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REGULAR ARTICLE

The innovation process as a complex structure with multilevel rules

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Abstract Increasingly, innovation is conceived in a context of conventions or rules and complexity. However, there is a need for a theoretical basis that describes the innovation process based on complexity. In this essay, we propose a multilevel micro-meso-macro framework that aims to meet this need and further the discussion on complexity. In this framework, the rule is adopted as an analytical concept and used to establish a bridge between the several theories employed. Two gaps are identified in the innovation process: the first is related to the simplicity with which complexity is generally treated, and the second refers to a lack of focus on the rules embedded in the theories used in innovation. The goal of this theoretical essay is to propose a multilevel micro-meso-macro framework, based on the rules and principles of complexity, which can be used to analyze the innovation process. As a result, we propose a new framework in which the innovation rules and the interactions between those rules are detailed and based on principles of complexity.

Keywords Innovation process · Complexity · Micro-meso-macro · Innovation · Evolution · Rules

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1 Introduction

Innovation is the driving force of economic development (Schumpeter 2004). It is widely recognized as a source of competitive advantage in an organizational environment that is subject to increasingly faster rates of change (Thomas and D'aveni 2009). Senior executives in global corporations consider innovation to be one of the three top priority strategies within their organizations (Boston Consulting Group 2009). However, it is difficult to maintain organizational performance based on innovation because the innovation process is a complex phenomenon (Dougherty and Hardy 1996; Garud et al. 2011).

The features of complexity, such as non-linearity, multilevel elements, interactions, trajectories, emergence and systems within systems, have been noted in various publications on innovation. Non-linearity can be seen in the innovation process through the false starts, abrupt endings and vicissitudes that are typical of the process (Van De Ven et al. 2007; Garud et al. 2011). Multilevel elements are observed in the various theories of innovation, including those of institutions, dynamic capabilities, resources, networking, learning and economic evolution (Crossan and Apaydin 2010). Interactions occur between networks of people and technologies from different fields of practice (Nonaka and Takeuchi 1995). Trajectories are identified over time, for example, when a first version of a radical innovation is introduced, and a series of incremental innovations appear later, usually in the form of a logistic curve (Perez 2010). Emergence occurs when the innovation process generates a variety of results (Davis et al. 2009). Systems within systems are found, for example, in the concept of the technological revolution, defined as a set of interrelated radical advances that form a larger constellation of interdependent technologies (Perez 2010).

Given the importance of innovation for the growth and vitality of organizations, researchers have been interested in understanding, from the perspective of complexity, the process by which innovation occurs (Van De Ven et al. 2007; Garud et al. 2011; Bongsug 2012). However, despite the advances made in the understanding of innovation provided by various approaches, there is still a need for a coherent and explicit theoretical basis that can explain the innovation process (Crossan and Apaydin 2010). In recognizing the lack of a theoretical basis, Hanusch and Pyka (2007) suggest new theoretical propositions should be based on the set features found in complexity theory.

In response to the inability to clarify and to explain theoretically the innovation process from the perspective of complexity (Hanusch and Pyka 2007), the micro-meso-macro framework (Dopfer et al. 2004) was developed in the field of evolutionary economics. This framework seeks to contribute to improving the understanding of the innovation process (Dopfer 2012) supported by the complex systems theory and self-organization (Dopfer et al. 2004; Dopfer and Potts 2009).

The micro-meso-macro framework differs from the approaches most often used in the literature to explain innovation in terms of its ontological premises and heuristic assumptions. It uses a heuristic strategy inspired by the generic concept of evolution, through the concept of self-organization, which is characterized by the ability of systems to transform themselves endogenously over time through the ability to create novelty (Foster 1993; Witt 2008).

By adopting the concept of self-organization, the micro-meso-macro framework assumes a monistic ontological perspective; i.e., a change in the economy and nature pertains to the connected spheres of reality (Foster 1993; Witt 2008). Thus, this framework differs from the Schumpeterian approach to innovation that adopts a dualistic ontological perspective, in which the economic and biological evolutionary processes are distinct, participate in different spheres and are disconnected from reality (Witt 2008). It also differs from the neo-Schumpeterian approach, which also adopts a dualistic ontology and a heuristic strategy that attempts to generalize Darwinian Theory (Witt 2008). Finally, the micro-meso-macro framework is also distinguishable from the approach of universal Darwinism, which adopts a monistic ontology and a heuristic strategy to generalize Darwinian Theory (Witt 2008).

By adopting a monistic ontological perspective (Dopfer et al. 2004; Dopfer and Potts 2009), the framework introduces an analytical level that accommodates concepts and languages that apply to two or more disciplines or theories (Dopfer and Potts 2010). An example of one of these fundamental analytical concepts is that of the rule. The concept of rules can be viewed as the first element that contributes towards an understanding of the innovation process from the perspective of complexity. In biology, the concept of rules refers to genes. In the micro-meso-macro framework, from an economic perspective, rules are the economic drivers of evolution, giving rise to innovation and driving the evolution of the system (Dopfer et al. 2004; Dopfer 2005). The process of acquiring rules is the central unit of the dynamic principle of evolutionary economics (Dopfer and Potts 2009). There are several levels of rules: generic or first-order, second-order and orderzero rules (Dopfer et al. 2004). The idea of there being various levels of rules can be viewed as the second element that contributes towards an understanding of the innovation process from the perspective of complexity. This feature makes it possible to include various theoretical concepts that may be involved in the innovation process (Crossan and Apaydin 2010).

Despite these two important elements, we have identified two gaps in the micro-meso-macro framework that must be filled before it can be fully applied to an understanding of the innovation process from the perspective of complexity. Although systems theory and self-organization, as contemplated in the micro-meso-macro framework, constitute two pillars of complexity (the first gap), the latter also works with information and cybernetics theories and dialogical, recursive and hologramatic principles (Morin and Le Moigne 1999). Together, these elements form the seven principles of complexity, which are seen as being interdependent from and supplementary to one another (Morin and Le Moigne 1999). Thus, the seven principles of complexity should allow a greater understanding of the existing complexity and fill the first gap in the micro-meso-macro framework, thus permitting the incorporation of greater complexity.

The second gap concerns the rules involved in the innovation process. Regarding the idea of understanding innovation using the concept of rules, Dopfer et al. (2004) and Dopfer and Potts (2009) provide an indication of those theories that might help identify the multilevel rules involved in innovation process, although they do not present them in detail. Theories of institutions, dynamic capabilities, resources, networking, learning and evolutionary economics may contribute to this end (Crossan and Apaydin 2010).

It is suggested that the innovation process cannot be explained by isolated factors, but rather by multidimensional structures of factors at multiple levels of reality. Therefore, the goal in this theoretical essay is to propose a multilevel micro-meso-macro framework, based on the rules and principles of complexity to analyze the innovation process. It is hoped that this theoretical essay will contribute towards the evolution of the debate regarding the understanding of the innovation-driven evolutionary dynamic and provide a better grasp of the economy as a highly complex structured system subject to change.

This essay contains five sections. The first includes a brief review of the micro-meso-macro framework, mainly incorporating the possible contributions of multilevel rules in innovation. The second presents the seven principles of complexity. The third highlights the elements of complexity both present and absent in the micro-meso-macro framework, and the complementarities of the contributions of multilevel rules. The fourth section, based on the results of the analysis in the previous section, presents a description of the proposed new framework. Finally, in the fifth section, the implications for businesses, public policy and scientific research are discussed.

2 Micro-meso-macro framework

The micro-meso-macro framework is based on systems theory and the concept of self-organization, which have been used in earlier research to explain the emergence of new factors in economic systems (Dopfer et al. 2004; Dopfer 2005). For those authors, the fundamental aspect of change and coordination within economic systems is the growth and development of knowledge, a process directed by the discovery, adoption, adaptation and dissemination of rules.

The micro-meso-macro framework serves to trace the evolutionary process from the human mind to the complex structures constituting the economy. It includes models of changes in micro units, models of population dynamics in meso units and models of organizational processes at the macro level (Dopfer and Potts 2009).

There are four structural elements within the framework. The first is the recognition that the human mind is the first locus of the economic system, where it originates and is adopted, and where rules are retained (Dopfer 2005).

The second structural element of the micro-meso-macro framework is the concept of the generic rule (Dopfer and Potts 2009). A generic rule is a deductive procedure that guides operational activities. In this context, the term deductive is seen as incorporating a set of terms such as heuristics, designs, plans, deductive logic, legal rules and strategies (Dopfer 2005). A generic rule specifies what to do and how to combine things, and it is this knowledge combined with resources that produces value (Dopfer and Potts 2009). The idea of the generic rule also appears in the games of innovation approach (Miller and Floricel 2007; Miller et al. 2008), where organizations participating in the same space, the meso-analytical space, may follow a dominant logic regardless of their functions within this defined space.

The third structural element is the ability of the rule carriers to complete their operations and to create value. These operations can take various forms, for example, incorporated within the production of capital goods, socially in networks or internally in habitual action or mental routines (Dopfer and Potts 2009).

Finally, the fourth element is the meso trajectory, which is the process by which meso units are formed and become established (Dopfer and Potts 2009). The generic rules and their associated rules are defined as a meso unit of the economic system. The process of acquiring generic rules is the central unit of the dynamic principle of evolutionary economics and comes about through the meso trajectory (Dopfer and Potts 2009). The meso trajectory can be described using the micro, meso and macro levels (Dopfer et al. 2004; Dopfer 2005; Dopfer and Potts 2009). The meso trajectory consists of three parts: Meso 1, origin; Meso 2, adoption; and Meso 3, retention, with both micro and macro dimensions. The meso trajectory affects both macro and micro organizations in an economic system and involves a process of creative destruction, disorder, and initial order and organization with the new idea and new population. The meso trajectory is fully explained in Dopfer et al. (2004) and Dopfer (2005).

Regarding the addition of a new generic rule to the micro unit, the theory of dynamic capabilities proposes the existence of activation triggers (Zahra and George (2002). Zahra and George (2002) explain that activation triggers are events that encourage or deter a firm from responding to specific external and internal stimuli. They suggest that internal triggers may take the form of organizational crises such as failure to perform or important events that redefine a firm's strategy. External triggers are events that can influence the future of the industry in which the firm operates and include radical change, technological change, the emergence of a dominant design and changes in government policy.

An analysis of the micro-meso-macro framework starts at the micro level, which refers to one or more generic rules carried by a rule carrier. The micro unit of analysis can be the social organization carrying the generic rules (Dopfer 2005). In summary, one can say that discussion at the micro level is concerned with how a micro unit within the economic system uses the generic rules and how the processes by which such rules are adopted and change. More specifically, it deals with the way in which micro units originate, adopt, adapt and retain a new generic rule. From an evolutionary perspective, each micro unit is continuously engaged in solving a problem that results in the construction and maintenance of a complex system of rules (Dopfer et al. 2004). A micro unit may carry many generic rules (Dopfer and Potts 2009).

From a static perspective, in a simplified model of a micro unit that carries generic rules, those rules are influenced by orderzero and second-order rules. Hierarchically, orderzero rules consist of the system's constitutional rules and represent the legal or informal norms rooted in the cultural context in which the agency is inserted (Dopfer and Potts 2009). Within a context of innovation, these rules may be associated with the concept of the rules of the game (Miller and Floricel 2007; Miller et al. 2008). The rules of the game are defined as a set of standards that inform decision makers and reinforce the maintenance of a consistent pattern of activity in the organization (Miller et al. 2008). The rules of the game can be used by decision makers when building business models that will support investments in knowledge building and developing the skills and methods required to acquire knowledge (Miller et al. 2008).

Miller and Floricel (2007) sought to determine which elements might make up the rules. The most relevant contributions relate to the knowledge-production dynamism, structuring potential and demand specificity. Thus, these rules are presented as forces that act together to form context-dependent settings (Miller and Floricel 2007). Second-order rules are specific to the development of new ideas. They relate to the way in which new knowledge is learned, adopted, adapted and retained. These rules expose the agency to the outside world (Dopfer and Potts 2009). To some degree, these rules correspond to the concept of dynamic capabilities (Teece and Pisano 1994; Winter 2003; Teece 2007). The key aspect of this theory is the ability to identify environmental changes, perceive needs and opportunities and then implement the necessary changes in the organizational routines to reconfigure resources and the routines themselves (Pavlou and Sawy 2005).

Second-order rules may also be linked to the idea of action rules (Miller and Floricel 2007; Miller et al. 2008). Action rules refer to the activities, strategies, structures and practices that are intended to increase the likelihood of the organization innovating (Miller and Floricel 2007). A third association that can be added to the idea of second-order rules refers to the conditions that promote and the barriers that inhibit the development and adoption of new ideas. The theory of knowledge creation also indicates these elements (Nonaka and Takeuchi 1995). The promotional conditions are intention, autonomy, fluctuation and creative chaos, redundancy and variety (Nonaka and Takeuchi 1995). The barriers are divided into individual and organizational barriers. Individual barriers relate to accommodation and the threat to self-image. In contrast, organizational barriers relate to the need to justify the knowledge, which can be seen in the need for the firm to have a legitimate language, organizational histories, procedures and paradigms.

The meso level is represented by the generic rule and all its carriers. When an economic system is seen from the meso perspective, what one sees are meso populations of rule carriers and their evolutionary moments (Dopfer et al. 2004; Dopfer 2005).

The macro level is more concerned with the structure of the rules. The macro level of the generic evolutionary model is first built by viewing this level as an order that joins all the meso units that make up the macro as a whole, in a state of coordinated generic equilibrium (Dopfer and Potts 2009). There are two distinct levels of macro coordination. The first seeks to understand whether the generic rule and other associated rules (the orderzero and second-order rules) fit in a coordinated fashion, to form what is known as the surface structure. The second seeks to understand whether the generic rule connects with other generic rules, that is, the deep structure (Dopfer and Potts 2009).

A flaw may occur in the economic system if there is a failure in any of the two levels of macro coordination. In neoclassical theory, a failure in the economic system represents a failure in the coordination of the operational activities. From an evolutionary perspective, a failure in the economic system can be associated with any level of coordination within the macro level of the micro-meso-macro trajectory (Dopfer and Potts 2009).

The idea of a structure of rules within the macro level refers to the concept of configurations. A configuration can be seen as a multidimensional constellation of distinct characteristics that occur together (Meyer et al. 1993). This theory, like the micro-meso-macro framework, also suggests that the results of an organization or system are more closely related to such constellations of characteristics than to any individual characteristic (Delery and Doty 1996). As with the micro-meso-macro framework, configurations theory also seeks to describe the different states of the organization or system by examining different internal dimensions within the specific context and to understand how these different dimensions are sequenced over time (Mintzberg et al. 2003). It also shares the premise that there is a need to break the existing linear paradigm, because it assumes that there are complex relationships of causality and nonlinear relationships (Meyer et al. 1993).

Another similarity between the two concerns the presence of a complementary effect between the elements of the configuration, in the sense that a particular result may or may not appear when certain elements are present (Meyer et al. 1993; Dopfer et al. 2004). However, configurations theory goes a step further and suggests other types of interaction between the elements. Configurations can be understood as a whole rather than the sum of the parts that compose it; therefore, it tends to involve synergistic effects in the sense that the resulting system is greater than the sum of the parts (Miller and Friesen 1980; Delery and Doty 1996). Moreover, there may be various types of relationships, indicating that the elements function more like interactive networks (Black and Boal 1994) in that there are effects related to the number and density of interactions in the system. It is also assumed that a configuration can achieve the same result starting from different initial conditions and through a variety of paths (equifinality). Thus, there may be no optimal configuration, even when organizations are faced with the same environmental contingencies (Katz and Gartner 1988).

3 Morin's theories on complexity

The idea of complexity arose from the need to bridge the existing classical paradigms built upon reductionist and deterministic knowledge, where objects under study were removed from their context without considering the interrelationships within their environment and the influences they caused and suffered (Morin and Le Moigne 1999). Within complexity thinking, there is no intention to exclude the traditional precepts, to replace certainty with uncertainty or to eliminate separation and introduce inseparability, but instead to enter the space between these extremes and show the importance of the interactions (Morin and Le Moigne 1999).

Complexity thinking has seven guiding principles: the systemic or organizational principle, the hologramatic principle, the retroactive circle principle, the recursive circle principle, the self-eco-re-organization principle, the dialogical principle and the reintroduction of knowledge in all knowledge principle (Morin and Le Moigne 1999; Cruz et al. 2006). We will not discuss the hologramatic principle here, as it is partially covered in the systemic principle and is not relevant in the context of the micro-meso-macro framework.

The systemic principle explains how knowledge of the parts is connected to the knowledge of the whole (Morin and Le Moigne 1999; Cruz et al. 2006). A system can be defined as a global unit organized by interrelations between elements, actions or individuals, thus forming a whole (Morin 1981). To understand better the concept of system, three important definitions need to be established (interrelationships, organization and system) and analyzed from a dynamic perspective (Morin 1981).

The interrelationships refer to the types and forms of links between the elements, actions or individuals that make up the system. The interrelationships between the elements are complementarities of the parts that form an organization (the concept of organization proposed here is different from that commonly used in the field of management). Complementarities may occur, for example, through informational communications. This arrangement assumed by the parties, or organization, gives rise to the very qualities of the organization. When analyzed at a given point in time, the organization can be understood as the system itself. In this case, the organization also has the same qualities as the system, which represents the whole. However, systems are dynamic and change over time. In the process of evolution, the parties may rearrange, create or change the interrelationships. This transformation creates a new arrangement of the parts, or a new organization, which may result in new qualities. When this happens, there is a new organization of the system (Morin 1981).

Therefore, it is possible to discuss two characteristics of a system: emergence and heterogeneity (Morin 1981). Emergence refers to the qualities or properties of a system that are novel when compared with the qualities or properties of components considered in isolation or arranged differently in various systems (Morin 1981). Morin (1981) explains that the concept of emergence is closely linked to the ideas of: 1) "quality, property"; 2) "product, since the emergence is produced by the organization of the system"; 3) "globality, since it is inextricably linked to the global unit"; and 4) "novelty, since the emergence is a new quality with respect to the qualities of the preceding elements."

Two consequences arise from this feature. The first is that, in an attempt to study a system by disassembling its parts, the system would disappear, as the system exists only when the interrelationships, and consequently their qualities, are present. When the system assumes a new organization, one emergence may disappear and a new one appear (Morin 1981). The second is that the emergence represents more than the sum of the qualities of the parts that make up the organization, as the emergence is new and of a different quality, which may be greater or less (as result of impositions) than the sum of the parts (Morin and Le Moigne 1999).

The system described so far can be seen to be homogeneous. However, a system comprises types of elements that may vary also in number and display their own qualities. The qualities of the individual elements are called micro emergences. They are absent or virtual when they are isolated, and acquired and developed when they are in relation with other parts or with the whole (Morin 1981).

In addition to micro-emergences, another phenomenon causes heterogeneity within the organization, which is that of impositions. These are capable of making the qualities of the elements within the system disappear. This characteristic is due to restrictions and constraints that occur in the interrelationships between the parts of the organization (Morin 1981). Thus, an organization is not always able to enhance the quality of its components, and therefore the system may be smaller than the sum of the parts (Morin 1981).

Another principle of complexity is the retroactive circle. This principle breaks the principle of linear causality, as it assumes that the cause acts on the effect and the effect purpose acts on the cause (Morin and Le Moigne 1999; Cruz et al. 2006). The retroactive circle can be negative or positive. When positive, it amplifies the phenomenon. When negative, the loops of action and reaction act to stabilize the system, similar to a thermostat in a boiler: the colder the environment, the more the boiler operates to heat the environment and thus to stabilize the temperature (Morin 1981).

The principle of the recursive circle introduces the notion of self-production and self-organization. It is a generating circle in which the products and effects are themselves the producers and cause of what they produce (Morin and Le Moigne 1999; Cruz et al. 2006). Morin and Le Moigne (1999) cite, as an example, individuals as products of a reproduction system originating over various eras; however, this system can only reproduce if the people become active in the system. This principle places the individual within the context of a dynamic system, because individuals are what they are owing to their experiences. Thus, individuals have an understanding of, and interpret reality based on themselves and then reproduce it depending on their knowledge and experience. This principle points to the need to understand the history of each of the parts, how each evolves and interprets reality (Morin 1992).

The self-eco-re-organization principle begins with the concept of self-organization. It's related to the autonomy, which seeks to characterize how the parts of the system reorganize themselves, thereby causing continuous changes in the system (Morin and Le Moigne 1999; Cruz et al. 2006). By introducing the "re", the notion of continuous change and transformation is added (Morin 1985), "eco" brings the idea of interrelationships and dependency on the external environment (Morin 1985), and the idea of "self" introduces the idea of organizing one's self (Morin 1985). This principle emphasizes that a system is dynamic and that it can change incrementally or radically, which is implicit in the systemic principle.

The dialogical principle assumes that two principles that should exclude each other may not be indivisible in the same reality. Thus, antagonistic, complementary and competing phenomena may occur simultaneously (Morin and Le Moigne 1999; Cruz et al. 2006). What is apparently antagonistic can be complementary, so that one cannot think of separating these production systems.

The reintroduction of knowledge in all knowledge principle places the subject as the center of the process; thus, all knowledge is a translation made by individuals at a particular time and in a particular culture (Morin and Le Moigne 1999; Cruz et al. 2006). This principle shows that a lack of information can be alienating in certain processes. However, from a more positive perspective, information is also an enabler of the transformation of the system.

4 Revealing complexity in the micro-meso-macro framework

In this section, we conduct an analysis of the micro-meso-macro framework in order to identify which principles of complexity are present, which are absent, and where necessary to fill any gaps with elements borrowed from innovation theories. A summary of this analysis is shown in Tables 1 and 2.

The analysis begins with the principle of "self-eco-re-organization" (Morin and Le Moigne 1999; Cruz et al. 2006), which is included in the concept of the generic micro-agent and its three levels of rules (Dopfer et al. 2004; Dopfer 2005; Dopfer and Potts 2009). The idea of "self-organization (Morin and Le Moigne 1999; Cruz et al. 2006) has been linked to the concept of second-order rules. These rules apply to the processes of learning, adopting, adapting and retaining new knowledge (Dopfer and Potts 2009). The theories of dynamic capabilities (Teece and Pisano 1994; Winter 2003; Teece 2007), games of innovation (Miller and Floricel 2007) and knowledge creation (Nonaka and Takeuchi 1995) suggest which second-order rules might be associated with innovation. The idea of "eco" (Morin 1985) is associated with the concepts of orderzero rules (Dopfer and Potts 2009). Games of innovation theory (Miller and Floricel 2007) gives an indication of what rules these might be. The idea of "re" (Morin 1985) is associated with the three phases of generic rules and their implications at micro–macro levels (Dopfer et al. 2004; Dopfer 2005).

The "systemic principle" (Morin and Le Moigne 1999; Cruz et al. 2006) is linked to the concept of macro level and meso units (Dopfer et al. 2004; Dopfer 2005; Dopfer and Potts 2009). The rules found at the various levels are the "elements" or parts of the system (Morin 1981). The notion of "heterogeneity" (Morin 1981), is contained in the

Table 1 Principles of complexity present in, and theoretical elements of innovation included in the micro-meso-macro framework

Principles of complexity	Elements of complexity identified in the micro-meso-macro framework	Theoretical elements of innovation included in the micro-meso-macro framework
Self-eco-re-organization principle (Morin and Le Moigne 1999; Cruz et al. 2006)	Concept of the generic micro agent and its three levels of rules (Dopfer et al. 2004; Dopfer 2005; Dopfer and Potts 2009)	
• Self-organization (Morin and Le Moigne 1999; Cruz et al. 2006)	Second-order rules (Dopfer and Potts 2009)	Dynamic capabilities (Teece and Pisano 1994; Winter 2003; Teece 2007); games of innovation (Miller and Floricel 2007); knowledge creation (Nonaka and Takeuchi 1995)
• Eco (Morin 1985)	Orderzero rules (Dopfer et al. 2004; Dopfer 2005)	Rules of the game: knowledge-production dynamism, structuring potential and demand specificity (Miller and Floricel 2007)
• Re (Morin 1985)	Evolutionary phases of the generic rules (Dopfer et al. 2004; Dopfer 2005)	
Systemic principle (Morin and Le Moigne 1999; Cruz et al. 2006)	Meso units and Macro-Level (Dopfer et al. 2004; Dopfer 2005; Dopfer and Potts 2009)	
• Elements (Morin 1981)	Rules (Dopfer et al. 2004; Dopfer 2005; Dopfer and Potts 2009)	
• Heterogeneity (Morin 1981)	Meso units (Dopfer and Potts 2009)	
• Global Unit (Morin 1981)	Macro-level (Dopfer and Potts 2009)	
• Organization (Morin 1981)	States the macro-level assumes over the course of its trajectory (Dopfer et al. 2004; Dopfer 2005)	
• Interaction (Morin 1981) • Complementarity and imposition among the elements (Morin 1981)	Deep and surface structures of the macro-level. (Dopfer and Potts 2009) Certain results are deemed to arise or not arise in the presence of certain elements (Dopfer and Potts 2009)	Equifinality (Katz and Gartner 1988); Synergy (Delery and Doty 1996; Miller and Friesen 1980); Network analysis (Black and Boal 1994)
• Emergence (Morin 1981)	Success and failure in the system under analysis (Dopfer et al. 2004; Dopfer 2005; Dopfer and Potts 2009)	
Recursive circle principle (Morin 1992)	The adoption of a rule by an agent is a function of its own history (Dopfer et al. 2004)	

Table 1 (continued)

Principles of complexity	Elements of complexity identified in the micro-meso-macro framework	Theoretical elements of innovation included in the micro-meso-macro framework
Reintroduction of knowledge in all knowledge principle (Morin and Le Moigne 1999; Cruz et al. 2006)	Adoption of a new generic rule in the economic system (Dopfer et al. 2004; Dopfer 2005)	Dominant logic (Miller and Floricel 2007; Miller et al. 2008)

Source: Elaborated by the authors

concept of meso units, which represent the interaction of generic rules, second-order, orderzero and operational rules (Dopfer and Potts 2009). The "global unit" or system (Morin 1981) is represented by the framework's macro level or the structure of the rules (Dopfer and Potts 2009009). The idea of "organization" (Morin 1981) is associated with the states assumed by the macro level over the course of the meso trajectory levels (Dopfer et al. 2004; Dopfer 2005). The idea of "interaction" (Morin 1981) between the elements within this principle is identified by the structure of generic rules and lower level rules (surface structure) and the structure of the generic rules (deep structure) (Dopfer and Potts 2009). "Complementarity" and "impositions" (Morin 1981) are explicit in the micro-meso-macro framework, as certain results are deemed to arise or not arise in the presence of certain rules (Dopfer and Potts 2009). Configurations theory enhances the understanding of the macro level, as it facilitates the measurement of the synergy (Delery and Doty 1996), equifinality (Katz and Gartner 1988), networks and their various measures for comparison (Black and Boal 1994). "Emergence" (Morin 1981) is associated with the success or failure of the system due to the virtues or problems in the operational coordination, surface structure and deep structure (Dopfer et al. 2004; Dopfer 2005; Dopfer and Potts 2009).

The "recursive circle principle" (Morin 1992), is identified at the micro level, where the adoption of a rule by an agent is a function of that agent's own history (Dopfer et al.

Table 2 New elements suggested for inclusion in the micro-meso-macro framework, based on the gaps identified by the principles of complexity

Principles of complexity	New elements of complexity indicated for the micro-meso-macro framework
Retroactive circle principle (Morin 1981; Morin and Le Moigne 1999; Cruz et al. 2006)	Success or failure in the economic system acts on both the rules for introducing a new generic rule, as well as on the evolution of an existing generic rule It would include the concept of activation triggers present in the theory of dynamic capabilities (Zahra and George 2002)
Dialogical principle (Morin and Le Moigne 1999; Cruz et al. 2006)	Conflicting and complementary rules may coexist, as, for example, with the existence of conditions that inhibit and foster the second-order rules (Nonaka and Takeuchi 1995)

Source: Elaborated by the authors

2004). This principle appears in the Meso 2 phase. In this phase, it is recognized that path dependency can interfere with the adoption or otherwise of new rules (Dopfer et al. 2004).

The "reintroduction of knowledge in all the knowledge principle" (Morin and Le Moigne 1999; Cruz et al. 2006) is contemplated in the adoption of a new rule in the general economic system. Considering the economic system, which is understood to be constituted by generic rules, its structure representing the knowledge of this system (Dopfer et al. 2004; Dopfer 2005), the adoption of a new generic rule represents, in the final analysis, the reintroduction of new knowledge. In the field of innovation, the idea of including a new generic rule can be associated with the concept of dominant logic present in the theory of games of innovation (Miller and Floricel 2007; Miller et al. 2008).

The "retroactive circle principle" (Morin and Le Moigne 1999; Cruz et al. 2006) is not considered in the micro-meso-macro framework. Incorporating this principle of complexity would mean accepting the existence of feedback between the rules structures (e.g., economic success or failure) and the dynamic of the rules (causes). The existence of this feedback can be supported by the existence of the concept of activation triggers (Zahra and George 2002). Organizational crises due to poor performance or a lack of performance regarding some generic rule would influence the relationship between the sources of knowledge and the organization's experience of the outside. Thus, it can be assumed that activation triggers contribute both to the adoption of a new generic rule and to its development by the micro agent.

The "dialogical principle", which assumes that two principles should exclude each other (Morin and Le Moigne 1999; Cruz et al. 2006), is not considered in the framework. Incorporating this principle of complexity would mean accepting the presence of conflicting rules at different levels within the micro-meso-macro framework. These conflicting rules could be generic, orderzero or second-order rules. Given that second-order rules concern the development of new ideas, the presence of conflicting rules could be inferred, for example, by the presence of barriers and stimuli to learning, as suggested Nonaka and Takeuchi (1995).

Based on the analysis conducted in this section, the principles of "self-eco-re-organization", "the recursive circle principle" and the "reintroduction of knowledge in all the knowledge principle" can be said to be present in the micro-meso-macro framework (Table 1).

The analysis also indicates that the "retroactive circle principle" and the "dialogical principle" could be incorporated into the micro-meso-macro framework (Table 2).

5 Framework for a complex and dynamic configuration of rules for innovation

Based on the analysis performed in the previous section, this section presents a description of the proposed new framework, referred to as the Framework for a Complex and Dynamic Configuration of Rules for Innovation.

The theoretical framework that sets out the configuration of the dynamic rules for innovation (Fig. 1) assumes a systemic character, that is, the existence of a whole or a global unit composed of interdependent elements organized through links in which emergences arise (Morin and Le Moigne 1999; Cruz et al. 2006).

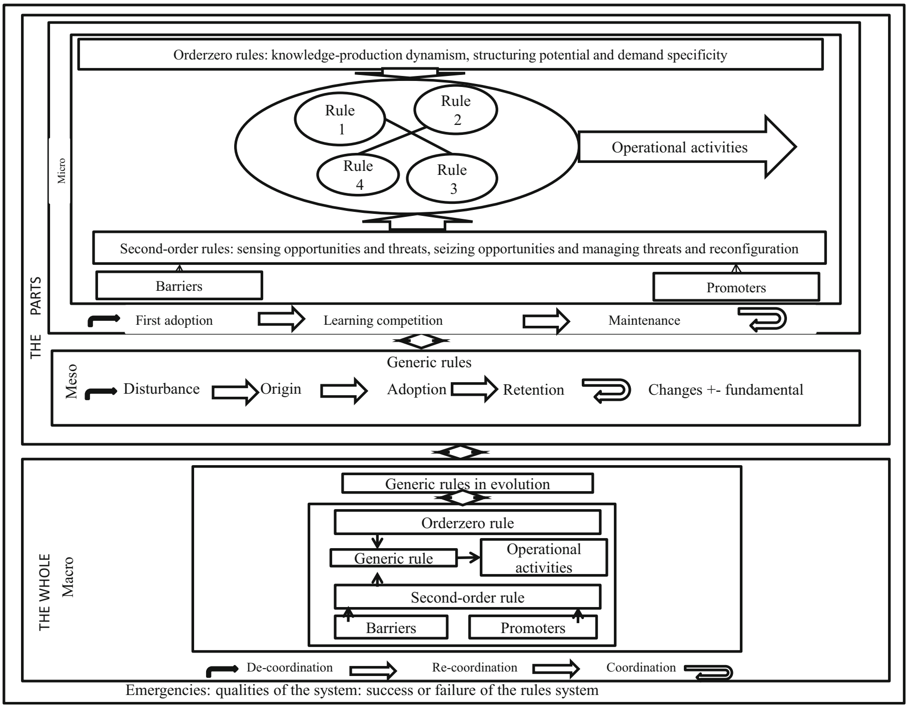

Figure 1 Framework for a complex and dynamic configuration of rules for innovation. Source: elaborated by the authors

From an economic perspective, the system, or the whole, is understood as a structure or a complex configuration of rules that relate over time (Dopfer et al. 2004; Dopfer 2005). The processes by which new rules originate are adopted and disseminated within the economic system facilitate economic development and system evolution, and give rise to innovation (Dopfer et al. 2004; Dopfer 2005).

The system's limit is the meso-analytical space, which is understood as a subsystem of the economy and as a separate unit within innovation studies (Dopfer et al. 2004; Dopfer 2005). There is no classificatory basis in this distinction, such as, for example, clusters or industrial districts. The term is used to identify and to conceptualize the rules that help to build and to evolve the economic system (Dopfer et al. 2004; Dopfer 2005). This limit is also understood to be the space within the economy where independent innovative dynamics are generated. It is in this space that the exchange of information and the strategic interdependencies of firms meet, producing the most intense knowledge production and regulation processes (Miller and Floricel 2007).

The system consists of three levels of interplay: the micro, meso and macro levels (Dopfer et al. 2004; Dopfer 2005). The micro level[1] deals with the adoption of orderzero rules, which interact with second-order rules, and both affect the first-order or generic rules (Dopfer et al. 2004; Dopfer 2005). Generic rules affect operational rules in terms of adding value (Dopfer et al. 2004; Dopfer 2005).

[1] The superscript number is also shown in Fig. 1; the text here describes the relevant part of Fig. 1 in greater detail.

The meso level[2] focuses on the generic rules and their population of updates (Dopfer et al. 2004; Dopfer 2005). These are the system's unit of analysis. The process of adopting a new generic rule begins with the presence of a trigger activation (Zahra and George 2002), which is new information recognized by the system and that has the potential to transform that system (Nonaka and Takeuchi 1995). This may be feedback (Morin 1981; Morin and Le Moigne 1999; Cruz et al. 2006) associated with the performance of the structure of macro-level rules. The trigger may also be an external trigger that can influence the future of the industry in which the firm operates, including radical changes, technological change, the emergence of a dominant design and changes in government policy. The absorption of this new information may initiate the adoption of a new generic rule. The evolution of the generic rule follows the stages of origin, adoption and retention, with consequent changes at the micro and macro levels (Dopfer et al. 2004; Dopfer 2005). New disorders can be sequentially absorbed, and then a new process of change can be initiated. The ability to identify new disorders and, therefore, the appearance of new rules, is dependent on the path followed by the system (Dopfer et al. 2004; Dopfer 2005). Thus, the system may not be homogeneous because it contemplates the possibility of the existence of several generic rules that evolve with their own dominant logics (Miller and Floricel 2007) and can be distinct from those of the system as a whole (Morin 1981).

The macro level,[3] which represents the whole, consists of an associative structure of multilevel rules (Dopfer et al. 2004; Dopfer 2005); it is also the representation of the system and is composed of the parts.

At the most fundamental level are the orderzero rules (constitutional rules) (Dopfer and Potts 2009), which may be the rules of the games of innovation theory. The rules of the game can be identified *a priori* as knowledge-production dynamism, structuring potential and demand specificity (Miller and Floricel 2007).

Knowledge-production dynamism refers to the flow of relevant and new information to which businesses have access. It may refer to the following: 1) the access to a strong and steady flow of new scientific knowledge; 2) a strong flow of new knowledge, although based around a limited set of basic principles or the addition of new applications and functions to previously held information; and 3) produced by learning from experience with existing products, production systems and the use of standards, especially to obtain improvements and to reduce costs (Miller and Floricel 2007).

The structuring potential is the way in which the micro agent is impacted by knowledge. It can occur in a number of ways: 1) when there are public regulations and policies, intellectual property protection that limits access to knowledge; 2) when firms have a disproportionate market share in relation to others or achieve technological dominance over their competitors as a result of economic processes, such as economies of scale and scope of innovation, production and distribution or through network effects and reputation; and 3) when the interested actors are not socially sensitive and are subject to non-linear logic (Miller and Floricel 2007).

Demand specificity is the extent to which consumers increase their demand for differentiated products and services and are willing and able to pay for such new services. Such demands may occur when: 1) the customer base consists of large firms or government agencies that use products in many complex applications or as critical components within a production system; and 2) when consumer needs are similar and the products are not critical for their performance, and thus consumers can judge the quality of the products, but cannot create specific demands regarding innovation. Such conditions occur with individual purchasers or in mass industrial markets (Miller and Floricel 2007).

At the second most fundamental level are the generic rules. These rules cannot be defined *a priori*, since they are dependent on the main activity of the system. They are dominant logics (Miller and Floricel 2007; Miller et al. 2008) that guide the organization of the operational activities and resources (Dopfer and Potts 2009).

At the third most fundamental level are the second-order rules (rules of knowledge acquisition) (Dopfer and Potts 2009), which may be indicated through the theories of dynamic capabilities (Teece and Pisano 1994; Winter 2003; Teece 2007), games of innovation (Miller and Floricel 2007) and knowledge creation (Nonaka and Takeuchi 1995). The rules at this level are activities that involve sensing opportunities and threats, seizing opportunities and managing threats and the reconfiguration of these activities that is necessary to adjust the system and maintain it over time (Miller and Floricel 2007; Teece 2007).

Firms can sense opportunities and threats in a number of ways: 1) by developing organizational activities aimed at discovering, interacting and evaluating information about customers' performance expectations; 2) from science and technology production centers outside the company; 3) from suppliers; and 4) from the firm's internal environment, such as research and development departments, among others (Teece 2007). Miller and Floricel (2007) propose firms should undertake activities that allow them to meet, to interact with and to evaluate the buyers, as well as joining networks of firms. The idea of networks is explained because firms do not usually innovate alone, but interact with other actors including consumers, regulators, stakeholders and innovation support agencies. These partners provide financial resources and access to markets and information (Miller and Floricel 2007).

Seizing opportunities involves activities intended to outline the design and performance specifications of the products and business model (Teece 2007). The business model is a plan for the financial and organizational architecture of an organization. It involves defining which technologies and features should be part of the product and service, how the cost structure should be designed or redesigned to meet customer needs, the way in which technologies are organized or combined, the market segment to be reached and the mechanisms and means by which they must be captured (Teece 2007).

Teece (2007) proposes that knowledge can also be used to manage complements to gain economies of scale and scope or asset co-specialization. Measures to avoid disappointment are also recommended, because, according to the author, errors are common in managerial decision-making. Hence, the author suggests the creation of organizational structures, incentives and routines to foster and to renew creative action and to develop routines that allow the evaluation of assets and routines that no longer create value. Teece (2007) also suggests there is a need to understand how ownership can be affected by the firm's appropriation of innovation. Accordingly, the author suggests there is a need to be familiar with the "appropriability regime", i.e., the level of existing legal and natural protection, the nature of the asset complementary held by the innovative firm, the relative positioning of the innovator and its potential imitators in relation to the complementary assets and the stage of development of the industry.

Regarding the process of seizing opportunities, Miller and Floricel (2007) propose activities designed: 1) to develop new products, processes and services with the goal of finding segments within the target customer group who value reliability, security, cost, and durability; 2) to manage product architectures and to align them with emerging standards; and 3) to develop and to transform scientific knowledge into products by innovation management processes and competitive and collaborative strategic actions aimed at different types of comparative advantage. Collaborative strategies may target, for example, the expansion of markets and competitive strategies and the construction of knowledge as a way to maintain competitive advantage (Miller and Floricel 2007).

The process of managing threats and reconfiguration involves performing activities that ensure the firm remains fit over time and, if necessary, is able to avoid unfavorable situations (Teece 2007). This implies continuously aligning and realigning the firm's tangible and intangible assets. The activities that help sustain the firm's continuity in the changing environment are: 1) managerial decentralization, because it favors the proximity of higher-level managers within the organization to new technologies, to the customer and to the market (this requires adopting more flexible hierarchical structures that favor the exchange of information and the development and integration of internal and external skills); 2) co-specialization, the strategic management of combinations of assets so as to incorporate value; 3) governance, to give incentives to align the interests of the firm, minimizing the agency effect and blocking actions that dissipate income; and 4) learning activities such as knowledge transfer, know-how integration and intellectual property protection (Teece 2007).

Second-order rules refer to a set of activities that increase the likelihood of doing certain things and do not necessarily guarantee that such things will be done. Social integration mechanisms can reduce the barriers to the assimilation of information (Zahra and George 2002). The phases of knowledge creation proposed by Nonaka and Takeuchi (1995) may indicate which social integration mechanisms can be adopted to improve the efficiency of each second-order rule. They describe four types of activities: socialization, externalization, combination and internalization situations. Socialization means sharing and creating tacit knowledge through direct experience. Externalization involves articulating tacit knowledge through dialogue and reflection. Combination situations involve systematizing and applying explicit knowledge, while internalization represents learning and acquiring new tacit knowledge through practice (Nonaka and Takeuchi 1995).

Together with second-order rules, imposition relationships may be present (Morin 1992). These dimensions refer to the barriers and the promoters of the adoption of new knowledge (Nonaka and Takeuchi 1995; Zahra and George 2002). The barriers can be individual, organizational and/or external. Individual barriers include accommodation and threat to self-image (Nonaka and Takeuchi 1995). Organizational barriers involve a lack of exposure to diverse and complementary knowledge, past experience, lack of social integration mechanisms (Zahra and George 2002), histories, legitimate language, organizational procedures and organizational paradigms (Nonaka and Takeuchi 1995). External barriers may relate to the presence of appropriability regimes (Zahra and George 2002). The promoter dimensions may foster autonomy, fluctuation and creative chaos, redundancy and variety (Nonaka and Takeuchi 1995).

In the macro structure, or in the representation of the whole, several types of relationships can occur. The following relationships can be assumed: 1) a complementary relationship (Morin 1981); 2) a synergistic relationship (Delery and Doty 1996; Miller and Friesen 1980); 3) an equifinality relationship (Katz and Gartner 1988); 4) and features derived from networks (Black and Boal 1994).

In the configuration of dynamic rules for innovation, emergence (Morin 1981) can be linked to the success or failure of the rules system. This may occur, for example, owing to the appearance of a new rule, connected to the dynamism of the production of information, structuring potential and demand specificity or connected new second-order rules, linked to the micro processes of acquisition, deployment and reconfiguration. It may also occur due to the appearance of a new generic rule.

6 Final remarks

With the aim of contributing to the understanding of the innovation process, this essay proposed a new framework for a complex and dynamic configuration of rules (Section 4). This framework includes multilevel rules involved in the innovation process, more principles of complexity and new possible interactions between the different levels. The relationships between those parts (the different levels) and the whole are emphasized with the aim of inserting those previously missing elements of complexity theory into the micro-meso-macro framework.

Elements associated with the second-order rules have been borrowed from the theories of dynamic capabilities, games of innovation and knowledge creation. The theory of games of innovation has contributed elements associated with orderzero rules. Configurations theory has contributed elements used to analyze the interactions existing within in the structure of rules represented by the macro level.

The comparison made between the principles of complexity and the micro-meso-macro framework led to the inclusion of the retroactive circle and dialogical principles within the new framework.

With the inclusion of the retroactive circle, the whole can be seen to influence the parts. This is due to the possibility that success or failure in the economic system, represented by the macro level rules, would act as an activation trigger for inserting a new generic rule or make an existing one evolve into a new phase.

The inclusion of the dialogical principle has made it possible for conflicting rules to co-exist, in association with the barriers and promoters linked to second-order rules.

Although the Framework for a Complex and Dynamic Configuration of Rules for Innovation has not been applied and, therefore, can be considered a limitation of the present study, it also represents an opportunity for future research. This framework could be applied when attempting to understand how the structure of a system of rules is organized, changes and evolves; for example, how organizations incorporate new contextual demands in their innovations, both in terms of competitiveness and sustainability. In this sense, the framework could be adopted in research concerning how a system incorporates new themes in product innovation (e.g., sustainable development) or in organizational innovation (e.g., corporate social responsibility, social businesses and social innovation).

Another challenge for the framework is to build a proposal for a methodology associated with the themes used in this research. Such a methodology would need to consider the dynamic examination of the parts (multilevel rules), but principally the whole. With regard to this, an initial proposal on the form that such a method might take can be seen in Pedrozo et al. (2012).

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