoretical-methodological framework in sociology. However, it can be asked of specific approaches within the field. Garfinkel's [12] ethnomethodology, for example, was developed as a micro-focused account of social order, in explicit opposition to the macro approach of Parsons' [27] structural-functionalism. The former examines how order is built from everyday interaction, whereas the latter investigates the maintenance of order as a system property. Ethnomethodology can be better at explaining the emergent nature of order, but it falls short in its account of the long-term dynamics of social phenomena. Structural-functionalism provides more tools to explain long-term dynamics, but lacks the tools to explain the formation and maintenance of order at the micro-level.

If NESS is taken in a wider sense to mean a shift to a focus on non-linearity, processes, mechanisms, emergence, computer modelling and so on, then it could be argued that a more significant departure from traditional mainstream sociology might be needed. Initially, the relationship between sociology and NESS in this wider sense, and complexity theory in general, is one of cross-fertilization. Several key concepts from NESS were introduced early in mainstream sociology. 'System' is the paradigmatic case. The concept entered sociology in the mid-twentieth century, thanks to Parsons, who was particularly interested in the newly developed fields of cybernetics and system theory. Subsequent developments in sociology, such as [18] work on autopoiesis, fed back to general system theory. In the same way, some sociological contributions, for example, to social network theory, have proved fundamental for the application of the complexity framework in social and general science.

In addition to this relationship of cross-fertilization, some contributions from classical sociology, such as Marx [5], Durkheim [30] and Foucault [24], have been reinterpreted through the lens of complexity theory, with the suggestion that there is common ground between their work and complexity theory. Yet, the fact that very different contributions can be interpreted as containing complexity thinking should serve as a warning of the issues that might arise when linking sociology and NESS in a wider sense. While it is true that sociology has a diverse theoretical-methodological foundation, the discussion about how much traditional sociology can inform complexity theory should always be approached critically. A critical stance is also needed because some of the philosophical principles put forward by NESS are not new in sociology. In its challenge to the traditional approach to abstraction and generalization in social science, NESS shares some of the philosophical principles of schools or movements that are rarely associated with complexity theory, such as postmodernism [7].

To summarise, sociology has not faced the same constraints and difficulties that economics has faced due to the latter's commitment to the notion of equilibrium. Although the more general focus on order and the low level of formalization have led to the development of several theoretical paradigms and sub-disciplinary areas that do account for some of the key features in NESS in the wider sense (e.g. symbolic interactionism and figurational sociology emphasize processes, and historical sociology emphasizes non-linearity and path dependence), there has not yet been a wide-reaching account that addresses them all together. However, more recent work in the study of complex social phenomena in computational sociology begins to address this issue through the prism of a specific methodological approach, namely, agent-based modelling.

4 Sociology and Agent-Based Modelling

Over the past 30 years, agent-based modelling (ABM) has increasingly been used in sociology as a research tool. ABM is a modelling technique well-suited to formalising and testing explanations of social dynamics. Explanations can be based on ideas about the emergence of complex adaptive behaviours from simple and local activities [2, 10, 14].

In comparison to alternative techniques, such as variable-based approaches using statistical or mathematical modelling, ABM allows modellers to simulate the emergence of macroscopic regularities over time from interactions of autonomous and heterogeneous agents [13]. In such models, individual entities, their decision-making rules and interactions are directly represented. The emergent properties of an ABM are thus the result of 'bottom-up' processes, the outcome of agents' interactions. The absence of any form of top-down control is a hallmark of ABM, since the behaviours and interactions at the agent-level bring about the observed regularities in the system. With this technique, sociologists can study properties of emergent orders that arise from interactions among a multitude of autonomous heterogeneous agents. And they can understand the ways in which such emergent orders influence or constrain the decisions and actions of the agents.

The interest in ABM also reflects the growing attention to complex adaptive systems and non-equilibrium sciences by sociologists; that is, the possibility that human societies may be described as highly complex, path-dependent, far-from-equilibrium, and self-organising systems [6, 20, 23]. Complexity theory and the accompanying trappings of complex systems provide the theoretical basis for ABM. For this reason, while modellers are usually interested in addressing specific theoretical questions and working in particular substantive areas, they almost invariably draw on complexity concepts when using an agent-based approach. Because agents' actions are not independent and agents are autonomous, it may be impossible to predict whether a system will achieve equilibrium. In these models, a continuous interplay between the emergent structures and the agents' actions takes place, altering the dynamics of the system and sometimes moving it towards unpredictable

states. Therefore, the emphasis on processes and on the relations between entities that generate macroscopic regularities, both of which can be examined by these models, accounts for the developing link between complexity theory, ABM research and NESS.

ABM involves two main components. Firstly, these models include a population of agents. The agents are the computational representation of some specific social actors—individual people or animals, organisations such as firms or bodies such nation-states—capable of interacting, that is, they can pass messages to each other and act on the basis of what they learn from these messages. Thus, each agent in the model is an autonomous entity. The artificial population can be heterogeneous with agents having differing capabilities, roles, perspectives and stocks of knowledge.

Secondly, ABM involves the definition of some relevant environment, the virtual world in which the agents act. It may be an entirely neutral medium with little or no effect on the agents, as in some agent-based models based on game theory, where the environment has no meaning. In other models, the environment may be as carefully designed as the agents themselves, as in some ecological or anthropological agent-based models where the environment represents geographical space that affects the agents' behaviour.

The use of ABM by sociologists has consolidated an emerging disciplinary branch: agent-based computational sociology [31]. In this subfield, one of the main objectives of ABM is to test, by experimental means, the hypothesised mechanisms that bring about the macroscopic phenomenon the researcher is interested in explaining. A mechanism describes a constellation of entities (i.e. agents) and activities (i.e. actions) that are organised such that they regularly bring about a particular type of outcome [19]. Therefore, sociologists explain an observed macroscopic phenomenon by referring to the mechanisms by which the phenomenon is regularly brought about.

In ABM these mechanisms are translated as the model microspecifications, the set of behavioural and simple rules that specify how the agents behave and react to their local environment (which includes, of course, other agents). Once the population of agents and the environment are defined, sociologists working with ABM can implement the microspecifications and run the computer simulation in order to evaluate whether these rules generate the macro phenomenon of interest, over the simulated time. The motto of ABM is, then: "if you did not grow it, you did not explain it" [11]. When the model can generate the type of outcome to be explained, then the researcher has provided a computational demonstration that a given microspecification (or mechanism) is in fact sufficient to generate the macrostructure of interest. This demonstration, called *generative sufficiency* [11], provides a candidate mechanism-based explanation of the macro-phenomenon. The agent-based sociologist can later use relevant data and statistics to gauge the generative sufficiency of a given microspecification by testing the agreement between 'real-world' and the generated macrostructures in the computer simulation. On the other hand, when the model cannot generate the outcome to be explained, the microspecification is not a viable candidate explanation of the phenomenon and the researcher has demonstrated the hypothesized mechanism to be false.

Note that, in this perspective, there is a sharp distinction between generative explanations and the mere description or discovery of regularities. It is not sufficient to identify, for instance, a statistical association between two or more variables. In ABM, what defines an explanation is the explicit representation, in computer code, of the underlying generative mechanism, which is a deeper reconstruction of the social regularity [16] agent-based models can be used to perform computational experiments that explore plausible mechanisms that may underlie observed patterns. That is one of the promises of ABM: given the limitations of experimental methods and the complexity of social phenomena, agent-based models are important for this kind of endeavour [17]. ABM allows systematic exploration of consequences of modelling assumptions and makes it possible to model much more complex phenomena than was possible earlier. ABM also allows more applied models to be developed. They have proved particularly useful in representing socio-technical and socio-ecological systems. In this mode agent-based models become policy models, with the potential to be of use in policy making.

5 Sociology and Policy

The relationship between sociology, the public arena, and policy-making has been a controversial one. The emergence of sociology in the nineteenth century crystalized a widespread disenchantment with modernity. As described above, early sociologists focused on the consequences of the major social changes of the eighteenth and nineteenth centuries. They were adamant about the necessity for an intellectual response to the social turmoil generated by these changes. The most distinctive character of this response was that it needed to come from the application of the scientific method. The implications of belief were not always conceived in the same way. Early positivism, for example, put forward a very radical approach. Comte [15] was particularly frustrated by what he thought was an unscientific discussion about social issues in the public arena. He considered this discussion should be discarded in favour of sociology, which should be transmitted to the public through the formal education system. He believed sociology, by unveiling the laws of social phenomena through the application of the scientific method, would achieve a truth status higher than any opinion about public matters. While Comte's radicalism found few followers, the alleged formative character of sociology's findings has been a distinctive trait of the discipline and one that has significantly influenced its connection with the public agenda. Sociologists have often operated with the idea that there is something about sociology that is of value to everyone, including those in charge of policy. This idea is grounded on two interconnected assumptions: first, that sociology provides 'useful knowledge' i.e. sociologists consider that the discipline is publicly relevant because it answers questions that people, including policy-makers, ask in their everyday life. The second assumption is that sociology, because of its scientific character, constitutes a key source of information for anyone interested in having an informed opinion about the social world [35]. These two

assumptions about the ubiquitousness and reliability of sociological knowledge, however, have not led to a fruitful relationship between sociology and policy.

Developing sociologically grounded policy is difficult for many reasons. From its earliest days, sociologists have been concerned with justifying the scientific character of sociology. This has not been easy because of the constant comparisons with more developed and established disciplines and the multiple obstacles for the professionalization of the discipline, e.g. departments of sociology were not common before the second half of the twentieth century. The conditions of professionalization are important in another way. On many occasions, the subject matter of sociology has been defined by highlighting the opposition between the roles of social scientist and politician. The former is allegedly meant to focus on the explanation of social issues, whereas the latter is meant to use these explanations in a pragmatic and responsible manner, in order to induce social change. A sociologist involved in policy issues would thus not be doing sociology, but politics [37]. This separation between the explanatory and pragmatic aspects of social science has led sociologists to be highly critical about the implementation of social science in policy, e.g. through economic models based on an instrumental and rational approach to individual action.

However, in the UK at least, this may be changing as the impact agenda creates new incentives for sociologists to engage with policy-making and the public sphere. The increasing popularity of NESS and particularly methods such as ABM offers hope to those wishing to see a greater influence of sociology on policy. ABM offers a more formalized form of knowledge that can appear familiar to policy-makers versed in the methods and language of economics. Many policy-makers, in response to the 2008 economic crisis, are in search of more nuanced understandings of 'the social' than those that neo-classical economics can provide. Moreover, the turn towards the language of participation in politics creates an expectation of actual participation. Methods such as participatory modelling, where stakeholders are brought into model development and evaluation, offer powerful tools for bringing together communities and the public into decision-making [4].

6 Concluding Remarks

This chapter addressed the relationship between sociology and NESS. It was argued that sociology is a multiparadigmatic discipline: different theories and methods coexist temporally and geographically. Thus sociology's relation to NESS depends on what one takes both to be. NESS, understood as a move from the formal apparatus for the study of equilibrium, does not imply a major shift from traditional sociological theory. However, if NESS is a shift towards complexity theory, then the relationship becomes less clear. Even though some complex features have long been articulated in sociological theorization, the discipline has not yet embraced the principles of NESS as a whole.

The chapter considered agent-based modelling as an approach that provides a more coherent inclusion of NESS and complexity into sociology. Finally, the relationship between sociology and policy-making was discussed. It was suggested that agent-based modelling is a method that can bring together the concerns of traditional sociologists and those interested in complexity theory, NESS and influencing policy.

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