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A comprehensive framework to research digital innovation: The joint use of the systems of innovation and critical realism

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ABSTRACT

This study addresses calls to expand the boundaries of digital innovation research at multiple levels of society to comprehensively study the structure and evolution of innovation processes and outcomes. We contribute by proposing a framework composed of systems of innovation (SIs)[1] as an alternative and holistic conceptual base and unit of analysis, which accounts for the interconnected components located beyond the organizational microenvironments that ultimately affect innovation in organizations. Given the compatibility of SIs and the ontology of critical realism (CR)[2] as well as some flaws in SI research practice, we also use critical realist research approaches to guide the study of the state and transformation of SIs. We further explain the joint use of SIs and CR by applying them to the area of information systems innovation diffusion.

Introduction

Business strategy increasingly depends on the pervasive and instrumental role of digital innovations to create competitive advantages for firms and whole industrial sectors (e.g. Bharadwaj et al., 2013; Nylen and Holmstrom, 2015). Examples include trans-firm collaboration and business processes in platforms (e.g. Howard et al., 2006), the development of new products and services in ecosystems (e.g. Suseno et al., 2018), and efficiency and costs reduction in shared infrastructures (e.g. Messerschmidt and Hinz, 2013). As these innovative efforts require diverse organizations to agree, coordinate and jointly work to accomplish interdependent objectives (e.g. Nambisan et al., 2017; Tilson et al., 2010; Yoo et al., 2012), leading actors, such as multinational corporations, business associations and software manufacturers, must develop the strategic capability of agency to influence the redefinition of technological architectures and industries in order to create and capture value in external environments characterized by complexity, uncertainty and competing priorities (ibid).

This approach differs from the alignment of the internal information system (IS) function to business strategy (e.g. Avison et al., 2004; Chan et al., 1997) because it considers the evolving character of digital innovation and the distributed role of different actors to affect the external resources that organize, deliver and diffuse technologies in society such as institutions, common practices and standards (e.g. Bharadwaj et al., 2013; Yoo et al., 2010). As a result, Bharadwaj et al. (2013, p. 473) ask 'how can we draw the boundaries of digital business strategy and how can we best characterize its scope?' and identify this quest as one of the essential

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[1] Systems of innovation (SIs).
[2] Critical realism (CR).

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guides for the future thinking on digital business strategy and framework of the next generation of insights. To address this innovation-based perspective, we adopt a systemic and holistic view of digital business strategy to represent and study the form and dynamics of the external sociotechnical environment that matters for organizations (c.f. Merali et al., 2012; El Sawy et al., 2010; Tanriverdi et al., 2010).

Although heading in the right direction, research on digital innovation is still far from comprehensively addressing its strategic dimensions. There have been important calls to consider more flexible boundaries beyond the focal innovator (e.g. Henfridsson and Bygstad, 2013; Winter et al., 2014), the systemic nature of innovation at societal levels (e.g. Loebbecke and Picot, 2015; Winter et al., 2014), the evolution of innovation structures (e.g. de Reuver et al., 2018; Tilson et al., 2010) and the agential role of leading actors (e.g. Nambisan et al., 2017; Winter et al., 2014). This research contributes by proposing a framework composed of SIs (e.g. Cooke et al., 1997; Freeman, 1987; Nelson, 1993) as a conceptual base and alternative unit of analysis, which posits innovation processes in society as intricate and multilevel systems of actors, activities and institutions. We also propose CR (e.g. Collier, 1994; Danermark et al., 2002; Sayer, 2000) as the philosophical stance and provider of research approaches to study the structure and evolution of SIs.

The paper is structured as follows. First, we expound the opportunities for the study of digital innovation. We continue by explaining SIs and how to formulate SI-based units of analysis in the ambit of digital innovation, as well as pointing out some related deficiencies in SI research practice. We then move on to CR and demonstrate the compatibility between SIs and the ontology of CR. After that, we explain and exemplify the study of information systems innovation diffusion based on SIs and critical realist approaches. Finally, we formulate a set of relevant research questions to guide the study of digital innovation through SIs and CR.

The need to expand digital innovation research

We use the comprehensive conceptualization of digital innovation given by Nambisan et al. (2017, p. 224): 'the creation of (and consequent change in) market offerings, business processes, or models that result from the use of digital technologies … [In which] the outcomes themselves do not need to be digital … It includes a broad swath of digital tools and infrastructure … for making innovation possible … And the possibility that the outcomes may be diffused, assimilated, or adapted to specific use contexts such as typically experienced with digital platforms … Digital innovation management refers to the practices, processes, and principles that underlie the effective orchestration of digital innovation'.

Research in this area has been noticeably more engaged with organizationally bound digital innovations than with distributed and decentralized innovation processes and outcomes (Sorensen and Landau, 2015). Furthermore, 'most, if not all, extant research is targeting the focal actor [(e.g. a platform owner or the adopters of an innovation)]' (Fichman, 2004; Selander et al., 2013, p. 184). While valuable, this preponderance must be adjusted because digital artifacts are ubiquitous, and their affordances (Majchrzak and Markus, 2012) cause ample innovative possibilities characterized by convergence and generativity to produce unprompted novelty by different types of actors (Zittrain, 2006). According to Yoo et al. (2012), these traits make digital technologies the foundation to create or combine complementary innovations (e.g. Gawer, 2009), where the development of activities are undertaken by diverse, often unexpected and geographically dispersed participants who collaborate with different knowledge (e.g. Barrett et al., 2012).

Pervasiveness in innovation processes goes beyond the network of organizations involved in the development of digital innovations. For example, the success of digital platforms is highly determined by the exogenous environment that impacts the innovative capacities of their ecosystems (Tiwana et al., 2010). This includes technological trajectories, financial opportunities for developers provided by complementary platforms (e.g. Armstrong and Wright, 2007; Eisemann et al., 2006), and the influence of regulatory agencies and other actors that supply services to several platforms (e.g. for content, bandwidth and storage).

The external environment has become so relevant that it can shape the focus of entire studies. Accordingly, de Reuver et al. (2018) suggest departing from innovator-centric research due to the increasing complexity of digital innovation as an object of study, which in addition makes problematic the definition of the units of analysis. They exemplify this with the complexity of platforms that are mashed up into larger infrastructures (e.g. shopping platforms that access data from social media infrastructures) (Evans and Basole, 2016), overlap at different architectural levels (e.g. operating systems and browsers as platforms for application development in mobile devices) (Pon et al., 2014), flourish in different industrial sectors (e.g. de Reuver et al., 2015; Kiesling, 2016), and greatly depend upon 'boundary resources' (Eaton et al., 2015), including software tools and regulations which drive the relationships between owners and developers. Furthermore, each of these aspects is affected by diverse institutional and market-related arrangements at multiple levels (de Reuver et al., 2018).

Due to the concentration on focal innovators, there are also few studies on the evolution of complex sociotechnical systems (e.g. de Reuver et al., 2018; Tilson et al., 2010; Tiwana et al., 2010), and about the necessary work of change agents to initiate, organize and make evolution and radical innovation happen in these scenarios (e.g. Nambisan et al., 2017; Nambisan and Sawhney, 2011; Tilson et al., 2010). For instance, as a complement to the predominant cross-sectional research in the area, de Reuver et al. (2018) call for longitudinal studies that conceptualize digital innovation as a comprehensive unit of analysis at societal levels with the purpose of understanding the real complexity of the dynamics of evolution. Relatedly, Tiwana et al. (2010) urge for more research on the evolution of platforms through the coevolution of the choices of platform owners -regarding both technical designs and the extent of participation of developers in the governance of the platforms- and the dynamics of the external environment that affects their ecosystems.

The evolution of digital innovation in broader and systemic contexts is a challenging undertaking. Yoo et al. (2012) argue that distributed innovation entails new forms of risks (e.g. Pentland and Feldman, 2007), in environments with several contradictory logics and marked resistance to change. In view of these difficulties, Nambisan et al. (2017) recommend a focus of research on problem-solution design pairs which trigger technological trajectories (von Hippel and von Krogh, 2016), and on the social-cognitive sense-making of the individual innovator and their social system in convincing others about the opportunities of radical innovations (Nambisan, 2017). The aim is to understand how the inertia of current paths and the aversion to inherently uncertain endeavors can be reduced (Kaplan and Tripsas, 2008). Connectedly, they also assert the need to study 'orchestrators', who are the agents that generate collective actions towards the creation of solutions that match the problems or opportunities (e.g. Nambisan and Sawhney, 2011).

Similarly, Tilson et al. (2010) state that there are periods of stable sociotechnical configurations because of previous investments and control points such as regulations, standards and interfaces (e.g. Eaton et al., 2010; Herzhoff et al., 2010). These are challenged by rivals who attempt to establish and solidify new technological regimes by designing substitute innovations, developing them and engaging diverse stakeholders in the entire process and use (ibid). Due to the complex landscapes in which agents and actors interact and negotiate, Tilson et al. (2010) suggest studying the evolution of digital infrastructures (c.f. Edwards et al., 2009) in a way that cuts across multiple levels of analysis, interests and time scales in order to build deeper explanative models. However, 'little, if any, research has been geared toward developing a comprehensive understanding of the range and contingencies of causal structures [of digital infrastructures] and [their] evolution' (Henfridsson and Bygstad, 2013, p. 908; Koutsikouri et al., 2017).

Now, much of IS research has been explicitly or implicitly based on the sociotechnical systems approach (Hirschheim and Klein, 2011). Although this has and will continue to provide a robust framework to explain IS within individual organizations, Winter et al. (2014) contend that some of its historical assumptions must be adapted to study emergent digital innovations such as infrastructures, platforms and commercial IS packages (c.f. Pollock and Williams, 2008), as well as, again, because of the generative potential and capacity of expanding and combining digital innovations. They agree with the view that IS research must alternatively contemplate phenomena that surpass the organizational 'container' (e.g. Pollock and Williams, 2008; Sorensen and Landau, 2015) and the effect of the often conflicting goals, norms and values of diverse people and organizations (e.g. Pollock and Williams, 2008; Winter and Berente, 2012). They add that these objects of study are structured in the form of recursive downward, upward and lateral causations in 'nested' systems (Costello et al., 2013). In other words, IS research should go beyond organizational 'encapsulation' by considering the systemic processes composed of intricate relationships at multiple levels of inheritance in society, ultimately producing negotiated and innovative outcomes through the joint work of different groups of stakeholders (Winter et al., 2014).

Importantly, Winter et al. (2014) also state that the upward causations imply that lower-level systems may precede the total emergence and evolution of the higher-level systems that influence them, so members of lower-level systems could become agents in building the extended sociotechnical environment to which they belong. They conclude by proposing crucial research objectives for the IS community -basically, 'how to identify relevant boundaries for analysis of information systems and the organization of work … [and] draw on work on defining boundaries from general systems theory' (p. 265). They add that 'the IS field should embrace an entrepreneurial standpoint: assessing a sociotechnical system, finding useful boundaries, and taking action to add any missing elements. Increasingly this is as likely to mean providing an organization around existing work infrastructure as it is to mean providing an information system within an organization' (ibid).

We summarize and integrate the distinct reviews and calls above into two crucial research areas. First, there is a necessity to study the systemic boundaries of innovation at societal levels to consider the multilevel causes that ultimately affect digital innovation outcomes in organizations. Second, it is vital to understand agency and the way it influences the mobilization of resources and the evolution of the macrostructures of innovation systems. We address this by proposing a comprehensive research framework based on SIs (e.g. Cooke et al., 1997; Edquist, 2005; Nelson, 1993) as an alternative and holistic conceptual base and unit of analysis, which puts the boundaries of multilevel innovation processes at center stage by considering them as objects of study, including complexly interconnected components beyond focal innovators and their microenvironment. SIs also accounts for the nature and work of agency, as well as the mutual effects between agents and structures to explain the evolution of systems, including radical innovations and technological trajectories in society. In addition, we propose CR (e.g. Archer, 1995; Bhaskar, 1997, 1998) as the philosophy of SIs in order to make full use of its research approaches to study the creation, diffusion and use of digital innovations in entire countries, regions, sectors and other organizational aggregations.

Systems of innovation

SIs is a conceptual base to understand and explain innovation processes in society (c.f. Cooke et al., 1997; Freeman, 1987; Nelson, 1993). It was developed under the foundation of general systems theory, evolutionary economics and institutional economics (e.g. Edquist, 2005; Soete et al., 2010). According to SIs, innovation is about producing, diffusing and using new knowledge or novel combinations of new or existing knowledge (ibid). As we will explain, SIs considers the real complexity of activities, actors, institutions and relations that exists beyond the confines of organizations, which ultimately affects innovative efforts inside organizations. SIs is an abstract and general framework which is operationalized when the researcher defines a specific system of interest (Carlsson et al., 2002; Edquist, 2005), for example the diffusion of an IS innovation in an industrial sector. The aim of research on SIs is to discover and theorize the configuration of components shaping the systems of interest and understand their evolution.

Innovation is a collective achievement of different actors from the public, private and third sectors, for example government departments and agencies, local governments, non-governmental organizations, financial institutions, universities, research centers, customers, suppliers and industry associations (e.g. Asheim and Isaken ,2000; Lundvall, 1992). Actors also include individual people, who through their reflectivity, creativity and capacities realize innovations (Acs et al., 2014; Lindholm-Dahlstrand et al., 2016; Qian et al., 2013). In doing so, actors carry out activities that make innovation possible (e.g. Bergek et al., 2008; Edquist, 2005, 2011; Hekkert and Negro, 2009). These activities are usually very diverse, for instance related to research and development, competence building, the formation of new product markets, the articulation of quality requirements from demand, networking through market and other mechanisms, the provision of services for innovating firms, and the creation and changing of organizations and institutions needed for innovation (Edquist, 2005, 2011).

The institutional environment plays a key role in innovation because it influences the performance of actors (e.g. Asheim and Isaken, 2000; Edquist, 2005, 2011) by setting the 'rules of the game' (Edquist, 2011, p. 1728; North, 1990) through laws, regulations, common practices, routines, habits, trust, etc., which are embedded in communities, networks, organizations and people (Asheim and Isaken, 2000).

The outcome of SIs is also affected by the relations of hierarchies of causes and feedback loops at multiple levels among their activities and institutions (Edquist, 2005; Markard and Truffer, 2008). Through complex interactions, 'the [components of an SI] must be seen to support and reinforce -or offset- one another' (Edquist, 2005, p. 190). The properties of each level emerge from not only additive but also transversal effects of unlike kinds of components, so emergent properties are constructed and irreducible to their components (Cooke, 2012).

Core to SIs is the concept of boundaries. This is vital for knowing what is inside and outside of a specific system (Edquist, 2005). As will be explained in the section 'The SI as an Alternative Unit of Analysis in Digital Innovation Research', the boundaries of an SI are defined from the research and identification of the causal components of innovation processes at different levels of society (ibid). From this, the intricate composition of specific activities, actors, institutions and relations, according to the corresponding systemic boundaries, forms the structure of an SI (e.g. Carlsson et al., 2002; Edquist, 2005; Hekkert et al., 2007).

The SI conceptual base explains not only the structure of systems but also their evolution. The distinction between radical and incremental innovations is central to understanding change. A successful radical innovation establishes a technological paradigm, which drives the innovative efforts in an SI for a considerable period of time (Dosi, 1982). This influences the creation and diffusion of incremental innovations within the same structural regime, which is known as a technological trajectory (Dosi, 1982; Nelson and Winter, 1982). The preponderance of other disruptive innovations over time starts new cycles of technological paradigms, including their related structural changes and trajectories.

The heterogeneity of actors plays a major part in explaining the structure and transformation of SIs. Apart from their specific role in the systems, actors differ mainly in terms of knowledge and competencies to develop, absorb and use new knowledge (e.g. Carlsson et al., 2002; Lundvall and Borras, 2005; Metcalfe and Georghiou, 1998; Nelson and Winter, 1982). They tend to innovate incrementally in line with their state on these aspects, but knowledge and competences are also gradually altered in the process. This duality is ongoing and known as path dependency (Arthur, 1989; David, 1985). Path dependency affects the actors' choices of both, innovations and the structural aspects related to their role, for instance the internal and external division of labor and relationships (Nelson and Winter, 1982; Metcalfe and Georghiou, 1998).

However, actors have the potential capacity to reflect and take different courses of action due to the 'specific socio-material entanglements that ensue' (Garud et al., 2010, p. 768). While many actors can be affected by structural inertia (Gustafsson and Autio, 2011), others compete and look for radical change to pursue economic benefits from technological novelty (Garud and Karnoe, 2001). Mindful deviation is the calculated and purposeful decision to compete and change to create new paths, based on the departure from current artifacts and rules (ibid). This is done knowing that it may create temporal inefficiencies because of the time lapse for novel ideas to mature in complex systems, but potentially better futures (ibid). Also, when a path generates undesirable consequences, for example low rates of creation of innovations, and the affected actors fail to react, other participants such as policymakers and industry associations may intervene to improve the system (Gustafsson and Autio, 2011).

At times of paradigmatic competition, rival parties, which lead either the status quo or radical change through path creation, compete for the choices of the population. In so doing, they become active agents striving for legitimacy by forming coalitions and lobbying for favorable structures (e.g. Bergek et al., 2008; Hekkert and Negro, 2009), which is known as institutional entrepreneurship (Garud et al., 2007; Hung and Whittington, 2011). 'It is not simply the case that [structures] enable or constrain actions undertaken by agents within them. The generation of novelty by these agents also changes the macro rule structures of the [SIs] within which they are embedded' (Kastelle et al., 2009, p. 19).

To conclude, the complex nature of the structure of SIs and their openness to the external environment create uncertainty concerning the results from innovation processes (e.g. Meijer et al., 2006). This is exacerbated by the degree of actor heterogeneity and the fact that they may make imperfect decisions. The extent of uncertainty also depends on whether the innovation in question is radical or incremental, with radical innovations having higher uncertainty not only because of their unclear possibilities for success in the market but also due to the major structural changes required to improve, produce and diffuse them (Verspagen, 2005).

The SI as an alternative unit of analysis in digital innovation research

The SI framework clearly addresses the opportunities in digital innovation research because it conceptualizes innovation based on systemic boundaries at multiple levels in society, and explains agency and how actors influence technological change. It penetrates the details of those aspects by explaining the components of systems in terms of activities, actors, institutions and relations, and expounding on how actors are influenced by the paths of technological trajectories and the potential for path creation due to radical innovations. Furthermore, SIs sheds light on the uncertainty inherent to innovation due to the complexity and openness of systems, the heterogeneity of actors, and the constant possibility of structural change and the establishment of new technological paradigms. In this section we extend the SI conceptual base and consider some characteristics of its research practice to understand the SI as a unit of analysis in digital innovation research.

To start, scholars have defined diverse types of SIs, and research has mostly concentrated on distinctive topics depending on each type. SIs can be classified according to three aspects: geography, sector and technology (e.g. Carlsson et al., 2002; Edquist, 2005;

Hekkert et al., 2007; Malerba, 2004). Geographically speaking, we can distinguish between regional, national and transnational SIs. Regional SIs are relevant because much innovative knowledge is tacit and 'sticky', which is formed and propagated mainly by face-to-face interaction, mutual trust and shared values, meaning that these aspects tend to be localized in regions (e.g. Braczyk et al., 1998; Cooke et al., 1997). Regarding national SIs, they are a matter of analysis where a considerable extent of innovation-related policies, non-firm organizations, infrastructure and resources are decided upon at the national level (e.g. Freeman, 1987; Lundvall, 1992). Transnational SIs take the stage when there are complementarities and potential for innovation among regions of different countries, which could require a formal political entity to create ties and lead the evolution of shared systems (e.g. Caracostas and Soete, 1997; Perkmann, 2003).

A sectoral SI enables a focused context to better understand the activities, actors, institutions and relations that directly affect performance and transformation, as well as the division of labor between industrial sectors (e.g. Breschi and Malerba, 1997; Malerba, 2004). Finally, technological SIs are even more focused because they tend to embrace fewer systemic components. Thus, they lend themselves to investigating the detailed dynamics among networks of agents and institutions for the establishment of technological paradigms to materialize innovation and business opportunities (e.g. Carlsson and Stankiewicz, 1995; Hughes, 1984).

The first task in researching SIs is always to determine the function of the system (Carlsson et al., 2002; Edquist, 2005) -that is, the system of interest. To begin, an SI should embrace a geographical area. Then, it could be about a sector or technology. Two simple cases are the software sector in Europe (Steinmueller, 2004) and the personal computer system in Taiwan (Hung and Whittington, 2011). In other situations, there may be compelling reasons to mix different sectors or technologies in a study, for instance in the case of the convergence of internet and mobile telecommunication technologies in Europe (Edquist, 2004) and the dependence of IS on information and communication technologies (ICTs) in developing countries (Baskaran and Muchie, 2005; Mansell and When, 1998).

A defined system of interest is normally affected by subsystems and structures located in various SIs (c.f. Asheim and Gertler, 2005; Edquist, 2005; Hekkert et al., 2007). It implies that a comprehensive study of a system of interest would need to integrate the research done on several types of SIs (Iliev, 2005), and that the actual boundaries are unknown at the start of a study (Edquist, 2005). For instance, the results of research on IS and ICTs in the least developed countries raised concerns about the potential effects of new IS-related international regimes (Mansell and When, 1998). Similarly, work on the SIs for IS and ICTs in emergent and sub-Saharan African countries revealed unequal access to ICT infrastructure and IS skills among regions (Baskaran and Muchie, 2005). Finally, overseas managers, international capital and foreign distributors for assembling products became vital for the development of the personal computer sector in Taiwan (Hung and Whittington, 2011).

As mentioned, the study of SIs has mainly concentrated on geographies, sectors or technologies, but a system of interest usually has interacting components that belong to all these systems. Although highly valuable to understanding innovation from different perspectives, this division between topics of attention and the methodological traditions of various research communities have mostly generated partial and superficial descriptions of systems of interest instead of comprehensive theoretical explanations (Iliev, 2005; Meeus and Oerlemans, 2005; Radosevic, 1998). This can be interpreted as a misalignment between research aims and the units of analysis (Carlsson et al., 2002). 'The theoretical challenge is to relate entities at various levels and to different but inter-conditioning processes … a clear understanding of SIs requires an essential theoretical bridge enabling the analysis of the bridge between macro and micro aspects of innovation processes' (Golichenko, 2016; Lundvall, 2007; Meeus and Oerlemans, 2005, p. 60; Meeus and Hage, 2006; Freeman and Soete, 1997).

It is argued that the initial cause of the low theoretical development about SIs has been the ad hoc and simplistic policy orientation of much of the research that forged the area (Meeus and Oerlemans, 2005). The appeal to policy has focused researchers on studying isolated subsystems according to the imperatives of specific political jurisdictions, typically via a deterministic approach, instead of taking a holistic view of innovation and theory-building interests (Oerlemans and Pretorius, 2006). A related deterrent to the theoretical growth and integration of SIs is the knowledge areas and practices of scholars (ibid). It is very difficult for most researchers to manage the diverse disciplines that should be systematically mixed in the study of SIs (Meeus and Oerlemans, 2005; Oerlemans and Pretorius, 2006) -for instance, organizational studies, management science, economics, political sciences and sociology (e.g. Casper and van Waarden, 2005; Edquist, 2005). A similar difficulty occurs due to the often changeable interdependence of different technological fields since it requires knowledge in several areas and working with diverse specialists (Oerlemans and Pretorius, 2006).

Now, the technological SI strand has been practically the only one studying the role of individual actors in promoting and realizing change (e.g. Carlsson et al., 2002; Lindholm-Dahlstrand et al., 2016). In response, a group of scholars has recently focused on the subsystem that fosters and supports entrepreneurs as relevant actors in the creation, discovery, experimentation and exploitation of innovations (Acs et al., 2014; Lindholm-Dahlstrand et al., 2016; Qian et al., 2013). In spite of this, it is evident that there has been an ongoing emphasis on the study of structures at the expense of the human and social actions that are conducive to the endogenous evolution of systems (Acs et al., 2014; Hung and Whittington, 2011; Lindholm-Dahlstrand et al., 2016; Qian et al., 2013). 'Firms are conceived as puppets on institutional strings' (Meeus and Oerlemans, 2005, p. 61).

This can be attributed to the early focus on national SIs. This was due to a strong desire to discredit the orthodox view of linear innovation, in which it was assumed that some specific organizations were in charge of the creation of innovations and that the innovations were then diffused to knowledgeable and well-informed adopters (Acs et al., 2014). The idea was to provide policymakers at the national level, purported to be the main change agents for innovations, with a better conceptual foundation to understand innovation processes and to alter the broad institutional landscape that influences incumbent organizations (ibid). Oerlemans and Pretorius (2006) argue that there has been a preference for the status quo in policymaking because of the more powerful lobbying and economic capacity of incumbent organizations. In this scenario, the need for research on individual agency and the role of entrepreneurs in driving the evolution of SIs has been largely forgotten (Hung and Whittington, 2011; Qian et al., 2013). In addition, Carlsson et al. (2002) state that the focus of research on static structures can also be attributed to the inherent complexity of national SIs. These systems include a very large number of components and intricate linkages at different levels, which significantly change during paradigmatic competition and the establishment of new technological trajectories (ibid).

To summarize, the content and boundaries of systems of interest ought to gradually become known as new findings, relations and lines of inquiry emerge from multilevel research processes. Accordingly, the study of SIs should be a discovery process in which the SIs are, simultaneously, the units of analysis and the objects of study. In the process, any structural component could become especially relevant and deserve to be researched in detail as a subsystem, for instance e-entrepreneurship, IS-related legislation, IS policy implementation and human capital. However, the research so far on SIs has not been, for the most part, oriented to developing multilevel systemic theories on structures, nor has it given much relevance to individual agency as a driver for SI evolution. Meeus and Oerlemans (2005), Oerlemans and Pretorius (2006) and Lundvall et al. (2002) call for explicit research approaches to address these particular challenges. Edquist (2002, 2005, 2011) and Oerlemans and Pretorius (2006) argue that research on SIs must include comparative studies between existing systems because researchers can learn from contrasting contexts and performances. They also state that comparative research would help to identify system failures and recommend policies. Furthermore, comparative studies can help to discover opportunities to evolve, and to avoid trajectories which favor particular vested interests (Oerlemans and Pretorius, 2006). CR can perfectly address all these needs.

Critical realism

CR (c.f. Collier, 1994; Danermark et al., 2002; Sayer, 2000) is a metatheory, originally developed from a general philosophy of science called transcendental realism (Bhaskar, 1997) and a more specific human science philosophy called critical naturalism (Bhaskar, 1998), by adding an interpretive thread to a deep ontological stance primarily conceptualized from the natural sciences (Sayer, 2000). Basically, critical realists contend that there is a concrete and mind-independent reality that has real consequences for the perceptual and cognitive functions of social actors (Bhaskar, 1997, 1998).

More explicitly, CR states that there are three domains of reality. The domain of the empirical relates to our experiences, the domain of the actual relates to the events that we directly or indirectly experience, and the domain of the real to the generative mechanisms that give rise to these and other related events (Bhaskar, 1997). The generative mechanisms are structured material and immaterial entities, including other events and experiences, which have causal powers that can be (partially) triggered by the meaning people give to them, and instantiated by intentional or unintentional, and rational or irrational actions of people (Bhaskar, 1997, 1998).

However, the final effects of mechanisms are still contingent on the external macrostructures to which they belong. A macrostructure is formed through the joint activity and relations of multiple structures and their consequent generative mechanisms. Thus, some mechanisms reinforce or counteract others (Bhaskar, 1997; Danermark et al., 2002; Sayer, 2000). Reality is also stratified, so each stratum is generated by the mechanisms and powers of an underlying stratum, but qualitatively speaking a stratum has its own structure and powers as a consequence of an emergent process caused by the interaction of its dissimilar constituents (Bhaskar, 1997; Collier, 1994).

In CR, structures and people are distinct phenomena which possess their own powers. Humans, 'like any empirically given object, are fields of effects that possess their own causal powers' (Bhaskar, 1998, p. 111). As a result, there is a dual relationship in which social structures and acting people affect each other (e.g. Archer, 1995; Lawson, 1997). To explain this, Bhaskar (1998) enunciated the transformational model of social activity. In principle, social structures enable or constrain the actions of people. Therefore, people may simply reproduce the structures, though they may also behave as agents in transforming the structures based on their own powers and purposeful goals. As new structures emerge, they have their own powers.

Archer (1995) decomposed social structures into (1) structural systems -associated with material relations and their emergent properties including the allocation of physical and human resources, as well as the organizations (e.g. corporate finance departments) and frameworks (e.g. employment laws) that affect the relations- and (2) cultural systems -about the relations of ideas and their emergent properties including the preponderance of theories, norms, beliefs and values, as well as the organizations (e.g. internal communications areas) and frameworks (e.g. history) that affect the relations.

This structural-cultural distinction explains how the situational logic, in terms of the congruencies and incongruences of the structural and cultural systems, conditions how different groups of people reflect and react (Archer, 1995, 2007). A congruent situational logic will encourage the reproduction of structural and cultural systems, which is known as morphostasis. Conversely, an incongruent logic could result in morphogenesis, which is about the transformation of social structures. Importantly, people themselves pass through what is called a triple morphogenesis. They transform themselves into intentional primary agents through their individual responses to social structures, then into organized corporate agents by triggering their strategic capabilities to affect the structures, and finally into effective actors in the modification of social structures by going beyond their formal roles due to the characteristics of their personal identities (ibid.).

Most features of the social structures are relatively enduring because they condition people's activity (Archer, 1979). However, the complexity and open character of the structures, the definitive role of people in interpreting and instantiating mechanisms, and the inherent possibility of structural and cultural change under diverse situational logics create uncertainties about the outcomes of society at any given time (e.g. Danermark et al., 2002; Sayer, 2000). Any regularity represents a temporal tendency in the exercise of causal powers of the mechanisms of a particular structure, given a congruent logic (Bhaskar, 1997).

It is important to emphasize that almost all the applications of CR in IS research have focused on individual organizations or corporate groups. To our knowledge, there are only two studies that apply CR at higher levels of analysis. One of them is an initial attempt by a government-funded program to diffuse fast broadband and a system to organize community projects in rural Australia (Dobson et al., 2013). The researchers use reflexivity concepts to understand how people took decisions under different situational logics. The study is longitudinal and explains the effects of the decisions of the adopters, the program organization and the government on one another in a multilevel structure. The other research is a historical analysis of the policy formulation and implementation of e-government-for-development plans in Kenya (Njihia and Merali, 2013). This found a series of structural and cultural mechanisms that created diverse situational logics through time, which opened opportunities and influenced a triple morphogenesis in several actors for the formation of the agential networks that were decisive for change.

CR as an ontological base of SIs

There is a clear compatibility between the SI framework and CR ontology. Ontology matters because it guides studies in terms of epistemology and research approaches (e.g. Archer, 1995; Fleetwood, 2005; Reed, 2009). To begin, both frameworks depict reality as macrostructures that are constituted of a multiplicity of components, relations, multilevel emergence of powers and the subjectivity of people to give life to the social realm. There are also parallels in terms of temporal stability and change. Path dependency and tendencies in technological trajectories happen in contexts of congruent situational logics and regularity in the exercise of the causal powers of structural mechanisms. Also, radical innovations influence actors to create new paths in situations of incongruent logics. Here, people undergo triple morphogenesis to become actors of change in order to modify systems and legitimize their innovation-related outcomes, which can be seen as institutional entrepreneurship. The dominance of new technological paradigms and trajectories occur in cycles through time, thus emulating the transformational model of social activity.

There is also compatibility in relation to generative mechanisms (Castellacci, 2006). CR produces general abstractions to represent the operation of mechanisms since the domain of the actual is contextually heterogeneous and intricate (Sayer, 1992). Given this complexity, CR also states that society -the intransitive object of science- is independent of scientific results -the transitive object of science (Collier, 1994). Therefore, theories on structures and mechanisms are mainly works in progress, fallible and temporary representations of reality (ibid). Likewise, an important aim in SIs is the development of appreciative theory (Castellacci, 2006; Hommen and Edquist, 2008; Muchie and Baskaran, 2009). This type of theory is expressed in the form of causal statements that explain diverse contexts in terms of generic abstract constructs (Hommen and Edquist, 2008; Nelson and Winter, 1982). It is also adjustable in response to the analysis of new and contrasting empirical material (ibid).

There has been very little effort to connect SIs and the CR ontology. Iliev (2005) found important similarities between them. He was motivated by the lack of a philosophical base to guide research approaches in the area of SIs. Also, Castellacci (2006) explained the compatibility of CR with frameworks derived from evolutionary economics, including SIs. The arguments of both are similar in their focus on the components, institutions and multilevel relations in systemic structures, the correspondence of the dynamics of technological paradigms and trajectories with the transformational model of social activity, as well as on the inherent uncertainty in structures given their complexity, open character and the heterogeneity of actors interpreting and acting.

Similarly, there have been few attempts to relate CR-based research to the study of SIs. For example, some important links have been made between core CR research components and a framework connected to SIs that is called business systems (e.g. Whitley, 2000a). Business systems is about the participation of firms in the institutional shaping of markets and the effect back on diverse organizational outcomes, for instance corporate governance, employee-firm relations and innovation (ibid). Regarding innovation, Whitley (2003) highlights similarities with SI-related ‘developments in evolutionary and institutional economics, particularly those concerned with the role of knowledge in economic affairs and the nature and role of firms in generating new technologies and structuring markets’ (p. 496). The main differences between business systems and SIs are that the latter is more open-ended since its interests stretch beyond the functions of firms (Hommen and Edquist, 2008), and that it has been expressly created to understand and study innovation processes and technological change in society (Hommen and Edquist, 2008, Whitley, 2003, 2006).

Importantly, Whitley recommended the use of comparative analyses (Whitley, 2000a, 2000b, 2003) by applying extensive and intensive methods (Whitley, 2003) in order to provide deep causal explanations of the configuration of the relevant institutions that influence economic activities. He also matched the dynamics in business systems with morphogenetic ideas, including the reactions of organizations to diverse situational logics, agential powers, and the capacity of firms to jointly work to alter institutional structures according to their interests (Whitley, 2003). Finally and directly connected to SIs, Castellacci (2006) suggested a focus on contrasting tendencies in comparative studies -that is, demi-regularities- and the use of retroductive inferences to abstract theory in the research of SIs. As we will explain in detail in the next section, all these concepts are core components of CR research approaches.

Joint application of SIs and CR in digital innovation research

This section explains how to study comprehensive SI-based units of analysis by using CR approaches. Two of the most often employed explanatory frameworks in CR research are Danermark et al.’s (2002) staged model for studying the composition of social structures and Archer’s (1995) morphogenetic approach to researching agency and structural change processes (e.g. Dobson, 2012, 2013; Raduescu and Vessey, 2008). Given the novelty of the joint use of SI and CR, we develop a thought experiment (Gendler, 2000) on the application of the CR research approaches to study a scenario (Ducot and Lubben, 1980) of a SI for IS innovation diffusion. We use the area of IS innovation diffusion, a relevant part of digital innovation (e.g. Fichman, 2004, Fichman et al., 2014; Jha and Bose, 2016; Nambisan et al., 2017), as a context to illustrate research processes, methods and findings.

Function of the system

As previously discussed, the first task in studying SIs is to define the system of interest, that is, its function. Edquist (2005) recommends defining it in terms of narrow categories of innovations, given the complex diversity in the composition of broader systems. For instance, the function could be the diffusion of big data systems in the SMEs of the English regions. A function gives a focus to the task of researchers in order to investigate the conformation and evolution of a concrete system. In addition, Edquist (2002, 2005, 2011) suggests using comparative case studies on the same innovation categories and preferably with different 'innovation intensities' in order to better understand 'what is good or bad, or what is a high or a low value for a variable in a system' (Edquist, 2002, p. 232). In this sense, the cases could be differentiated by geography, sector or time. To continue the example, the cases could be about the jurisdictions of some of the Local Enterprise Partnerships, which are the bodies responsible for overseeing economic development at a local level in England, let us say the North East, Lancashire, Oxfordshire and Dorset partnerships.

The staged model

Danermark et al. (2002) proposed an explanatory staged approach to research the conformation of social structures. The stages include description, analytical resolution, abduction/theoretical re-description, retroduction, comparison between different theories and abstractions, and concretization and contextualization. These may follow a nonlinear sequence, require switching to previous stages, be intertwined, and some may need more work than others. This may depend on, for instance, the complexity of the function of the system, the extent of theoretical development in the areas of concern and the acquaintance of the researchers with those areas. As the study of systems is a discovery process, these aspects could affect the stages at different points in time.

Description and analytical resolution

The description and analytical resolution stages are closely related. Their character is explorative and the outcome is the formulation of initial lines of inquiry about unobservable structures. In the description stage, the aim is to form an account of the concrete events that will be a matter of analysis according to the experiences of the people involved with them. This could be undertaken using qualitative methods such as interviews with the SME decision-makers to build preliminary stories about adoption processes and factors.

In the analytical resolution stage, the task is to dissolve the whole into various components which are believed to be the empirical manifestations of the multilevel interaction of a greater number of structures and generative mechanisms. Lawson (1997) uses the term 'demi-regularity' to characterize the relatively stable occurrence of an observable event, which indicates the occasional but less-than-universal tendencies of generative processes in a specific time and space. Demi-regularities are potential objects of study, especially if they contrast between different cases (e.g. Danermark et al., 2002, Lawson, 1997; Zachariadis et al., 2013). They can be identified through the use of extensive research (Ackroyd and Karlsson, 2014; Downward and Mearman, 2007; Sayer, 1992; Zachariadis et al., 2013), which is based on large numbers of observations and statistical analyses to appreciate the spread and relevance of the issues initially detected in the description stage (ibid).

For example, an extensive study might find significant correlations between the adoption of big data systems in the North East and Lancashire and three variables: the availability of expert advice on information technology (IT), competitive pressures and the compatibility of the systems with the internal practices. The results in Oxfordshire and Dorset might denote a significant association only with compatibility with internal practices. Thus, the conclusion would be that the availability of IT expert advice and the competitive pressures are demi-regularities that deserve further investigation. It would be promising to understand what is common among the four SIs to explain the differences noted in the two demi-regularities, especially if the SIs had contrasting performance on information systems diffusion.

Abduction/theoretical re-description

The objective in the abduction/theoretical re-description stage is to devise alternative conceptual frameworks to hypothesize the underlying structures that could explain in more general and social-level terms the events experienced by people and groups. It could start by using the qualitative information gathered in the description stage, which is useful to illustrate not only the manifestation of the demi-regularities but also the visible aspects that affect them.

For instance, the opinions of the SME decision-makers in the North East and Lancashire on the availability of IT expert advice could be based on perceptions about the number of qualified IT graduates in the region (e.g. Mongkhonvanit, 2014; Wolfe, 2012), and the affordability and independence of their services (e.g. Priest, 1999; Robson and Bennett, 2010). In this scenario, the quantity and quality of IT university degrees would be expressions of the regional university system structure, whereas service affordability and independence would be manifestations of the national IT support structure. We could also theorize that dependence on IT experts could be reduced if the big data systems were hosted on public clouds (e.g. Muller et al., 2015; Iyer and Henderson, 2012), which would be a consequence of a technological component, namely the cloud provision structure. This would explain the lack of relevance of available IT expert advice in Oxfordshire and Dorset.

Retroduction and comparison between different theories and abstractions[3]

If abduction is to 'reinterpret something as something else', retroduction is to 'move from knowledge of one thing to knowledge of something else' (Danermark et al., 2002, p. 96). In formal CR terms, retroduction is the guided and disciplined research movement from observable events to abstract and fundamental generative processes (Sayer, 1992). This mode of inference is achieved, for

Table 1
Summary of our use of the staged model.

Stage	Aims	Methods	Outcomes
Description	Explore the concrete events that will be the matter of analysis	Interviews with SME decision-makers	Account of adoption processes and factors
Analytical resolution	Dissolve the whole into various demi-regularities, which are believed to be the manifestation of the interaction of underlying structures and mechanisms	Extensive research, based on large numbers of observations, statistical analysis and contrastive cases	Demi-regularities: availability of IT expert advice and competitive pressures
Abduction/Theoretical re-description	Formulate alternative theoretical frameworks to hypothesize underlying structures and mechanisms	Previous interviews and existing theoretical research. We have not developed competing explanations in the exercise	Potential structures for the availability of IT expert advice: impact of the regional university system and national IT support structures on the provision of experts, and the moderating effect of the technological cloud provision structure on the need for expertise
Retroduction and comparison between different theories and abstractions	Abstraction of a general system of structures and mechanisms based on the acceptance, combination, extension or modification of the theoretical frameworks	Intensive research, based on a few contrastive case studies in their causal contexts and deep systemic comparisons using counterfactual thinking	System for the availability of IT expert advice: the structures devised in the previous stage plus the impact of the regional living conditions structure on the provision of experts, and the moderating effect of the sectoral cloud market structure on the need for expertise
Concretization and contextualization	Appreciate the fit of the system in other concrete situations either to modify the system or to inform policy and practice	Not applied in the exercise	Not applied in the exercise

example, by contrasting different contexts and using counterfactual thinking in order to isolate the most basic properties that give rise to a phenomenon (Danermark et al., 2002; O'Mahoney and Vincent, 2014). The approach is qualitative in nature and involves a small number of cases in their causal contexts, which is known as intensive research (Ackroyd and Karlsson, 2014; Downward and Mearman, 2007; Sayer, 1992; Zachariadis et al., 2013). As a result of this process, some conceptual components of the theoretical re-description should be accepted, combined or eliminated according to their explanatory power, but also new relevant structures, mechanisms and relations may be identified and added to the model (Danermark et al., 2002; Hurrell, 2014).

Following our example, we could do comparative case studies (e.g. Tsang, 2014; Wynn and Williams, 2012) of the four English regions to build a deeper explanation regarding the availability of IT expert advice. For instance, the investigation could find good (1) university system structures in the regions with dependency on IT expert advice and a healthy (2) national IT support sector structure. However, one of the regions with that dependency could still contain a relatively low number of experts due to the migration of those professionals to other regions, perhaps as a result of another structure, namely (3) the regional living conditions (e.g. Kitson et al., 2004; Storper, 1997). Also, (4) the cloud provision structure could be, in effect, a regulator of the perceived need for IT experts, especially in sectors of the economy where the SMEs understand the benefits of cloud computing, trust cloud suppliers and know about service level agreements (e.g. Alshamaila et al., 2013; Loukis and Kyriakou, 2018; Oliveira et al., 2014). These would be constituents of an additional structure, namely (5) the sectoral cloud market. This could be discovered by contrasting the composition of sectors in the regions with dependence on IT expert advice but with good cloud provision, with the regions with no dependence on IT expert advice.

Concretization and contextualization

Although research on SIs should focus on narrow functions, e.g. the diffusion of big data systems in the SMEs of the English regions, the models of structures, mechanisms and relations constructed in the previous stage are not necessarily generalizable in their totality. For this reason, an objective of the concretization and contextualization stage is to appreciate how a model works in specific and concrete situations, with the possibility of triggering further research to improve and extend the theoretical system initially abstracted (e.g. Blom and Moren, 2015). Another important aim of the stage is to undertake applied research in order to explain concrete events to inform policy and practice. Clearly, the application of this stage is optional.

Recap of our use of the staged model

We summarize here how we have addressed the calls to study the structures of digital innovation in a systemic way at societal levels. Table 1 shows the aims of each stage, the research methods referenced in our example and the outcomes. The outcomes of each stage fed the corresponding next stage in the process, and progressively contributed to building the theoretical construct for our system of interest. This exercise is a linear application of the staged model on part of an SI, which is useful as an entry point to

[3] We do not compare theories in this exercise since we have defined only one theoretical re-description in the previous stage.

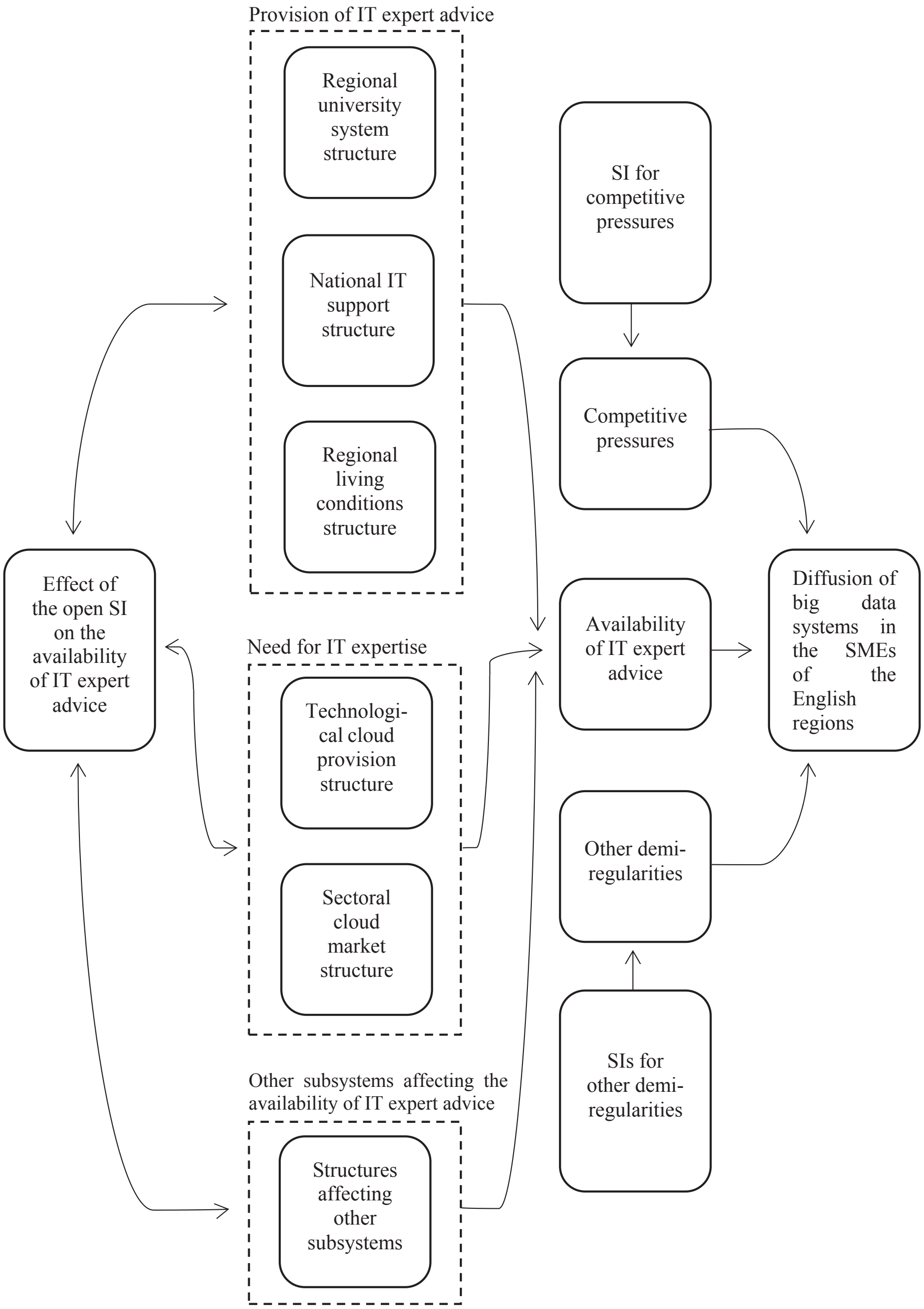

Fig. 1. SI for the diffusion of big data systems in the SMEs of the English regions.

understanding and performing more comprehensive studies.

Fig. 1 depicts the boundaries of the SI and expands on the outcomes shown in Table 1. The states and effects of two subsystems, namely the provision of IT expert advice and the need for IT expertise, would explain the degree of perception concerning the availability of IT expertise. At the same time, each subsystem is composed of a group of structures. Each structure can be reproduced due to the powers of its generative mechanism (Bhaskar, 1997, 1998). However, the joint effect of the structures will emerge (Bhaskar 1997; Collier 1994) -within their corresponding subsystem and then through subsystems-, and be instantiated as individuals make sense of the whole and act according to that (Bhaskar, 1997, 1998). In addition, the structures may mutually depend on other subsystems at different levels because of the open and complex character of the social realm (e.g. Danermark et al., 2002; Sayer, 2000). Finally, the undertaking of the concretization and contextualization stage could indicate the presence of further demi-regularities, multilevel subsystems and structures (Danermark et al., 2002).

The morphogenetic approach

In this subsection we illustrate how to study agency and its influence in the change of the systemic structures of digital innovation beyond organizational boundaries. The morphogenetic approach (Archer, 1995) is aligned with the transformational model of social activity (Bhaskar, 1998) by considering social structures and agency as different phenomena with their own powers. It adds a time dimension for the processual analysis of their interaction, with the purpose of understanding change and trends in society. This artificial separation is called analytical dualism, and assumes that structures precede the actions of people, and that the actions and interactions of people come before the reproduction or transformation of the structures.

Accordingly, to consider dualism, research needs to be longitudinal. So, the first part of a study should measure diffusion and model the initial structures which enable or constrain the behavior of actors in particular contexts. The latter could be done by using Danermark et al.'s staged model, as in our example which illustrates the diffusion of big data systems in the SMEs of the English regions. The research should then focus on explaining how actors reflect based upon their situational logic, and decide either to reproduce the structures or to transform themselves thorough triple morphogenesis to seek structural change. After that, a study should turn to investigating the dynamics of how some groups compete with others to gain acceptance, and impose or maintain the structures that are the most convenient for them.

The trigger for change in an SI may occur in diverse ways and originate from diverse actors. For instance, IS academics could disseminate their research results to the representatives of the SME sectors that would greatly benefit from the IS (e.g. Bastow et al., 2014; Chandler, 2014), let us say the Creative Industries Federation and the British Hospitality Association. Such research could be relevant to altering the cultural system of the personnel of these bodies by making them reflect about the benefits of using big data systems and the possibilities of successful adoption by SMEs (e.g. Morelli and Spagnoli, 2017; Xiang et al., 2015). They could decide to act as effective actors and rely on the Federation of Small Businesses and the United Kingdom (UK) IT Association to strengthen their lobbying capabilities to influence the design and realization of wide-reaching measures to eliminate or ameliorate the systemic barriers to diffusion. The intention is to make other systemic actors become organized corporate agents to materialize the required modifications in the system. For example, a barrier such as the low quality of IT expert advice for SMEs could be tackled by combining different initiatives, including redesigning academic IT programs, subsidizing training for IT consultants, implementing IT consultancy accreditation schemes and awarding recognitions for high-quality IT advice.

There would be many other actors involved in the design, administration and implementation of these initiatives, which normally operate in environments with conflicting priorities and limited resources, for instance the Directorate-General Regional and Urban Policy, Innovate UK, the Department for Business, Energy and Industrial Strategy, the Department for Education, Universities UK, Local Enterprise Partnerships, and the Chartered Institute for IT. For example, the design and administration of an IT consultancy accreditation scheme for SMEs could be assigned to the Chartered Institute for IT, which could use grants from the Department for Business, Energy and Industrial Strategy. The lobbying activities would be centered on influencing the government department to allocate funds to the scheme instead of granting it to other competing initiatives in its business enterprise and industrial strategy policy areas.

Finally, the extent of diffusion should be measured after the implementation of the initiatives, and the systemic work under the resulting structures should be contrasted with the work under the structures found at the beginning of the study. Clearly, some studies could be forward looking and emancipatory, using an action research approach (Ackroyd and Karlsson, 2014; Ram et al., 2014). Alternatively, by starting with the final structures, research could be done in reverse order to understand what happened in the system. The study of long retrospective periods of structural evolution would require historical methods (Archer, 1979; Mutch, 2014).

Conclusions

The scope of digital business strategy has been substantially extended due to its dependence on the increasingly complex external environment that affects digital innovation. This study proposes a comprehensive framework to address the calls to research digital innovation in a systemic way to encompass the multilevel causes at societal levels that affect IS in organizations, as well as explain agency and how it influences the structural evolution of systems and technological change. Addressing these needs, the first contribution is to consider SIs as an alternative and holistic conceptual base and unit of analysis to study the creation, diffusion and use of digital innovations in countries, regions, sectors and other organizational aggregations. The second contribution is the use of CR research approaches to study SIs given the compatibility between both, along with some flaws in the SI research practice, namely the lack of development of multilevel systemic theories and an over emphasis on structures to the detriment of individual agency and endogenous change.

We explicated and exemplified the staged model to untangle the composition of SI-based units of analysis. Core concepts such as demi-regularities, abduction and retroduction can guide the integration of the research of different types of SIs at multiple levels in individual studies, by addressing the units of analysis as concatenated and inclusive wholes, while consistently incorporating relevant activities, actors and institutions as they are identified in the progress of research. This would imply an extended set of questions to discover systemic causations, including: What relevant activities directly affect digital innovation in organizations? What actors perform those activities? What relevant institutions affect the actors? How are the activities related to each other? What is the composition and relations of a second level of activities, actors and institutions affecting the first level? Are there further relevant levels? Why? What are their composition and relations? What are the common subsystems and structures that explain different outcomes across comparative cases?

We also applied the morphogenetic approach to research the dynamics of SIs and consider the role of agents in the endogenous development of systems. The concepts of analytical dualism, situational logics and triple morphogenesis are critical to understanding the temporal interplay of agency and structure for the reproduction and transformation of SIs. There are important questions for understanding change in SIs, for instance: How did the initial structures affect digital innovation? What actors tried to create or maintain paths? What was the rationale for mindful deviation? What were the structural changes proposed by the competing groups? What other actors were relevant to be influenced in the process? How did the competing actors organize themselves to undertake institutional entrepreneurship? What were the processes and results of the paradigmatic competition? What were the structural changes that were implemented? How did the resulting structures affect digital innovation?

As we have demonstrated, there are plentiful opportunities for the digital innovation field from the joint use of SIs and CR. SIs is what takes the attention of researchers from theoretical and practical standpoints through highly relevant topics and research questions about deep structures and evolution, while CR provides the research apparatus to implement these types of studies. We believe that this research is a firm step in this direction.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsis.2019.06.001.

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