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Abstract Complexity science and its methodological applications have increased in popularity in social science during the last two decades. One key concept within complexity science is that of self-organization. Self-organization is used to refer to the emergence of stable patterns through autonomous and self-reinforcing dynamics at the micro-level. In spite of its potential relevance for the study of social dynamics, the articulation and use of the concept of self-organization has been kept within the boundaries of complexity science and links to and from mainstream social science are scarce. These links can be difficult to establish, even for researchers working in social complexity with a background in social science, because of the theoretical and conceptual diversity and fragmentation in traditional social science. This article is meant to serve as a first step in the process of overcoming this lack of cross-fertilization between complexity and mainstream social science. A systematic review of the concept of self-organization and a critical discussion of similar notions in mainstream social science is presented, in an effort to help practitioners within subareas of complexity science to identify literature from traditional social science that could potentially inform their research.

Keywords Complexity · Self-organization · Social science · Order · Equilibrium · Social contract

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1 Introduction

Complexity science provides one of the most robust and overarching theoretical-methodological frameworks in contemporary science. It has developed the tools to study problems that were not amenable to classic scientific methods and has also provided a new way to look at many traditional problems (Holland 1995; Mitchell 2009). In social science[1], the interest in the complexity framework has been largely based on its potential contribution towards the understanding of the micro-macro link (i.e. the relationship between different levels of analysis) (Miller and Page 2007; Urry 2003). The field of agent-based modeling, for example, has taken advantage of the semantic and syntactic flexibility of computer languages and the information processing capabilities of current computers in order to shed light on the micro-macro transition by using computer simulations that behave in an analogous way to the phenomenon of interest (Gilbert 2008).

One key concept within complexity science is that of self-organization. Self-organization is used to refer to the emergence of stable patterns through autonomous and self-reinforcing dynamics at the micro-level (Skår 2003; Kauffman 1995). Simple studies such as Schelling's (1971) model of segregation or Axelrod's (1984) research on iterated prisoner's dilemma have become paradigmatic. In the former, segregation at the macro level appears as an unintended consequence of individual action, in the latter, cooperation is developed as an adaptive strategy because the traditional equilibrium of a one-off game works differently for the iterated version. What is interesting about these dynamics for social science is the connection between individual action and the result at the population level, for in many cases this connection is unknown or is misrepresented in traditional theory and research. This is due to the difficulty in dealing with the process of self-organization using traditional social methods, but also because of the technical and moral limitations that are present in social research.

In spite of its potential relevance for the study of social dynamics, the articulation and use of the concept of self-organization has been kept within the boundaries of complexity science and links to and from mainstream social science are scarce and rarely attempted (Cilliers 1998; Nowotny 2005). There are technical (e.g. computer programming is not found on the curriculum of the social sciences), disciplinary (e.g. social complexity is a field of inquiry in which researchers with all sorts of disciplinary backgrounds converge), and organizational (e.g. research on complexity usually requires a level of multidisciplinarity that goes against the traditional disciplinary division in academia) factors hindering proper cross-fertilization.

An additional impediment for the establishment of meaningful collaboration between those working in mainstream social science and social complexity is the wide range of theoretical traditions within social science. These theoretical

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[1] By 'social science' we mean those disciplines that account for dynamics on which a social institution results from the interaction of individual actors (e.g. individuals-markets), as well as those on which the micro level is constituted by social aggregates that produce a macro-pattern at a higher level of organization (e.g. countries-world system). It does not, however, account for cognitive and psychological processes, even though the concept of self-organization can be equally used to account for problems within these domains.

traditions can diverge in significant ways, sometimes hindering the fact that many have developed concepts similar to self-organization, but kept them constrained by clear disciplinary boundaries, which undermine the identification of potential valuable theoretical insights, even for a researcher with a background in social science.

Having these difficulties in mind, this article presents a review of different areas of inquiry in traditional social science that could provide important resources for those working in social self-organization within the complexity paradigm. It is intended to serve as a contextualization by mapping the explicit and non-explicit uses of the term in mainstream social disciplines. In order to do this, the article first presents a systematic review of the term 'self-organization' in social science, where explicit uses of the term are accounted for. This is followed by an analysis of the constituent terms, 'self' and 'organization'. Later, three foundational concepts in social science (order, equilibrium and contract) are discussed as examples of non-explicit uses of self-organization. The article finishes with a section on formalization issues in the study of social self-organization.

It is important to note that the aim of the discussion is not to put forward an exhaustive review of self-organization and similar concepts in the entire social science literature, so the reader might find omissions from a historical or disciplinary point of view. The aim is, instead, to present a critical and conceptual discussion that encourages the development of robust links between mainstream social science and social complexity. Given that the audience for the article are those working in the latter, the discussion centres exclusively on the literature from mainstream social disciplines. It is assumed the approach to self-organization by those working within the complexity paradigm is more homogeneous and relevant literature is easier to find. In order to facilitate the review, the analysis presented here focuses solely on the concept of self-organization, without addressing closely associated terms, such as complexity and emergence. It also avoids discussing the relevance, correctness or validity of the social science concepts identified as related to self-organization. The final goal is not to advance a generalizing model of self-organization in social science, but to provide a foundation for further theoretical and conceptual interdisciplinary connections.

The next section lists the main features associated with self-organization in complexity science. Section 3 presents the systematic review. Sections 4 and 5 disaggregate the concept on its individual components 'self' and 'organization', respectively. Section 6 examines three foundational concepts in social science related to self-organization: order, equilibrium and contract. Finally, Sect. 7 briefly discusses methodological constraints in the approach to social self-organization.

2 The notion of self-organization

The notion of self-organization has been more robustly articulated since its inclusion within the complexity framework, however, it should not be thought of as a subordinate concept. Self-organization has been a pervasive idea in scientific thought, with a longstanding subject of inquiry in different fields of knowledge

(Skår 2003; Capra 1996). The relation between self-organization and complexity should be seen more as one of cross-fertilization. The work of Nicolis and Prigogine (1977) on dissipative structures, for example, provided some of the philosophical foundations that allowed transferring the complexity framework, which had remained within the domain of physical systems, to biological systems, and, later, to social systems as well. In turn, it was the production on these latter fields which partly led to the realization that complexity should not be studied only in terms of structures, but also of processes.

References to the notion of self-organization can be traced back to foundational classical and modern thinkers, such as Heraclitus (Kirk 1951), Descartes (1968) and Kant (1952). Current accounts of self-organization, however, commonly refer to Ashby's (1947) work in cybernetics as the contemporary precursor. Although in the early decades of the twentieth century different authors in the natural, biological and social sciences focused on self-organizing dynamics, Ashby is acknowledged as the first one using explicitly the concept 'self-organization' in a somewhat similar manner to contemporary accounts, among other things, because of its strong emphasis on the mereological character of self-organizing dynamics in complex systems. The further advancement of the concept and its inclusion into the complexity framework took a few more decades and were fostered by additional theoretical-methodological and technological developments, especially advances in computing.

Because of the overarching nature of complexity science, there is an overabundance of definitions of self-organization. A monolithic definition is unlikely, as well as undesirable. Gilbert et al. (2015) suggest there are four factors that are common across definitions: pattern formation, autonomy, robustness and resilience, and dynamics.

The first factor is associated with the product of the process of self-organization. The literature on self-organization contemplates several kinds of patterns and ways to measure them; in social science, many of the patterns of interest are usually designated by nominalized verbs (e.g. cooperation, segregation, stratification, normalization, etc). Autonomy deals with the controlling force or mechanism behind the process. As the prefix 'self' suggest, the concept deals with processes without coordination or central control. Price setting is one paradigmatic example of a self-organizing process in the social domain, for it emerges from the interaction between offer and demand.

Robustness and resilience are used to suggest self-organizing dynamics display a level of stability over time and space that makes their identification possible. Robustness refers to a system's ability to resist change whereas resilience allows for change but refers to the system's ability to endure despite this change. In social science, robustness and resilience often require subjective criteria, associated with the role given to the different intervening factors. Take, for example, the case of a political system that experiences a coup. Robustness and resilience could be linked to the regime's ability to appease civil unrest or to the revolutionary forces' ability to overthrow the regime without significantly changing the normative framework. The two concepts need not match every time. If the revolutionary forces succeed, the system might be considered to lack robustness, for political discomfort was not

channelled through official mechanisms, eventually altering the regular operation of the system; yet resilient, because it does not totally dispense with prior political and social institutions.

Finally, dynamics refers to the processual part of the phenomenon. A self-organizing system will have variables and relations that vary in time; the analysis of the system is done considering this variability instead of focusing on the individual states. A well-known theoretical-methodological limitation in social science is accounting for spatio-temporal dynamics, this is the reason why new methodological approaches, such as agent-based modeling, have gained relevance in the study of self-organization in the social science domain.

3 A systematic review

Before diving into a deeper discussion of the links between self-organization, its component parts, and the connections with social science, it is useful to attempt to get a sense of the current use of the term in social science. To do this, a systematic review was carried out[2]. The basic aim of most systematic reviews is to use a well-defined, and transparent, search strategy to find published literature, and to use this literature to attempt to answer specified research questions.

Here, the aim is to provide us with a footing from which to understand the use of the term self-organization in social science. While it is not suggested the review is exhaustive, it does help to see the broad trends in the recent past. The aim in this section is not to critically assess the use of the term, but simply to describe *how* it has been used.

The key questions of interest in the review were:

1. How is self-organization used in social science? Is it used as a metaphor, or literally?
2. Are there any patterns in time, discipline, or approach in relation to the term's usage?

3.1 Strategy

The search strategy was as follows. The terms 'self-organization' and 'self-organizing' (and their British English equivalents) were used as keyword search terms in *Web of Knowledge*, *International Bibliography of the Social Sciences*, *Applied Social Sciences Index and Abstracts*, *EconLit*, *Sociological Abstracts*, *Worldwide Political Science Abstracts*, and *ScienceDirect*. Within these databases, where they included non-social science journals, filters were used to only include social science journals, using the databases' own definitions of this. For example, *Web of Knowledge* uses the tag 'social science' to refer to the list of disciplines

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[2] Petticrew and Roberts (2005) provide an excellent introduction to the use of systematic reviews in the social sciences.

defined within Thomson Reuters' Social Sciences Citation Index®, which can be found at http://ip-science.thomsonreuters.com/mjl/scope/scope_ssci/. Search results from prior to 1990 were not included, reflecting a focus on recent developments and the fact that the popularization of the concept of self-organization and its inclusion into the complexity paradigm only settled around this time (Skår 2003; Capra 1996)[3]. Only publications from peer-reviewed journals were included in the results.

The final selection of articles to be included was made based on the reading of the title of the article; where this was ambiguous, the abstract was used. The analysis of each article involved reading the paper, and recording key characteristics such as, a reader's summary, categorical codes for type of use, discipline of journal and first author, and methodology. Both the selection of articles from their title/abstract, and the analysis required to generate codes for type of use, required subjective judgements. There is potential for human error and bias to occur during these stages and affect the findings. To counter these risks and minimize errors, a rigorous practice of recording and checking was used when reviewing papers. In addition, transparency is maintained via the presentation of the full list of papers reviewed in the appendix to this article. The process of coding types of use of the term involved an evolution in the characteristics (i.e. codes) as the papers were read. This began with a basic metaphorical-literal split, and developed into the three uses described below. In total, ninety-four papers were found and used in the review. Whilst this list is intended to be complete given the specific search criteria outlined above, it is likely it has limitations in scope owing to quirks in authors' use of terminology and journals/databases' categorization processes, meaning some relevant articles may not be included in the review. However, it is important to recognize these omissions are unlikely to significantly affect the findings of the review, and the conclusions made on them.

3.2 Findings

When analyzing the final selection of papers, the way in which the term was used was coded. Three types of use were identified: terminological, analogical and literal. These are discussed here along the lines of their use.

When the term is used in a terminological way, it is not used in conjunction with any other concept from complexity science and has been arrived at independently of its use in complexity science. It is the basic linguistic meaning provided by the constituent words 'self' and 'organization' that inspires its use, rather than any reference to the concept from complexity science. Only "autonomy" is clearly present of the four characteristics of self-organization described above. This type of use is particularly popular in political science. The terminological use is common when applied to group/organization formation. Examples include the formation of 'special interest' groups (Virdee and Grint 1994; Humphrey 2000). In the sociology

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[3] By way of illustration, a simple search in *Web of knowledge* for the terms "self-organization" and "Complexity", filtered by periods 1950–1989 and 1990–2016, yielded the following results: "Self-organization", (1990–2016): 45269 hits; "Self-organization" AND "Complexity", (1990–2016): 1477 hits; "Self-organization", (1950–1989): 632 hits; "Self-organization" AND "Complexity", (1950–1989): 17 hits.

of science, when considering collaboration of scientists (Melin 2000), 'self-organization' is also used in a terminological way. The distinction is made between top-down managerial inspired collaboration and self-organized collaboration between researchers.

A second use of the term, the analogical use, appears in studies from geography on the spatial organization of societies and economies (Heikkinen 2009; Collinge 1999; Kotus and Hlawka 2010; Phillips 1999; Fujita and Mori 1998). Here, the term is used to describe the way in the which spatial organization of towns and cities occurs and changes. Again, no explicit acknowledgement of complexity science or the scientific background for the study of self-organization is made. However, there is a stronger presence of the four factors identified above, particularly "dynamics". Similarly, in management and its related disciplines, there are articles which apply the term to management situations. They suggest allowing and encouraging self-organization is positive for management goals. Examples include the management of hospitals (Clancy 2009) and alliances between firms (Pyka and Windrum 2003). The key difference between terminological and analogical uses is that in the analogical use process is taken into account rather than only considering self-organization to be a static characteristic of an entity.

A literal use of the term implies an explicit awareness of or reference to complexity science, adopting the four characteristics of self-organization described above (e.g. Bousquet 2012). There are no areas in social science were the literal use is widespread and established, but some authors are adopting this use in their work. The term and concept have been considered, for example, within the discipline of evolutionary economics, but the use varies from analogical to literal translations from complexity science (Foster 1997, 2000; Geisendorf 2009). However, the term is being knowingly taken from complexity science and applied in evolutionary economics; many articles refer to a shift from 'Newtonian approaches' to 'complexity approaches', showing a familiarity with, and sympathy to, the complexity literature.

There is a stream of literature that uses the term in relation to small group dynamics, and a particularly prevalent one around the emergence of leadership and decisions in small groups (e.g. Smith and Comer 1994; Plowman 2007). This comes from disciplines more aligned with psychology, and applies the term in a relatively literal way. However, it is still rare for the authors to explicitly refer to background complexity science or explore their use of the term. There is a related stream of literature on crisis management (e.g. Lehmann 2011) which applies the term to the process of response to crises, such as terrorist attacks or foreign policy situations. The suggestion in these literatures is that allowing these responses to self-organize is a potentially desirable policy goal.

Since 1990, there has been an increase in the number of articles using the term. However, this increase is not fast enough to become visible to a wide audience. This would suggest that whilst the use of the term is becoming more popular, it would be false to suggest its take-up is accelerating. This is an important point, as without exponential growth in the term's use, from such a small base, it is difficult to suggest that the concept, or indeed even the phrase, is being acknowledged in mainstream social science.

Two disciplines[4] clearly dominated the use of the term. These were sociology and economics. It would seem fair to conclude that the movement in economics from some researchers, away from neo-classical thought, has inspired a search for new concepts, of which self-organization (and more generally complexity science) has been a clear beneficiary. The reason for sociology having such a strong usage is less clear. There is the growing social simulation literature, but this is yet to really enter the mainstream. In terms of methodological approach, the most interesting result was the low level of use of the term in papers taking a traditional quantitative approach, when compared to theoretical or qualitative work. This difference is intuitive, in the sense that it is difficult for traditional statistical approaches to take into account 'newer' concepts, such as self-organization. However, this also serves to demonstrate the messy nature of the term's use, as it contrasts with a less pronounced difference in uses across the applied-theoretical spectrum.

Of those articles utilizing a formal computational or mathematical modeling methodology, most common was the use of models which could be classed as agent-based models, or simulations, defined in a broad sense. Within this broad classification there was diversity. For example, some use more traditional econometric modeling to represent agent decision-making (e.g. Focardi et al. 2002; Goldbaum 2006), some use game theory (e.g. Helbing et al. 2011), and some use genetic algorithms (e.g. Vriend 1995). These simulations also represent the environment in which agents operate in different ways; including grid structures (e.g. Braha 2012), and networks (Focardi et al. 2002; Kirman et al. 2007). Other approaches used included cellular automata Heikkinen (2009), and petri nets (Kohler et al. 2007). Finally, some articles used experiments with people (often undergraduate students) (Guastello 1998, 2010; Guastello and Al 2005; Zaror and Guastello 2000), and pedestrians (Moussaid et al. 2009).

The systematic review evidences that the popularization of complexity theory in general science has not led to the popularization of the concept of self-organization in mainstream social science. There has been an increase in the use of the concept. Yet, 'self-organization' is often used in the literature without a robust background framework that provides useful insights for further elaboration of the concept. To identify potentially relevant insights, it is necessary to look for implicit approaches to self-organization. The rest of the text critically discusses the prospective contributions and advantages of some of these implicit alternatives.

4 The 'self' family

The concept of 'self', as a noun, is of high importance for social science. It has been mainly used as a substitute for 'subject' in those areas emphasizing the cognitive aspects of the individuals' character and decision-making. As such, it is at the core of the idea of agency, which is the base for many schools of thought in social science. The study of self is carried out particularly in areas related to individuals, such as psychology, behavioural economics, microsociology and cultural

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[4] Defined using the author and journal disciplines.

anthropology. However, this use of 'self' is not connected to the idea of 'self' expressed in 'self-organization'. It is used for the study of the subject as an entity with no connection to process or dynamics.

'Self', as a prefix, is popular in a variety of disciplines. Examples include: 'self-realization' in psychology and theology to refer to personal development; 'self-determination' in politics and law to refer to personal freedom; 'self-constitution' from philosophy to refer to agency of the individual; 'self-governance' from politics and law (similar to 'self-detemination'), which may refer to various scales of groups' (families, communities, nation-states) autonomy; 'self-management', which in business and management refers to individuals ability to plan careers, tasks or 'executive processes', and in economics, politics and sociology refers to decentralized organizations of labour associated with socialist ideals; 'self-control' from psychology to refer to the ability of individuals to control emotions and behaviour.

This short list of examples shows the variety of entities and groups that can be represented by the 'self'. It can be applied to individual people and their cognition, small organizations and their management or entire countries and governments. Beyond this, the same terms can sometimes be used to apply to two or more of these levels—e.g. 'self-governance'. Concepts such as 'self-realization' or 'self-constitution' might be accounted for in a self-organizing way, but they focus mostly on the study of the individual and not social phenomena. In other cases, such as 'self-determination' and 'self-governance', the prefix may be used to emphasize a sense of independence of some relationships without a further analysis of the dynamics, neglecting the most important aspects of the process of self-organization.

Focusing on the literature on 'self' as a way to gain insights about self-organization in the social domain might pose significant challenges, for the study of the concept is not articulated as an area of study in its own right. This literature, however, is useful as the autonomous nature can be one of the most controversial aspects of the study of self-organization in the social domain. Most social phenomena are not free from the influence of top-down sources of control e.g. public policy. A narrow reading of the autonomy requirement in self-organization might lead some to argue there is no self-organization in the social domain. This view, however, misses the way in which autonomy in the social domain can be achieved, for example, through the informal adoption or fulfilment of formal regulations or requests. This becomes visible in the study of organizations, the second component of the concept, which will be addressed in the following section.

5 Organization

This section will provide a short introduction to the study of organizations, focusing on two key questions: (1) What are organizations? and (2) How do organizations change? As the article discusses the use of self-organization in mainstream social science, the section will highlight the aspects of the reviewed theories that contrast with the approach to self-organization in complexity science or have some similarities with it.

5.1 What are organizations?

Apart from the use of 'organization' in the common, dictionary sense, the most frequent use of 'organization' in social science is to refer to entities as diverse as companies, governments, clubs, secret societies and other similar groups. Having in common that they include many individuals and they are purposeful, giving a precise definition of 'organization' that can be used in any of social science is difficult, if not impossible.

First of all, 'organization' can be used in at least three different ways, adding 'organizing' to complete the four O's proposed by Hatch (2011). The four ideas can be categorized depending on their level of abstraction and whether the word is used to refer to something that *is* or something that *is becoming*. The matrix shown in Fig. 1 summarizes these uses.

This classification differentiates specific organizations from the abstract idea of an organization or, in other words, what Weber (1949) would call the *ideal type* of organization. The second dimension of this classification distinguishes between state and process, separating again a specific case of an organizing process, for example, the restructuring of a university department, from the idea of organizing as process that can be applied to some entity.

It is clear in the classification that, although referring to a specific social entity, the concept of 'organization' has something to do with the common, dictionary use of organization. By using the idea of 'arrangement' or opposing it to 'mess,' the use of organization to refer to this type of entity carries with it some sense of order.

The study of organizations is spread across different disciplines and some cross-disciplinary fields. Each discipline focuses on different aspects of organizations or has different concerns about organizations. For example, in psychology there are studies of how individuals behave and work in organizational environments, in economics many studies focus on the cost-efficiency of organizing and in

	Being	Becoming
Abstract	Organization (an entity) 'Organization is an arrangement of things, people ideas and/or activities'	Organization (the act of organizing) 'Most things improve with more organization'
Concrete	Organizations (specific cases) 'IBM, the Red Cross and your family are organizations'	Organizing (a process) 'Let's start organizing this mess!'

Fig. 1 Table showing a classification of the different uses of 'organization' and 'organizing'. Adapted from Hatch (2011)

management the focus is on the performance of organizational structures. These are broad generalizations as the study of organizations in each discipline is very diverse. Any attempt to characterize the way each field focuses on organizations would miss the richness of the different approaches and the interaction between disciplines.

Organization theory, organizational behaviour and organization studies are the names given to the three main cross-disciplinary fields concerned with organizations. There is a big overlap between these fields, with it being difficult at times to tell if some study belongs to one field or another. Also, the topics and focus of each field are not well-defined.

There are many classification of theories of, and perspectives on, organizations (Ott et al. 2011; Lune 2010; Hatch and Cunliffe 2012). Scott (2003) proposes three perspectives that sum up theories of organizations, based on their history and influence on current theories: rational, natural and open systems. Each of the perspectives represent more than one school of thought, but grouping them together in these categories provides a framework for the discussion of the theories they represent, as well as a way of highlighting their similarities and differences.

The rational systems perspective considers organizations as groups with explicit goals and high levels of formalization (Taylor 1911; Fayol 1949; Womack et al. 1990; Weber 1947; March and Simon 1958). In this view, the behaviour of the participants is oriented to that goal and constrained by the formal structure of the organization. In the matrix above (Fig. 1), theorists using this perspective favour the 'being' column, organizations are considered entities and not processes, and there is a strong emphasis on the role of managers. The organization is not the result of individual actions by its members but the outcome of decisions made by managers.

With the same emphasis on organizations as entities and the role of managers, the natural systems perspective adds a new dimension to the study of organizations (Mayo 1945; Barnard 1938; Selznick 1949; Parsons 1947). Considering organizations no different than other social collectivities, the same forces that affect other collectivities will be present in organizations. Thus, theories proposing that organizations are formed by consensus or from conflict will both appear in organizational studies. Key to this perspective is that it considers the participants to have their own goals, separate from the goals of the organization. Thus informal structures become more important to understand organizations. This perspective still emphasizes the role of managers, with a top-down view of organization, and attention is given to the state and not the process. Yet, the acknowledgement of informal structures as influential in the organization becomes a step towards a process view of organizations as well as the beginning of a bottom-up approach.

The last perspective, the open systems perspective, comes with the acknowledgement that organizations are embedded in a context and that, even when boundaries may be well-defined, there are flows of interaction between the environment and the organization (Mintzberg 1979; Galbraith 1973; Weick 1995). While in the previous perspectives organizations were seen as isolated units, a closed system with limited or no influence from the outside, in this perspective they are considered as systems with open boundaries. Considering organizations as open systems is not only a consequence of the requirements or pressures that the environment imposes on the organization; it is also a consequence of members

having their own goals in addition to multiple loyalties and identities: members can belong to different organizations.

Theorists using an open system perspective consider organizations as a "system of interdependent activities" (Scott 2003, p. 29). Beyond the distinction of formal and informal activities, the focus is on the activities and how they are produced and reproduced. The perspective allows for a process view of organizations and, although in some cases a top-down view is used, a bottom-up approach based on the interdependent activities and the participants is possible.

Generally, the first two perspectives have been characterized as understanding organizations as entities and focusing on states rather than processes while the last perspective was characterized as the opposite. In many cases this may hold true, but both sides must be understood as the extremes of these categories and many theories will fall in between. In the same way, the three perspectives provide a simple categorization device which may not fit perfectly to describe the variety of theories in organizational studies.

5.2 How do organizations change?

Another way of understanding how organizations are perceived in social science is to look at how organizational change is considered. Although the first theorists adopted a static view of organizations (March and Simon 1958; Womack et al. 1990), associated with the rational system perspective, organizational change has been studied as an intrinsic part of organizations.

Demers (2007) proposes that organizational change theories can be divided in three chronological periods. In each period there are many schools, sometimes opposing each other. Despite the differences, schools from the same period share some similarities and also influence the next period's theories. Being chronologically ordered does not mean they are obsolete, many of these theories are still accepted and used decades later.

The first period goes from the 1930s to the 1970s. Due, in part, to the economic growth of the postwar era, theorists of this period were optimistic about change and saw it as equivalent to growth or expansion (Starbuck 1971). The theories of change they produced were similar to those of punctuated equilibrium in evolutionary biology (Eldridge and Gould 1972) in that organizations were seen as stable entities that went through delimited periods of change. The focus of these theories was not on change itself, that is, the process of change, but on the differences between the states before and after the change. As with the rational theories of organization, the role of managers is emphasized: Managers are in charge of change.

Two schools predominate in this era: voluntarism (Child and Kieser 1981) and environmental determinism (Hrebeniakand Joyce 1985). Although they agree in many points, the main difference between both schools is what each consider as influencing change. While theorists on the voluntarism side saw change as coming from within the organization, on the environmental determinism side they consider the environment to have a more significant influence on change.

The second period, going from the 1970s to the 1990s, still uses a punctuated equilibrium approach in many cases but the focus is now on the process of change

and not the difference between before and after (Miller and Friesen 1984; Tushman and Romanelli 1985), although theories of incremental change are beginning to be introduced. In general, change is no longer a synonym for growth, as in the previous period, but something to be avoided altogether. Managers are still in control of change, they decide how to react to changes in the environment, but there are new aspects to be considered that are beyond the rational perspective on organizations. In the same way that the natural systems perspectives included other human and social aspects in organizations, this second period is characterized by new approaches to the study of change that include the cognitive (Walsh 1995), cultural (Gagliardi 1986; Meyerson and Martin 1987) and political (Kanter 1983; Pettigrew 1985) dimensions of organizational change.

In both periods there are some theories that advocate for a bottom-up perspective on change (Demers 2007; Ranson et al. 1980), or at least challenge the view that managers can influence change on their own. In the first period, proponents of the environmental determinism are clear that the environment determines which forms of organization will survive, so it is not managers who define change but the environment and their options are limited to what the environment would accept. In the second period, there is a discussion between supporters of the managerialist-functionalist perspective (i.e. those who consider managers able to transform organizations deliberately) (Gagliardi 1986; Schein 1985) and the organizational-interpretive perspective (i.e. those who consider change as an organizational phenomenon and not limited to managers' decisions) (Meyerson and Martin 1987; Hatch 1993).

As with the previously defined perspectives on organizations, it is the third category or period that opens up to a dynamic view of organizations. In the third era, from the late 1990s until today, change is viewed as episodic but ever-present in organizational life, with no clear beginning or end. The focus is now on the dynamics of changing, especially on themes such as evolution, learning and structuration. Most research from previous periods dealt with the management of change, in the new period researchers have been looking into the increasing organizations' ability to change.

The main division of this era is not between managerialists and environmentalists as before, but between theorists using approaches from the natural sciences, for example, evolution (Aldrich and Ruef 2006), behavioural learning (March 1991) and complexity (Anderson 1999), and those using approaches from the social sciences and the humanities: radical (Hardy and Clegg 1996), postmodern (Alvesson and Deetz 1996), discursive (Brown and Humphreys 2003; Doolin 2003) and practiced-centered (Brown and Duguid 1991; Engeström 2000) approaches. On either side, bottom-up and top-down perspectives are considered, and a great deal of effort has been put on understanding the links between agency and structure.

Although there are few explicit references to self-organization in organization theory, except in the study self-managed groups or groups with a flat hierarchy, it appears that there is a trend in the study of organizations and organizational change towards a dynamic, self-organizing view. As stated in the introduction, self-organization is the emergence of stable patterns through autonomous and self-

reinforcing dynamics at the micro-level. In both areas, organization theory and organizational change, the new understanding is that organizations (stable patterns) are the result of the actions of its members that act based on their perception and their circumstances (autonomous) recreating the order perceived in the organization (self-reinforcing).

There are still some problems to be solved in organizational research, and generally in social science, to adopt explicitly the self-organization perspective. For example, the autonomy of the agents can be contested because there are asymmetric power relationships within the organization. In any case, the purpose of this section is not to defend organizations as self-organized systems but to provide an explanation of what is meant by 'organization' in social science.

6 Existing social science concepts

In a similar fashion to organizational studies, other interdisciplinary fields emerged during the late twentieth century, such as the new institutionalism (March and Olsen 2006), are likely to provide important insights for practitioners working within social complexity. Ostrom (1990) famous work on commons, for example, was advanced from within this latter framework and has deeply impacted the game theoretical approach to this topic. These relatively novel fields benefit from their interdisciplinarity. Practitioners are usually not constrained by traditional mainstream theoretical-methodological traditions and are more prone to explore new paradigms, including complexity theory and self-organization.

While most explicit references to 'self-organization' are likely to be found within relatively new interdisciplinary areas, traditional social disciplines can also provide important insights. There are, on one side, a few works that explicitly address the problem of self-organization, but barely made it into the mainstream, such as Luhmann's (1995) work on self-reference and autopoiesis, where self-organization is addressed under the general question of how social systems reproduce themselves over time. There are, on the other side, some works that cannot be so easily identified because the approach to self-organization is made implicitly and might not be as robust as the contemporary approach.

This section focuses on these implicit approaches to self-organization. It describes popular social science concepts that have historically dealt in different ways with the four features of self-organization described in the first section. Three concepts were chosen for analysis: equilibrium, contract and order. This is due to their foundational role in economics, politics and sociology, respectively. The analysis is not meant to imply that it is only through these concepts that the aforementioned disciplines have approached the problem of explaining self-organizing dynamics. It is put forward in order to show that concerns about self-organization, or at least some features of it, are longstanding in traditional social science. The analysis is not meant to be exhaustive regarding relevant authors or particular approaches to these concepts. It, instead, traces the general evolution of the concepts within the particular discipline.

6.1 Economics, equilibrium and strategic decision-making

The reference to equilibrium as a source of literature on self-organization might seem confusing, for literature on complexity science and self-organization usually emphasizes that these systems are in a state of non-equilibrium. Yet, the notion of equilibrium that has permeated complexity science comes from thermodynamics, not economics. While the theoretical-methodological assumptions in both cases are similar, the acknowledgement of the complex character of social phenomena has not led to the replacement of traditional equilibrium-based economics, but has instead resulted in the development of several, scattered sub-areas, such as non-linear economics and evolutionary economics.

The evolution of the concept of equilibrium in economics is interesting for it is a paradigmatic case of the transition in focus from macro to micro factors in the study of self-organizing social phenomena. The focus on markets in modern economics is linked to the particular historical and geographical context of the emergence of capitalism and the subsequent development of national economies in Europe (Gordon 1993). Classical political economy dealt with markets in terms of price fluctuation, derived from the interaction between offer and demand. The assumption that prices allow the achievement of a balance between offer and demand became the core principle of modern economics. The notion of auto-regulated free markets, depicted by popular concepts such as 'the invisible hand', provided the very foundation of the connection between economic thought and self-organization (Tribe 2003).

Classical political economy explores the structural and operational features of the factors of production in a market economy, usually land, labour and capital. Equilibrium was understood as the aggregate operation of these factors. Full employment, for example, could always be attainable because it was thought a situation of unemployment would be followed by a fall in wages, which would eventually increase the demand for labour and restore the initial situation of full employment. The conviction on the self-regulating nature of supply and demand was strong and even taken to other domains. It led Malthus (1993), for example, to suggest in a popular essay the natural tendency towards demographic equilibrium. While the notion of equilibrium was mostly approached from a macro perspective, individuals were the centre of attention in classical economics. Macro was always seen from an aggregative perspective.

This macro approach changed with the advent of neoclassical economics (Tribe 2003). The neoclassical approach relies on the previously developed theory of value i.e. the definition of how commodities acquire their price (Gordon 1993). In classical theory, value was closely associated with the amount of labour involved in the production of the commodity. Neoclassical economics changed the focus on the analysis of equilibrium by suggesting value is associated with individual perceptions. Commodities are thought to satisfy specific desires, there is a perceived utility in consuming them.

Different assumptions for equilibrium are introduced in the neoclassical case. First, individuals are assumed to be maximizers, both at the consumption and the production end. While the former wants to maximize utility, the latter wants to

maximize profit. Second, to guarantee maximization, two additional assumptions are introduced: agents are rational and have perfect information. The emphasis on individual decision-making, popularized especially by neoclassical economics, has provided a way to understand self-organizing phenomena, such as the market, in a bottom-up way, as the result of intentional decision-making.

The intuitive appeal of this assumption, along with the powerful methodological framework developed for the study of equilibrium, has led to the expansion of the neoclassical thinking to other areas of social research, for example, in the form of rational choice theory. The analysis of equilibrium has developed into a large and robust analytical framework that has set the foundations for several interesting findings regarding social self-organizing phenomena, such as the free rider problem (Hardin 2013). It has, however, also led to important miscategorizations, such as labelling collective action irrational or deviant (e.g. Olson 1971).

The high degree of abstraction and formalization in the study of equilibrium developed by neoclassical economists is perhaps the reason the discipline, unlike thermodynamics or complexity theory, has not totally dispensed with the concept. Contemporary approaches occasionally link back to the neoclassical formulation of equilibrium or employ specific formal formulations e.g. Nash equilibrium in game theory. In cases where the discussion involves theory and philosophy, the notion of equilibrium also plays an important heuristic role. Both Hayek (1949) and Schumpeter (1939), for example, critically discuss the dynamic and autonomous character of the neoclassical notion of equilibrium, in a manner that is compatible with contemporary approaches to self-organization. While their accounts differ from the mainstream neoclassical approach, they did not give up the concept of equilibrium.

This persistence of the concept, to a certain extent, hinders the theoretical and methodological diversity of contemporary economic approaches to self-organization. In latter decades, for example, an important effort has been carried out in economics and other areas in order to relax the basic cognitive assumptions, and therefore achieve greater realism regarding strategic-decision making. The literature on this subject, especially produced within multidisciplinary areas, such as behavioural game theory (Gintis 2009) and experimental behavioural economics (Caremer 2003), could provide novel resources for someone interested in decision-making aspect of social self-organizing phenomena, due to the increasing emphasis on the use of experimental methods.

The inquiry on decision-making allows for a more diverse approach to the patterned character of social self-organizing dynamics. This diversity in decision-making heuristics is a fundamental driver, for example, in the research on agent-based modeling, game-theory and network theory. The patterned nature of self-organization is explored by analyzing the impact of heterogeneity and different agent architectures, ranging from reactive to cognitively robust decision making-heuristics.

The exploration of the link between equilibrium and decision-making also provides important insights on the other three major factors of self-organization, either through theoretical or methodological developments. The increasing use of agent-based modeling and iterated games, on one hand, have facilitated the study of

dynamic and autonomous character of self-organizing phenomena due to their methodological features. The work on evolutionary economics, on the other hand, has imported some of the theoretical apparatus from biology to deal with the implications of feedback on equilibrium dynamics (Beinhocker 2007), providing important insights regarding robustness and resilience.

6.2 Political theory, social contract and the moral foundation of action

The contemporary notion of contract in social science can be linked back to the social contract tradition, a key school of thought in modern political and moral theory. Social (e.g. English Civil War) and philosophical (e.g. Enlightenment) changes in the 17th and 18th centuries provided the basis for the discussion on the moral foundations of the social and political order. This discussion was based on the realization that the state was not a pre-established form of government whose foundations were abstract or founded on divine will. Contractualism emerged as an inquiry about the legitimacy of the state, rooted in the increasing acknowledgement of the agential power of individuals. The notion of "contract" was put forward specifically to deal with the way political institutions are articulated through the interaction of autonomous agents (Kramnick 2010).

It is usually considered there are two main versions of contractualism. The first version, advanced by modern political thinkers, such as Hobbes, Locke and Rousseau, explores the way human nature affects the development of political institutions. The first of these accounts is put forward by Hobbes (1988) in his work *The Leviathan*. According to Hobbes, individuals are rational and self-interested by nature, and they will do everything in the pursuit of their desires. Hobbes hypothesized a state of nature in which all individuals have equal right to everything. This, he said, leads to a 'war of all against all', where individuals have to live in constant fear of death. Hobbes claimed the state would emerge as a result of the agreement of rational individuals aiming to avoid their own death.

Subsequent formulations of the social contract made a different use of the hypothetical notion of the state of nature. In Locke (2004), individuals are also free but there is a moral condition of mutual respect. Despite this condition, Locke concedes the possibility of war, especially over property. The state, thus, in Locke's view, emerges as a way to prevent war from escalating.

Finally, Rousseau's contract theory (1968) explores the implications of the state of nature in a two-stage approach, which is first naturalistic and then normative. The former accounts for the transition from the state of nature to the conditions of his time; the latter for the transition from those conditions to a proper form of government. Like Locke, Rousseau considers a morally grounded state of nature, but suggests vice and inequality are introduced as a normal result of the increase of population, division of labour and, especially, the creation of property rights. He suggests these unequal circumstances can be overcome by the acknowledgement of freedom and equality that every individual is entitled to. This acknowledgement will, eventually, lead to a democratic form of government.

Moral agreement constitutes the basis for the second type of contractualism. It can be traced back to Kant (2002), but it is more widely espoused in the twentieth

century contractualism. In these accounts, the discussion moves to the moral domain. Contractualism becomes an inquiry about the moral foundations and justification of interpersonal agreement. Political institutions are also one of the main focus, but moral contractualism is equally applied to circumstances where interpersonal agreement is needed, such as gender and race (Pateman and Mills 2007) relies on the hypothetical notion of the state of nature, but has focused more on the 'rules' of transition (e.g. Rawls' (1977) two principles of justice or Gauthier (1987) neo-Hobbesian game theoretical approach).

As with equilibrium, the notion of social contract also emphasizes individual decision-making. Hobbes' concept of rational egotistic actors, for example, significantly influenced methodological individualism in social science (Udehn 2001). However, the most important contribution of the literature on social contract is the hypothetical notion of the state of nature, because it has provided an important way to deal with the micro-macro character of the patterns produced by self-organizing phenomena. The current notion of emergence, which is fundamental for the theoretical-methodological apparatus of complexity theory (Miller and Page 2007; Goldstein 1999; Holland 1995), is basically a later and more general reformulation of the notion of contract. Emergence, like contract, is an inquiry about whether patterns, which are usually described as structures or institutions, can emerge from a state of non-sociality.

The dynamics of emergence and self-organization are usually thought to depend on initial conditions and particular properties of the interacting entities. Regarding the latter, because of the rationality and reflexivity typical of human beings, there is more diversity in the resulting patterns. This diversity is appropriately reflected by, for example, the different pay-off structures in game theory. Simulation and experimental methods, on the other hand, help providing some insights on the initial conditions.

The research on social contract, however, stresses some aspects that are not fundamental for the research on emergence and self-organization, because they are specific to the social domain. In real situations, rationality and reflexivity could derive in non-fulfilment of the contract or in social conflict aiming at the renegotiation of the contract (Hampton 1986). These aspect are not so easily addressed methodologically. Games, for instance, depend on compulsory turn-taking. Non-participation might just lead to the dissolution of the social dilemma the game is supposed to represent. Likewise, most games do not contemplate modification of the pay-off structure over time, for this also has important implications on the representation of the dilemma.

The personal conditions that allow for agreement have also been a common topic in the social contract tradition. There are discussions on whether, for example, agreements are reached on conditions that everyone agrees on or conditions that no one could reasonably reject. Both approaches, at the same time, depend on whether individuals are assumed to be self- or other-oriented and whether other-orientation is based on positive or negative emotions and sentiments (Superson 2009). Again, some of these differences are not so easily grasped methodologically. One valuable contribution of experimental methods, for example, is the emphasis on other-oriented preferences (Gintis 2009). Many of these developments have yet to have

major theoretical-methodological impacts. In games, for example, cooperation and trust are usually used interchangeably, although the latter implies specific cognitive and emotional traits that are not necessarily present when the former occurs (Yamagishi et al. 2005).

The exploration of the underlying foundations of social agreement leads to relatively independent lines of research, depending on whether the emphasis is on the properties of the interacting entities of on the initial conditions i.e. human nature or state of nature. This is visible, for example, in the methodological agenda of agent-based modeling. In its most basic sense, a social institution is a regular pattern of action (Seumas 2012). In agent-based modeling, some of these regular patterns have usually been studied using the label of "norm". Two major approaches can be identified: The first one focuses on the dynamics of emergence of norms (e.g. Axelrod 1986), the second one, on cognitive moral agents (e.g. Conte and Castelfranchi 1995). This distinction mirrors to a certain extent the two types of contractualism.

While interesting developments have been produced independently on these areas, such as Axelrod's (1984) results on cooperation for the iterated prisoner's dilemma, there is one clear advantage of bringing the two traditions together, which is a relatively recent concern (Neumann 2008). As mentioned, contractualism approaches social institutions from the perspective of a coordination problem that relies on individual adhesion to the agreement. Yet, the moral component also accounts for dynamics of alienation during the contract and dissolution or separation. Dynamic approaches do not focus on justification or endogenize it (e.g. Skyrms 1996) evolutionary approach to the selection between multiple equilibria. Cognitive approaches, on the other hand, do not put enough emphasis on the dynamical character of contract. A further exploration of the problems addressed in contract theory can give important insights on how robustness and resilience are linked to autonomy and dynamics in self-organizing social phenomena. Deciding on whether a self-organizing dynamic is resilient or robust depends on the conceptual scheme imposed by the researcher, which is, at the same time, connected to the normative scheme used by the individuals involved in the phenomenon of interest.

6.3 Sociology, order and interaction

The concept of order has one of the most important theoretical roles in sociology. 'Order' is usually taken as the focus of the discipline (Hechter and Horne 2003). There is not, however, a widespread definition. This is because the concept does not play a definitional, but a heuristic role. 'Social order', in most cases, equates to 'society', but society, at the same time, could refer to second level or formal institutions, individual practices, the material production of humanity or, simply, a stable situation of 'sociality'. From all these different perspectives, sociology explores the foundations of constitutive, maintaining or dissolving social dynamics. Except from the grand theories of the classics, however, all of these aspects are rarely addressed together. Most contemporary authors refrain from postulating an all-encompassing approach to social order. In turn, unlike equilibrium, sociology has not developed a robust formalization for the analysis of order.

The way different factors are weighted and accounted for when dealing with social order in sociology relies on particular assumptions regarding traditional social dualisms e.g. micro-macro, subjectivism-objectivism, agency-structure, free will-determinism, etc. The observational fact that there is society can be tackled theoretically in several ways. The social order is usually taken to be more than a mereological problem, that is, more than a simple aggregation of individuals, but the question of what else there is beyond aggregation has been answered in different ways. In general, approaches to social order in sociology can be classified in three broad types:

(1) studies of individual intentional action, where the base of sociality is the fact that some individual actions are oriented towards others;
(2) studies of sociality as the result of the adoption or recognition of norms and values;
(3) studies of centralized forms of coercion, e.g. the military or ideology, that maintain sociality with top-down mechanisms.

Some theories fall over more than one category. Parsons' (1991) structural-functionalist theory, for example, is usually identified within the second category because of his idea of functional auto-regulation of social systems. Yet, his theory is strongly rooted in the notion of voluntaristic individual action, which would qualify within the first category (Parsons 1949).

Sociological explanations of the type (1) above are usually put forward by methodological individualists e.g. Coleman (1990), Homans (1951) and Weber (1978). Some of these accounts are popular beyond the sociological domain because they are more readily available for methodological implementation in action-based approaches, such as game theory or agent-based modeling. The sociological approach to social action, however, is distinctive in that it has usually produced more robust accounts of action, either by emphasizing the structural implications, usually unintended, of individual action (e.g. Merton 1936) or by critically revising the principles of rational action approaches that dominate other social disciplines. Sociologists are particularly skeptical of instrumental, hyper-rational and exclusively goal-oriented forward-looking approaches to action (Joas 1996; Stones 2009).

These two distinctive features of sociological accounts of social order translate into an approach to self-organization that pays particular attention both to the patterned character that results from this action (e.g. Simmel's (1971) notion of social differentiation), as well as the cognitive processes that underlies the conceptualization of action as the building block of interaction and not just as a one-off event (Mead 1972). Theoretically and methodologically, interaction has usually been taken as a special case where action is oriented towards others. Yet, interaction requires a particular form of coordination that is grounded on some sort of mutual recognition. Realization of the need of this recognition is what eventually led Parsons to move from an action to a normative theory.

The coordinated nature of interaction is what makes types (2) and (3) above interesting for the study of self-organization. These views could be useful for the study of self-organizing dynamics in the social domain, for in (1) structural

constraints are usually neglected or endogenized. In game theory, for example, turn-taking, one of the simplest features, is one of this endogenized structural constraints for which social theory should, in principle, try to find explanation (Fararo 1984).

Normative sociological approaches are usually criticized because they allegedly introduce some form of top-down control that would prevent order from developing autonomously. Yet, that is only the case if the cognitive and structural demands for the social coordination underlying interaction are high. Micro approaches focusing on the experience of order as everyday life, such as ethnomethodology and phenomenology, tackled this problem of accounting for the nature of social interaction from an interesting perspective. These theories highlight the fact that people go about everyday life without constantly considering the foundations and regulations of social order (Garfinkel 1967; Schütz and Luckmann 1974). Yet, this order is fragile as it is constructed on everyday life interaction (e.g. Garfinkel's (1967) breaching experiments). People become aware of this order when it is disrupted and they have to consciously deal with it. This sociological literature on order can give insights in how shocks and disruptions are accounted for, which, in the study of self-organization in the social domain, can help in understanding resilience and robustness.

A focus on the normative character of interaction, associated with (2), can also provide valuable insights into the different factors affecting the conceptualization of order, beyond the conceptual character of a society's normative scheme. Durkheim's (1987) work on anomie, Simmel's (2004) work on estrangement and Goffman's (1990) work on the presentation of the self, for example, are all accounts connecting normative concerns about order with non-human factors, such as space, both social and physical. These social-physical connections have not been traditionally explored in social science, mostly because of theoretical-methodological restrictions e.g. most information about the social domain comes from personal surveys and data. It is clear, however, that some of the patterns displayed by social self-organizing phenomena are closely linked with non-social aspects. The effect of these aspects should not be underestimated. The mechanism of speciation in biology, for example, was identified as an independent process only after the spatial dimension of selective reproduction was accounted for (Mayr 2002).

Accounts of order of the third type, (3), could provide important insights about how autonomy operates in contexts where individuals can articulate and interact with second order institutions. Hegemony, for example, has an important component of diffusion, which has become an important topic in the study of self-organizing social dynamics. Research on diffusion dynamics has focused mostly on opinion formation at the individual level. Deviating effects have been accounted for mostly by features such as reputation. This neglects the fact that central institutions could have particular well-defined agendas. The implications of the participation of powerful institutions with hegemonic agendas in the diffusion landscape have not been explored thoroughly (Afshar and Asadpour 2010; Hegselmann and Krause 2002). This inter-level interaction is present in many areas of the social world. The challenge is understanding whether this inter-level interaction operates as a top-down form of control that thoroughly determine interaction, so as to prevent from calling the phenomenon autonomous.

The notions of equilibrium, contract and order deal in particular ways with the four crucial factors of self-organization, depending on the theoretical-methodological frameworks of the disciplinary domains in which they are used. It is important, first, to be able to reconstruct the theoretical insights of these traditions regarding self-organizing dynamics and, second, to understand how these different traditions can complement each other. Because of the reliance of economics on individual strategic decision-making, for example, the notion of equilibrium provides important insights regarding the notion of autonomy. Yet, as discussed, this tradition has neglected the moral foundations of action, which is a crucial aspect of the notion of contract, or how different top-down mechanism can also affect self-organizing dynamics, which is one of the focuses of the notion of order.

7 Formal models of social self-organization

Advances in the study of self-organizing phenomena depend greatly on how effectively these theoretical insights can be incorporated into formal computational and mathematical models. Not every insight can be formalized and, in turn, not every model can give full account of the four factors of self-organization: pattern formation, autonomy, robustness and resilience, and dynamics. In social science, one major difficulty is the dynamic aspect of self-organizing phenomena. The study of self-organization in the social domain is hindered by the lack of longitudinal data. Technical, economic and moral difficulties posed for the collection of this data gives computational methods, where artificial data is created, a key role.

The use of different computational methods brings to the fore the question about the patterned character of self-organization. The definition of 'pattern' is closely associated with disciplinary traditions. It depends on the nature of the object of study, along with the background theory and method employed to analyze it (Gilbert et al. 2015). Artificial data created by some computational methods, such as system dynamics, account for self-organizing phenomena in a similar way to traditional longitudinal methods regularly used in mainstream social science, either from a quantitative (e.g. time series, event history, duration and cohort analysis) or qualitative (e.g. process tracing, narrative and qualitative comparative analysis) standpoint. These methods account for the patterned character of self-organization through the identification and reconstruction on causal paths or trajectories, usually represented in different coordinate systems, such as time series or phase and state spaces.

Other methods provide a different approach to the patterned character of self-organization, through a focus on the spatial and emergent character of self-organizing social phenomena. The urban layout of cities, for example, has traditionally been a recurrent topic on discussions about social self-organization and complexity theory, in general (Urry 2003; Johnson 2004). Awareness on the spatial dimension is important because it can significantly affect the approach to the dynamic aspect of self-organization, which could translate in important variations in modelling choices. O'Sullivan and Perry (2013), for example, put forward a typology of spatial models, divided in three major categories: Aggregation and

segregation; Random walks and mobile entities; and Percolation and growth. While simple lattice models, such as cellular automata, for example, are clearly suitable for the analysis of the clustering produced in dynamics of aggregation and segregation, they are poor alternatives for the exploration of random walk dynamics. Interest on the spatial dimension of social self-organization has also led to increasing use of hybrid methodologies, combining, for example, different forms of simulation, such as agent-based models or microsimulation, with geographic information systems (Heppenstall et al. 2012).

Mathematical, computational and hybrid methods allowing for the analysis of interaction over time (e.g. agent-based modeling, dynamic network analysis and iterated games) link macro patterns with interaction at the micro level. This linkage provides a distinctive view on the autonomous character of the phenomena, which cannot be fully explored by methods focusing of causal paths or trajectories, for these methods usually lack an explicit representation of the relationship between the system and its subcomponents. The focus on interaction could also allow for a different exploration of the robustness and resilience of the system, for example, by introducing in a computer simulation some evolutionary dynamics e.g. learning or genetic algorithms, or through the experimental manipulation of the simulation parameters while the simulation is running e.g. suddenly reducing the amount of resources available.

Those methods based on explicit representation of agents or actions could differ significantly depending on the intricateness of the agents' cognitive structure. Agents could be treated like atoms (e.g. Chakrabarti et al. 2006), which either lead to straightforward interaction dynamics or allow for a stronger emphasis on the connection between those agents e.g. social networks. From there, increasing degrees of cognitive complexity have been proposed by several authors working on the fields of computer science, cognitive science, artificial intelligence and social science (see Balke and Gilbert (2014) and Shafir and LeBoeuf (2002) for reviews in computational and social science). These different cognitive structures could have an important impact on interaction and, hence, the pattern formation on self-organizing processes. Methodologically, the cognitive features of the agents might be the most important topic in the analysis of social self-organization. First, because of the large diversity of options in terms of modelling cognitive structures; second, because, despite this diversity, several contributions regarding agents' decision-making, especially from qualitative social science, have yet to be formalized; third, and most important, because decision-making is usually at the core of the presumed uniqueness of the social domain. If researchers are to make sense of self-organization in situations such as the adoption or adherence to norms, something has to be said about agents' decision-making.

The article does not advance a particular formal model of self-organization. First, because the focus has been on pointing out theoretical elements that could enrich the methodological approach to self-organization in the area of social complexity. Second, because the development of a robust account of self-organization requires dealing with diverse methodological implementations of the target phenomena. The selection of a method for the study of social self-organization hinges on the particular approach to representation. The four factors of self-organization could be

dealt with differently, depending, for example, on whether there is an explicit spatial or temporal representation of the phenomenon of interest or whether there is a robust representation of the agents' cognitive capabilities. Specific needs and interests of the researcher will translate into different methodological choices. Traditional social network theory, for example, can be particularly useful for the identification of patterns such as relational structures and hierarchies, but display limitations when dealing with dynamics. In the same way, games played with real subjects in a laboratory might provide completely different insights to those played by artificial agents in a simulation or to individual subjects in real settings, observed during natural experiments. It is expected the discussion in this article could lead practitioners to further exploration of the advantages and disadvantages of a wide range of methodological approaches.

The use of novel methodological tools for the study of self-organization should also have a significant philosophical impact. The complexity approach to self-organization, for example, might be considered incompatible with Parsons' (1991) top-down view of system regulation, but compatible with his notion of voluntaristic individual action (Parsons 1949). Yet, that might be due to the need to reconstruct all of Parsons' work to fit an overly simplistic approach to the micro-macro link. The depiction of this traditional dualism in social science is problematic because the boundaries between micro and macro are ill-defined. These boundaries were conceptualized early, when data and methodological options were limited, and have not changed much since. Now that there are methodological options for the study of self-organization that were not available before e.g. computer simulation, these philosophical foundations should be revised, for example, to substitute the traditional micro-macro dualism for a processual view of social phenomena.

These revisions would likely help achieving a more precise conceptualization of the four factors in self-organizing phenomena. For example, while top-down organization is usually dismissed in the self-organization framework, several formal or informal forms of interaction, for example, norms are sanctioned using top-down mechanisms. Norms, however, are usually taken as a canonical example of self-organization, not because of their implementation, but because of the divergence between prescribed and actual behaviour. There is no consensus about how to correctly conceptualize the crucial features of a self-organizing dynamic in terms of the four categories mentioned above.

8 Conclusions

This article aimed to help practitioners within subareas of complexity science to better identify literature from traditional social science that could potentially inform their research. We presented a review of different areas of inquiry in social science that could provide important resources for anyone interested in the topic of self-organization in the social domain. It is intended to serve as a contextualization by mapping the explicit and non-explicit uses of the term. To achieve these aims, the article first presented a systematic review of the term self-organization in social

science, where explicit uses of the term were accounted for. This was followed by an analysis of the constituent terms, self and organization. Next, three foundational concepts in social science (order, equilibrium and contract) were discussed as examples of non-explicit uses of self-organization. Finally, implications for formal modeling of social self-organization were discussed.

The systematic review showed that the concept of self-organization has been mostly used in three ways in the social science literature. The most common is terminological, whereby the concept is used based on the intuitive meaning of its constitutive parts, with no reference to complexity science. The second is an analogical use, in which a loose analogy is made to the use of the term in complexity science. Finally, there is a literal use, which uses the concept in the full sense given to it by complexity science. The terminological and analogical uses are unlikely to significantly contribute to the framework for the study of self-organization in social and general science. They lack a robust conceptual background and do not incorporate any of the developments in the study of self-organizing systems produced during the last twenty five years. The potential contribution from the literal use might be limited by how much integration can be achieved between social complexity and traditional social disciplines.

In order to overcome the difficulties arising from the theoretical-methodological diversity in social science and the lack of explicit use of the term 'self-organization' in traditional social disciplines, the article critically explored some areas where the concept has been deal with implicitly. It was suggested the area of organizational studies, as a robust and comprehensive field of study in social science, can provide important resources for anyone interested in the study of self-organization in the social realm. As it was only recently that organizational studies started consolidating as an independent field, the article addressed the associated literature based on the questions of what an organization is and how it changes. These questions are use to show how the current state of research in the field relates to the four basic features of self-organizing processes described in contemporary literature.

The article also discussed how three traditional disciplinary concepts: equilibrium, contract and order, have historically dealt with the main features of self-organizing phenomena in the social domain. These concepts, it was suggested, can provide important insights for the contemporary account of self-organization. The selection of concepts and the discussion of prospective insights was not meant to be exhaustive. There are many other concepts, such as 'Institution' or 'structure', which, from interdisciplinary fields of research or traditional disciplinary areas, can also prove useful. The discussion was advanced to exemplify the great variety of implicit approaches to self-organization that could be neglected by individual researchers, because of traditional disciplinary boundaries. It is intended to serve as an incentive for further interdisciplinary work within the social disciplines in the approach to self-organization and social complexity.

A final section addressed formal models of social self-organization. It was argued that, from a formalization standpoint, self-organization could be conceptualized differently, depending on three crucial methodological features. Methods initially

diverge in the way they approach the patterned character of self-organizing phenomena. Differences mainly depend on whether patterns are methodologically reconstructed and whether this reconstruction uses abstract or explicit representations of time and space. Additionally, the nature and character of these patterns varies depending on whether the methods have explicit representation of agents or actions and/or allow for interaction. Methods that include explicit representations allow for the linkage of the patterned and the dynamic features of self-organization. Finally, methods could diverge in the intricateness of the agents' cognitive structure. This has an important effect on the extent to which autonomous character of self-organization is explored methodologically.

It is undeniable that the current concept of self-organization developed within different subareas of complexity theory is useful and promising because it is underlain by an overarching theoretical-methodological framework. New methodological alternatives e.g. agent-based modelling, as mentioned, are better suited than traditional social methods for the exploration of the dynamic, patterned and autonomous character of self-organizing phenomena. Additionally, the complexity framework allows for a more robust exploration of the mereological character of self-organization, due to the emphasis on concepts such as system, modularity or hierarchy. Yet, there is value in attempting a more robust link with traditional social theory. This in spite of the fact most potentially relevant sources from mainstream social science approach self-organizing dynamics in an implicit way.

There is a large theoretical-methodological gap between social complexity and mainstream social science. Some fields, such as social simulation, have a higher impact on other traditional disciplinary areas outside the social sciences (Squazzoni and Casnisi 2013). Additionally, subareas or social complexity show high degree of thematic and methodological and specialization (Meyer et al. 2009, 2011). This fragmentation eventually hinders the explanatory potential of the advances in these areas of study. It is well acknowledged that the explanatory potential increases with conceptual and theoretical unification (Morrison 2000; Murphy and Medin 1999; Kitcher 1989). Social complexity should strive for unification within complexity subareas and with mainstream social science. Practitioners in social complexity, given the robustness of the concept of self-organization and the advantages given by the cognitive division of labour in these areas e.g. high levels of interdisciplinarity, could drive this unification in the study of social self-organization. This will require large amounts of collaboration and critical thinking for, as it is clear by the review, beyond the borders of complexity science, the concept of self-organization has failed to have a major impact.

Appendix

The systematic review found and used the following journal articles.

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