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RESEARCH ARTICLE

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The Dynamics of Architecture-Governance Configurations: An Assemblage Theory Approach

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Abstract

Research on digital infrastructures and platforms studies large-scale systems that are characterized by constant evolution, loosely defined boundaries, and growing complexity. This research demonstrates that evolution is driven by tensions (between stability and change), which are in turn determined by the systems' architecture and governance structures. This paper argues that architecture and governance are intrinsically related and conceptualizes them as a unified entity that we call an architecture-governance (A-G) configuration. We focus on the dynamics of A-G configurations—i.e., how architecture and governance interact and, in combination, shape the evolution of digital infrastructures, while, at the same time, change as emergent outcomes of the evolution of infrastructures. Toward this end, this paper applies assemblage theory as a lens for conducting a longitudinal study on an electronic prescription infrastructure. We identify three overall A-G configurations corresponding to different phases of the evolution of the infrastructure. This paper makes three contributions. First, we theorize the A-G configuration as an intertwined intermediate-scale entity that represents the form of the infrastructure and simultaneously constitutes an assemblage in its own right. Second, we demonstrate how an A-G configuration and its infrastructure coevolved through a series of interacting stabilization and destabilization processes operating within and across levels. Finally, we argue that tensions driving the evolution of infrastructures are also dynamic and that, accordingly, the focus of study should be on the processes of stabilization and destabilization rather than on stability and change themselves.

Keywords: Digital Platform, Digital Infrastructure, Architecture, Governance, Assemblage Theory, Evolutionary Dynamics, Healthcare

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1 Introduction

The increasing strategic importance of IT systems for enabling new forms of social and economic organizing poses new challenges to practitioners and researchers alike. These contemporary large-scale systems exhibit high degrees of complexity, are characterized by a growing number of interconnections and interdependencies among sociotechnical components, and tend to evolve over long periods of time through loosely coordinated actions of many autonomous actors, usually in ways that go far beyond the specifications of the original designers. Examples studied in the field of information systems (IS) include smartphone ecosystems (Sørensen, Reuver, & Basole, 2015; Eaton et al. 2015), web browser ecosystems (Tiwana, 2015), mobile payment platforms (Kazan et al., 2018), eHealth infrastructures (Hanseth & Bygstad, 2015), enterprise software ecosystems (Wareham, Fox, &

Cano, 2014), as well as large portfolios of integrated applications in large and distributed organizations (Ciborra et al., 2000), interorganizational systems (Reimers, Johnston, & Klein, 2014), and coordination hubs (Markus & Bui, 2012).

These large-scale systems evolve continuously over long periods of time, and their boundaries are constantly renegotiated as their functionalities are expanded, new sociotechnical components are connected, and new domains of use are discovered to serve emerging possibilities. The evolutionary dynamics of these systems have been documented in the literatures on digital infrastructures (Hanseth & Lyytinen, 2010; Tilson, Lyytinen, & Sorensen, 2010) and platforms (Constantinides, Henfridsson, & Parker, 2018; Tiwana, Konsynski, & Bush, 2010). Scholars within these research domains have elaborated on the idea of *tension* as a conceptual lens for understanding evolution. There are many examples of such tension, including: (1) the tension between the stability introduced by the installed base to enroll new actors and services and the flexibility to leverage the unbounded growth of actors and services (Hanseth, Monteiro, & Hatling, 1996; Tilson et al., 2010; Wareham et al., 2014); (2) the tension between the autonomy of independent actors seeking generativity through distributed control and centralized control (Tilson et al., 2010; Lyytinen, Sørensen, & Tilson, 2017; Wareham et al., 2014); and (3) the tension between short and long-term goals (Edwards et al., 2007), between tight integration and loose couplings (Lyytinen et al., 2017), and between the logic of generative and democratic innovations and the logic of infrastructural control (Eaton et al., 2015). These tensions are all directly or indirectly the outcome of actual systems' architecture and governance structures. However, more systematic research into how specific architectures and governance structures shape the evolution of large-scale systems such as digital infrastructures is still sorely needed.

A number of management science and law studies provide examples illustrating that the evolution of digital infrastructures and platform ecosystems is shaped by both their architecture and their governance structures and that these two structures are, in fact, intrinsically related. The best-known example is the role of the so-called end-to-end architecture in the evolution of the internet. Lawrence Lessig (1999) argues that this also represents "a regulatory modality" that he characterizes with the slogan "code is law."

The relationship between the architecture of technological systems and their organizing and governance structures is also explored to some extent within management research. There is solid empirical evidence supporting the argument that the successful development and evolution of a technological system depends on an alignment, or "mirroring," of the system's architecture and governance structures (MacCormack, Rusnak, & Baldwin, 2008).

Management research has also identified the power of "architectural control," defined as "the capacity to enable or constrain the design of a system component (or set of components) without exercising design rights over it directly" (Woodard, 2008, p. 4). For instance, in a landmark *Harvard Business Review* article based on their book *Computer Wars*, Ferguson and Morris advanced the proposition that "architecture wins technology wars." Specifically, they argue that "competitive success flows to the company that manages to establish proprietary architectural control over a broad, fast-moving, competitive space" (Morris & Ferguson, 1993, p. 87). Their main empirical data are related to IBM's position in the mainframe era; Microsoft acquired a similarly powerful role as a consequence of IBM's decision to use Microsoft's DOS as the operating system when they developed and launched the IBM PC.

A closely related concept is that of "architectural control points" (Woodard, 2008; Rukanova et al., 2020), or system components "whose decision rights confer architectural control over other components" (Woodard, 2008, p. 361). Rukanova et al. (2020), for instance, illustrate how using mobile phone SIM cards to provide secure identification for users of a mobile banking solution would have given mobile phone operators significant control over the solution that banks and mobile phone operators sought to establish. However, the emergence of smartphones and cloud computing opened up new options for designing a secure identification solution, thus removing the SIM card solution as an architectural control point. Taken together, these studies provide convincing support for the hypothesis that architecture and governance structures are intrinsically related. However, a theoretical grounding of this relationship is still lacking.

IS research has also demonstrated that the evolution of large-scale IT solutions is shaped by their architectures and governance structures and that the evolution of such systems also causes unintended changes in the architectures and governance structures themselves. For instance, digital infrastructures tend to grow in complexity as more information, technological features and components, and users and user organizations are integrated. Such growth in complexity often leads to unintended changes within the architecture by making the modules more tightly coupled and making the infrastructure more difficult to govern by, for example, bringing the infrastructure into a locked-in state (Arthur, 1994), thus making it less manageable (Ciborra et al., 2000; Hanseth and

Ciborra 2007). However, systematic research into this issue continues to be lacking.

The research presented above points to three gaps in the extant literature: First, the relationship between architectures and governance structures needs to be further explored. We will do this by conceptualizing this relationship as constituting a unified entity, which we call an *architecture-governance configuration*. Second, while prior literature provides evidence that the growth and generativity of digital infrastructures and platforms is a function of the architecture-governance (A-G) configuration, there is a need for systematic research clarifying how architecture and governance relate and interact with each other, and, in combination, shape the evolution of an infrastructure. Third, some of the studies mentioned above also illustrate that architecture and governance can change over time as the infrastructure grows. Nevertheless, there is a need to improve the theoretical understanding of how an infrastructure's architecture-governance configuration changes over time. In addressing these research aims, we seek to explain what we call the *dynamics of architecture-governance configurations.*

We draw upon the concepts of assemblage theory—e.g., assemblage, stabilization, destabilization, thresholds—as articulated by DeLanda (2006, 2016), and apply this conceptual lens in a longitudinal, in-depth qualitative case study of a regional electronic prescription digital infrastructure. Our study contributes by theorizing the concept of architecture-governance configuration, which we depict as constituting the *form* of a digital infrastructure and driving its evolution while at the same time being an outcome of the evolution (i.e., the evolution of the digital infrastructure feeds back into the A-G configuration). Our study also reframes the debate on the evolution of digital infrastructures in terms that reflect a process orientation in which the A-G configuration is not stable but changeable, as it is subject to iterations of destabilization and stabilization processes. Finally, through a process orientation on A-G configuration, we shift our focus from stabilizing factors (which have thus far prevailed in the literature) to destabilizing factors.

The following section reviews IS research that examines the evolution of large-scale systems and its relationship to architecture and governance. We then outline assemblage theory and present the main concepts that we draw upon to study the dynamics of the A-G configuration. Next, we introduce our research setting and general research approach. Then, we present the findings of our case study and the analysis of our results. Finally, we discuss the implications of our findings and conclude with a reflection on the contributions made by the paper.

2 Related Research

An emerging consensus among researchers seems to consider the evolution of digital platforms and infrastructures to be driven by tensions. Simultaneously these tensions are viewed as directly or indirectly related to the architecture and governance structures of digital platforms and infrastructures. We first review the tensions identified in the literature and then examine the relationship between these tensions and architectures and governance structures.

2.1 Evolution and Tensions

A number of studies elaborate on the idea of tension as a conceptual lens for understanding the evolution of digital infrastructures and platforms (Jackson et al., 2007; Tilson et al. 2010; Wareham et al. 2014). Digital platform studies regard evolution as driven by the tensions between openness and generativity (i.e., facilitating innovations among third parties), whereas platform studies identify tension as related to platform owners' need for control (Eaton et al., 2015; Tiwana et al., 2010; Wareham et al., 2014).

Infrastructure research has gestured toward a broader range of tensions. One example is the tension between the stability of the installed base used to enroll new actors and services and the flexibility to leverage unbounded growth of actors and services (Hanseth et al., 1996; Tilson et al., 2010). Another example of tension is the top-down demand for integration versus the persistent, bottom-up reliance on the installed base of systems and practices (Hepsø, Monteiro, & Rolland, 2009). A third example is the tension between sensitivity to local contexts and the need to standardize across contexts (Rolland & Monteiro, 2002). Building on extensive historical and social research on infrastructures, Jackson et al. (2007) points out three basic tensions in infrastructures' evolution, related to *time* (short-term decisions vs. long-term growth), *scale*, (e.g., global interoperability and standardization vs. local optimization) and *agency* (e.g., planned change vs. emergent change). We argue that, at a high level, all of these tensions relate to stability and change in the evolution of large structures.

Lyytinen et al. (2017) developed a more detailed and sophisticated framework explaining how tensions determine infrastructures' generativity and evolution. They define generativity as "from-within, inherent recursive growth in the diversity, scale, and embeddedness associated with digital infrastructures" (p. 253). Above all, they view an infrastructure's evolution as shaped by interactions between its underlying technologies, architected technologies, physical context, and socioeconomic context. For each of these domains, they identify one dominant tension determining an infrastructure's generativity:

respectively, fixed-state versus a variety of underlying technologies, stability versus change/flexibility of architected technologies, local versus global within the physical context, and control versus autonomy within the socioeconomic context.

Most research on tensions in digital infrastructures and platforms tends to view tensions in terms of trade-offs between opposites or extremes on a continuum with the goal of striking an appropriate balance between the opposites. One exception is Tilson at al. (2010) who present what they describe as paradoxes of control and change. They see paradoxes as dualities (Farjoun, 2010), i.e., as opposites that are "fundamentally interdependent—contradictory but also mutually enabling" (Farjoun, 2010, p. 202).

2.2 Tensions and Architecture: Governance Configurations

IS scholars researching corporate IT infrastructures have drawn on the enterprise architecture framework (Ross, Weill, & Robertson, 2006) as a way to address the tension between local and enterprise-wide control, and to develop and manage corporate IT infrastructures that support the evolution of the organization's business model. According to the enterprise architecture framework, in order to generate more value from IT investment, organizations must evolve their IT architecture through four stages (application silo, standardized technology, rationalized data, and modular).

In contrast, literature on digital infrastructure and platforms has investigated how to address the tensions discussed above by focusing on the conditioning role of architecture and governance (Henfridsson & Bygstad, 2013; Tiwana, 2014). In this research, *architecture* is broadly defined as a description of the decomposition of a system into individual components, the components' functions (i.e., what they do) and arrangement, and how they interact to provide the overall functionality of the system. Similarly, *governance* broadly refers to the set of structures and mechanisms determining how decisions about digital platforms and infrastructures are made.

IS literature defines a digital platform as "the extensible codebase of a software-based system that provides core functionality shared by all the modules that interoperate with it and the interfaces through which they interoperate" (Tiwana et al., 2010, p. 675), which, in itself, represents a specific architecture and governance structure, one that is explicitly aimed at managing tensions between stability and change (or flexibility), on the one hand, and between centralized and distributed control, on the other. Stability is integrated into the platform, which is controlled by the platform owner, whereas dynamic and unstable aspects are distributed across the apps, which are controlled in a distributed fashion (i.e., independently by individual app developers). Tiwana (2014), however, goes further by suggesting that what shapes the different evolutionary outcomes of digital platforms is the alignment of the more specific details of architecture and governance structures—meaning the design of the boundary resources and their related control structures. Accordingly, Tiwana argued for a co-design of (these details of the) architecture and governance structures. Wareham et al. (2014) gives a detailed description and analysis of the control structures applied by an enterprise system provider (i.e., the platform owner/controller) to manage the development of third-party extensions to the system.

Thus far, IS research on infrastructures has been limited to conceptualizing and analyzing architecture and governance in terms of trade-offs between opposites or extremes on a continuum—i.e., modular versus monolithic and tightly versus loosely coupled architecture, centralized versus decentralized governance, and so forth. Henfridsson and Bygstad (2013), for instance, found evidence that a modular architecture combined with a decentralized control structure offers a valuable trigger for attracting new users, developing new services, and expanding into new domains of use, whereas tightly coupled (or integrated) architectures and centralized control structures enable the attraction of new users and scope expansion but not the establishment of new services. Based on their framework covering the relations between ranges of tensions, Lyytinen et al. (2017) proposed a set of principles identifying how to balance tensions in various domains to maximize generativity—for example, loose coupling to physical components, modularity, loose coupling across layers, abstractions across domains, and distributed technical control.

Literatures on digital platforms and infrastructures tend to adopt a static view on architecture and governance, partly due to their focus on the concrete time scales of emergence and evolution (Reimers et al., 2014). Moreover, whereas infrastructure research has focused on how to design architecture and governance structures to strike the best balance between tensions, platform research is mainly based on the split between a stable core controlled by a platform owner and a dynamic periphery of apps controlled by app developers. However, some platform research has addressed how the boundary resources of digital platforms are changing in terms of the evolution of resources through "distributed tuning" processes (Eaton et al., 2015). Distributed tuning allows the interfaces of a platform to emerge and evolve through a "cascading action of accommodations and rejections of a network of heterogeneous actors and artifacts" (Eaton et al., 2015, p. 217).

Table 1. Architectural, Governance and the Change-Stability Tension

	Stability	Change
Architecture	Integration (efficiency) Uniformity, standardization Centralized	Modularization (flexibility) Variation Decentralized
Governance (strategy, organizing)	Consolidation Long term focus Planned change Centralized control	Local optimization, innovation Short-term focus Emergent change Distributed control

In summary, we concur with Farjoun (2010) and view the tensions between stability and change as the fundamental tension from which tensions between loose/tight couplings, distributed and centralized control, and standardization and flexibility can be derived. We also concur with him in terms of characterizing the relationship between stability and change as a duality and not a dualism, meaning that we do not see stability and change as opposite ends on a continuum in need of a proper balance, but as "fundamentally interdependent—contradictory but also mutually enabling" (Farjoun, 2010, p. 202). Further, we argue that some of the tensions address architectural issues while others focus on governance issues. Table 1 illustrates the respective alignment of architectural and governance structures. This implies then, that the evolution of large-scale systems is driven by the tensions between stability and change, which are the result of the interaction of specific tensions embedded into systems architecture and governance structures.

As discussed above, despite the empirical insights and concepts reported by the literature on digital infrastructures and platforms, research on the evolution of architecture and governance and its relationship to digital platforms and infrastructures remains scarce and is partially constrained by existing conceptualizations of architecture and governance. In order to address these constraints, we need a lens to help us analyze and understand three crucial aspects and to allow us to describe and analyze the relationships between technology and its human, organizational, and societal contexts. Such a lens is necessary to analyze how the different types of components of a digital infrastructure and its A-G configuration are related and work together during its evolution. Further, we need concepts to help us zoom in on smaller elements and zoom out to analyze larger wholes and the relationships and influence between parts and wholes. Finally, we need concepts to help us describe how a digital infrastructure evolves and changes over time. Therefore, we use assemblage theory, as interpreted and presented by DeLanda (2006, 2016). Although DeLanda draws extensively on Deleuze's process ontology (Deleuze & Guattari, 1987), we have chosen to use DeLanda's work because we find DeLanda's terminology and presentation more accessible than Deleuze's.

3 The Architecture-Governance Configuration as an Assemblage

In the IS field, the term *assemblage* has become increasingly popular, particularly among scholars of sociomaterial studies (Cecez-Kecmanovic et al., 2014; Doolin et al. 2014; Leonardi, Nardi, & Kallinikos, 2012), who use the term *assemblage* not to denote a theoretical concept but rather in a commonsense fashion to refer to arrangements of any mix of social and material elements. Orlikowski (2009), for instance, presents assemblages as synonymous with entanglements, configurations, networks, and associations. Moreover, such studies do not rely on the work of Deleuze or DeLanda in analyzing IS phenomena from the analytical lens of assemblage.

DeLanda develops assemblage theory (AT) as a process ontology and a theory of social complexity (DeLanda, 2000, 2006, 2010, 2016). For DeLanda, assemblages are wholes primarily characterized by *relations of exteriority*, which signify that a component part of an assemblage may be detached from it and plugged into a different assemblage where its interactions are different. That is, component parts are self-subsistent and retain autonomy outside the assemblage in which they exist. Relations of exteriority also imply that the properties of the component parts can never explain the relations that constitute the whole. That is, "relations do not have as their causes the properties of the [component parts] between which they are established" (DeLanda, 2006, p. 11). DeLanda distinguishes the *properties* defining a given entity from its *capacities to interact* with (or affect and be affected by) other entities. An entity's properties are given and may be denumerable as a closed list; its capacities are not given—they may go unused if no entity suitable for interaction is available. According to this view, the capacities to interact form a potentially open list since there is no way to tell in advance how a given entity might interact with innumerable other entities.

Assemblages emerge from the interactions between their parts; thus, the properties and capacities of an assemblage are derived from both the aggregation of the properties of its components and the interactions between those components. These capacities do depend on the component's properties but can also not be reduced to them since they involve reference to other interacting entities. Therefore, there is an *upward causality* that explains the emergence of an assemblage's properties and capacities. However, there is also a *downward causality* since "once an assemblage is in place, it immediately starts acting as a source of limitations and opportunities for its components" (DeLanda, 2016, p. 21). DeLanda (2006) advocated complementing this *vertical* view with a *horizontal* view to better account for the complexity of social reality in which entities at different scales—people, institutional organizations, networks, cities, nations, and so on—interact and overlap with one another in various ways. In other words, assemblages can interpenetrate each other and some relationships cut across different assemblages.

The concept of assemblage is also related to the "classic" distinction between an object's form, function, and matter (DeLanda, 2000; Kallinikos, 2012). In short, an object's form and matter are represented by its properties, while its function is represented by its capacities. DeLanda also discusses how an object's form emerges from the interactions between its parts at the same time as its form creates opportunities and constrains the evolution of the object's form: "the spherical form of a soap bubble emerges out of the interactions among its constituent molecules," at the same time as the spherical form of the bubble enables and constrain its evolution until it bursts (DeLanda, 2000, p. 34).

Assemblages are defined along two dimensions: The first dimension describes the variable *roles* that an assemblage's components may play and the second dimension defines variable *processes* in which components become involved. The roles that components engage in range from purely *material* roles at one end of the continuum to purely *expressive* roles at the other. Thus, for example, the material components can include individuals, organizations, or physical structures (e.g., buildings, networks, and computers). At the other end of the continuum are the expressions about those material entities, which may be expressive or linguistic (e.g., laws, contracts, norms, codes of conduct, rules) and non-linguistic (e.g., bodily expressions, dressing, acts of subordination, a company logo, a smartphone design). Most components will simultaneously have both material and expressive roles.

The second dimension, which is relevant for the purpose of this paper, refers to the *processes* in which components become involved that either stabilize or destabilize the assemblage. Stabilization is the process that gives shape and identity to an assemblage. DeLanda describes four kinds of stabilization processes: *territorialization, homogenization, coding,* and *interlocking*. Territorialization means that the boundaries between an assemblage and its outside context are becoming sharper; homogenization occurs through processes that increase the degree of internal homogeneity among its components, making them more similar; coding occurs through, for instance, formalizing contracts and agreements, writing and approving requirement specifications, and passing laws and regulations; and interlocking happens when components of an assemblage become more tightly related and interdependent.

Each of these processes has an opposite destabilization process. For instance, adopting social networking technologies like Twitter, Facebook, or Whatsapp are examples of deterritorialization processes because they blur the spatial boundaries of social interaction. Any component of an assemblage may participate in all these processes "by exercising different sets of capacities" (DeLanda, 2006, p. 12). For instance, a member of a political party can stabilize the party by voting in favor of all its issues while simultaneously destabilizing the party by engaging in scandalous behavior.

The combination and interaction of stabilization and destabilization processes drives the evolution of an assemblage as a continuous process. The dynamics involved in the assemblage's evolution can be explained using AT terms. Drawing upon complexity theory, or what DeLanda calls the mathematics of dynamic systems, AT can describe the continuous evolution of an assemblage as *path-dependent*, meaning that it evolves along certain trajectories. In other cases, destabilizing events may sometimes have no apparent effect until a certain *threshold* (e.g., critical mass) is crossed. Sometimes, the restabilization of an assemblage after its destabilization moves the evolution of the assemblage onto a new path so that the destabilization becomes a *critical juncture* in the evolution of the assemblage.

The AT concepts presented above (summarized and translated to the research problem of this paper in Table 2) provide an analytical lens for examining the dynamics of the architecture-governance (A-G) configuration and its relation to digital infrastructures. We use the A-G configuration to refer to a particular arrangement of architectural and governance elements that regulate the implementation, operation, and use of a digital infrastructure and shape its evolution. We do this through a longitudinal, in-depth case study (Yin, 2009) about an electronic prescription service for the public health system in the autonomous region of Catalonia, Spain.

Table 2. Overview of Analytical Lens

Concept	Definition	Assumptions regarding A-G configuration
Assemblage	Composite of heterogeneous parts (which themselves are assemblages) forming a set of part-whole relationships in which the component parts may participate in other wholes. A component part has properties that define it and capacities to interact with other heterogeneous entities. An assemblage and its properties and capacities emerge from the interactions among heterogeneous parts. Component parts can play material and/or expressive roles.	The A-G configuration is an intermediate-scale entity of the infrastructure that emerges from bottom-up and multiscaled processes of assembling multiple components. The A-G configuration can exhibit concurrent properties (e.g., integrated, modular, centralized) at different scales or based on different dimensions. Because of relations of exteriority, components of the configuration can predate and shape it.
Stabilization	Processes by which the boundaries of the assemblage become sharper (territorialization), the internal homogeneity of among components of the assemblage increases (homogenization), the components of the assemblage become tightly related and interdependent (interlocking), and that consolidate the identity of the assemblage through entities that play an expressive role (coding).	Stabilization processes operate centripetally giving the A-G configuration persistence. Re-stabilization processes allow the A-G configuration to reconstitute itself (changing its boundaries).
Destabilization	Processes opposite stabilization; that is, processes by which the boundaries of the assemblage become murky, internal heterogeneity increases, components become more loosely coupled and less interdependent, and the identity of the assemblage becomes less clear.	Destabilization processes operate centrifugally opening the A-G configuration for change.
Threshold	Points at which the assemblage undergoes a transition. The effects of destabilization events and processes are apparent once a certain threshold is crossed. Thresholds may be conceptualized in terms of intensities.	The A-G configuration goes through processes of destabilization and re-stabilization. When the infrastructure crosses a threshold (for instance, in terms of number of adopters, transactions, services), it triggers a major restabilization process that transforms the A-G configuration.

4 Research Design

Our research began in 2008 and lasted for eight years (from 2008 to 2015). We studied an electronic prescription infrastructure, called Rec@t,[1] covering the period 2000-2014. We focused on the front end of the infrastructure's life cycle (including conception, design, development, pilot, rollout, first uses) and subsequent evolution. Before we present the details of the data collection and analysis, we provide some background of the Spanish model of pharmacy contextualizing Rec@t.

4.1 Research Setting: The Pharmacy Model

The Spanish public health system has two main properties: universal access and the devolution of health care to the seventeen autonomous regions of Spain. The national administration is responsible for pharmaceutical regulation (e.g., evaluation, authorization, registration, and pricing of medications), and each autonomous region is responsible for pharmaceutical management. The pharmacy model is part of the National Health System, which comprises multiple components operating at different levels: citizens/users, pharmacists, pharmacies, regional Colleges of Pharmacists, the Council of Colleges of Pharmacists, regional health systems, and the National Health System.

At the lower level are the citizens and pharmacists. Citizens are the users of medications and other services provided by pharmacists. Until 2012 medications were provided to pensioners for free, working-age people paid 40% of the cost, and those suffering from chronic illnesses paid 10%. User charges traditionally funded less than 8% of the total public drug bill. Beginning in 2012, triggered by the sudden decline in public revenues following the 2008 financial crisis, several copayment reforms were approved by the central and regional governments.

[1] Rec@t stands for *Recepta Catalunya* (Catalan Prescription).

Pharmacists are health agents who dispense medications, produce patient-specific preparations, and perform other pharmaceutical care tasks such as health promotion, tracking patients' medication records, and checking drug interactions. In order to practice, pharmacists need a university degree plus compulsory enrollment in the College of Pharmacists of the province where they practice. Colleges of Pharmacists represent the interests of pharmacists and ensure that professional practice corresponds to the national code of ethics and regulations. In the autonomous region of Catalonia, there are four Colleges of Pharmacists, which coalesce into the Catalan Council of Colleges of Pharmacists (CCP). The CCP is a corporate and public legal entity that advocates for the pharmaceutical profession in Catalonia. It represents and defends the interests linked to the professional practice of Catalan pharmacists and ensures that regulations are followed.

Pharmacists practice in community pharmacies or hospital pharmacies. Spanish law establishes that community pharmacies are private health facilities of public interest subject to planning by autonomous regions. Pharmacies are the only health establishments authorized to dispense prescription-only and over-the-counter medications to the general public. The ownership of community pharmacies is limited to pharmacists; pharmacy chains are not permitted ownership types. One pharmacist or a group of pharmacists can own only one pharmacy. The establishment of pharmacies is regulated by each regional government responding to demographic and geographic criteria in order to guarantee homogeneous service access to citizens (99% of Spaniards have a community pharmacy in their municipality). On average a community pharmacy serves approximately 2,800 citizens.

Another relevant regional actor in Catalonia is the Catalan Health Service (CHS). The CHS is the public insurer and is responsible for planning, purchasing, and assessing health services according to the needs of the population. A core component of the pharmacy model is the agreement initially signed by the CHS and the CCP on January 31, 1995. The agreement, which is continually renegotiated according to changes in legislation, the profession, and society, regulates the conditions under which pharmacists provide pharmaceutical care, invoice according to contract economic regulations, temporarily fund dispensed drugs and health products, continuously deliver health care information to the CHS, promote health and disease prevention, and perform pharmaceutical surveillance and security alert management of drugs and health products to the population served by the CHS.

Before Rec@t was in place, the two main practices of pharmacies—namely, the dispensing and invoicing (and reimbursement) of medications—worked as follows (see Figure 1). Once a doctor determined the appropriate drug treatment for a patient, the patient was given a paper prescription. Doctors used clinical workstations to generate and print the prescriptions. The patient took the prescription and his or her health card to the community pharmacy, where the drug was dispensed. Then pharmacists stored and signed the paper-based prescriptions. Pharmacists used a pharmacy management system (PMS) for tasks such as tracking sales, inventory, and purchase orders. Those PMSs were developed by pharmaceutical wholesalers, software vendors, or individual developers. Periodically, pharmacies grouped the paper-based prescriptions they had dispensed in a given period of time and sent them to the Catalan Council of Colleges of Pharmacists (CCP). The CCP then checked all those prescriptions, scanned them, forwarded the scanned and paper prescriptions to the Catalan Health Service (CHS), and handled the invoicing for pharmacies. The CCP submitted a single invoice to the CHS; thus the CCP, rather than pharmacists, was the entity in charge of invoicing the CHS. The CHS reimbursed that invoice to the CCP, which checked for errors and finally paid pharmacies according to the signed prescriptions they had previously sent.

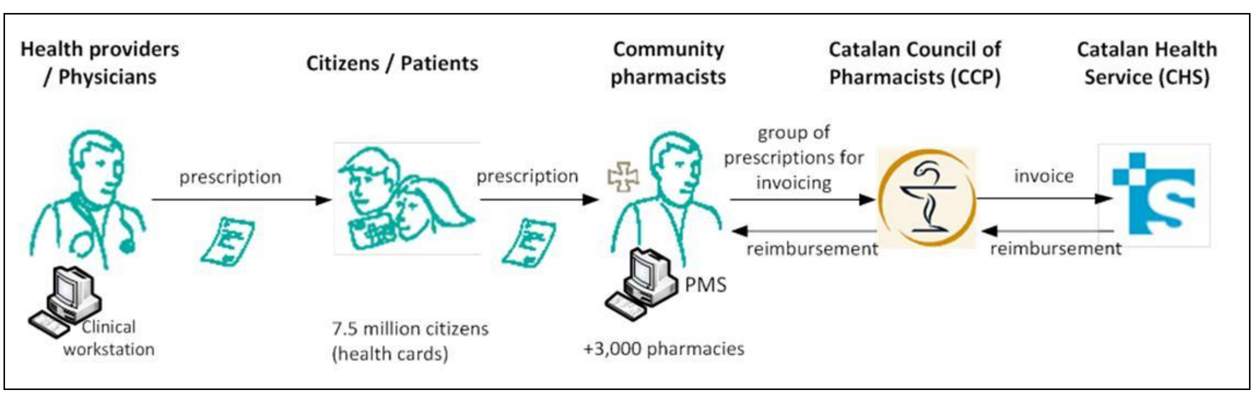

Figure 1. Flows Involved in Paper-Based Prescribing, Dispensing, and Invoicing

Table 3. Data Collection Sources

Data sources and information items	Use in analysis
Interviews (32 semistructured face-to-face interviews)	
Stage 1: May 2008-December 2008 10 interviews: executive of the CHS (1), consultants involved in the development of the core of Rec@t (2), vice president of the CCP (1), pharmacist (1), members of health providers involved in the project (5)	To explore the background of the project, the stakeholders, their views and attitudes regarding Rec@t and the main challenges during its design and development.
Stage 2: January 2009-September 2010 5 interviews: vice president of the CCP (1), ex-vice president of the CCP (1), pharmacists (1), IS manager of the CHS (1), IT manager of health provider (1)	To capture the technical, organizational, and political complexities around the pilot and rollout, how those complexities were addressed, and the role of each stakeholder.
Stage 3: February-May 2013 10 interviews: IT manager of the CCP (1), IT managers of health providers (3), pharmacists (3), project manager of PMS vendor (1), manager at CHS (2)	To capture the relevant changes of Rec@t since the rollout was completed in 2010.
Stage 4: May-September 2015 7 interviews: pharmacists (2), IT managers of health providers (2), consultant in charge of the operation of the system (1), consultants at CHS (2)	To capture the evolutionary changes of Rec@t, and the impact of Rec@t on the social assemblage (e.g., model of pharmacy, relations between actors, roles of actors).
Fieldwork	
Workshop attendance, feedback sessions with informants and other actors, direct on-site observation in pharmacies	To immerse ourselves in the cultural and technological context of Rec@t and Catalan public health.
Archival data	
Press documents, reports, organization yearbooks, meeting minutes, legal documents, presentations, mailing lists, videos	To identify events, understand ways of thinking and acting, and complement and extend evidence obtained in interviews and fieldwork.

4.2 Data Collection

We collected data between 2008 and 2015 from three main sources: fieldwork, archival data, and semistructured, face-to-face, in-depth interviews, aiming at data triangulation (Yin, 2009). When data collection started in 2008, Rec@t was being piloted; thus, data collection focused on both retrospective and real-time data events. Data collection took place in four intensive stages: May-August 2008, January-May 2010, February-May 2013, and May-September 2015. See Table 3 for a summary of data sources and their use in the analysis.

The data collected from in-depth interviews were valuable in identifying the main stakeholders, events, views, and attitudes regarding what Rec@t represented and its possibilities (first stage); the main complexities around the design, development, piloting and rollout, how they were addressed, and the role played by each stakeholder (first and second stages); and the evolutionary changes of the infrastructure and the changes in the pharmacy model (third and fourth stages). We conducted interviews with selected informants involved in the Rec@t project from its genesis to 2015. We also asked interviewees to reflect on archival data; this allowed us to better grasp the different ways of acting and thinking. We identified interviewees by applying the snowball sampling technique (Miles & Huberman, 1994); that is, we identified subjects for inclusion in our sample based on archival data and referral from other subjects.

Additional primary data were obtained through (1) attending several workshops (for physicians and pharmacists) where Rec@t was discussed and where we had informal conversations with attendees; (2) conducting feedback sessions with some of the interviewees during which we provided high-level reports on our findings (mainly during the third and fourth stages; see Table 3); and (3) direct on-site observation in several pharmacies in order to better understand the use of the system (we visited four pharmacies twice, amounting to eight hours of observations). These fieldwork data allowed us to immerse ourselves in the cultural and technological context of Rec@t and Catalan public health.

Since Rec@t is an infrastructure for the public health system, aside from interviews and fieldwork, we were able to access large amounts of archival data (e.g., press documents, reports, organization yearbooks, meeting minutes, legal documents, presentations, mailing lists, and videos) covering the period 2000-2015. Archival data very often served as our main source of evidence in that it revealed relevant events and changes in the infrastructure and particular ways of thinking and acting. We also used archival data to complement the evidence obtained through interviews and fieldwork. Moreover, since many of the events were documented by different sources, we could easily validate those data (Yin, 2009).

4.3 Data Analysis

Data collection and analysis took place iteratively. After each interview, we wrote up field notes including observations, impressions, and questions that emerged. These field notes constituted the first step in organizing the data and we often returned to these notes in our analysis. We also regularly wrote analytic memos based on our analysis of the interview transcriptions, field notes, archival data, and fieldwork. This enabled us to articulate our interpretations of the data at each of the four data collection stages and across those stages.

Our data analysis involved five main steps. We began our data analysis by identifying the key events around the genesis and evolution of Rec@t and constructing a chronology of events (see Figure A1 in the Appendix). In the second step, we analyzed the key architectural and governance components involved in those events (see Figure A1). With regard to the architecture, we identified new technological components (e.g., API, web service, physical server, a database, new fields in a database, a network), new relationships between technological components, and changes in the way technological components were arranged (e.g., centralization of certain data or web services). With regard to governance, we identified existing and new organizational structures, regulations, and norms that shaped the evolution of Rec@t.

In the third step of our data analysis, we drafted a preliminary thick descriptive narrative (Langley 1999) of the evolution of Rec@t that comprised the events and architectural and governance components previously identified. Afterward, we scrutinized and traced the changes to the architecture and abstracted three main overall architectures reflecting three different forms of Rec@t. The fourth step of our data analysis involved mapping each of the three overall architectures to a governance regime. We drew upon existing conceptualizations and coded them for one facet of governance: the collection of structural, procedural, or relational components of governance (Tallon, Ramirez, & Short, 2013). Structural components refer to structures that determine the locus of decision-making; in our case, those structures emanate mainly from working groups and committees. Procedural components describe how decisions are made, which, in our case, included pharmaceutical agreements, laws, standards, and contracts. Finally, relational components refer to practices that support the development among actors of a common set of values related to the system. Relational components included, for instance, an IT operations center, help-desk service, and an e-newsletter to support users.

We identified three main A-G configurations (centralized, dual, platform), each crossing several levels. In the centralized configuration, the architectural and governance components of the digital infrastructure were mainly located at the regional level. The dual configuration was characterized by the replication of some architectural and governance components at the regional level to the level of pharmacists (coordinated by CCP). The platform configuration emerged as the replicated components at the level of pharmacists (coordinated by the CCP) were opened up so that third parties could build new services for pharmacists on top of them.

In the final step of our data analysis, we drew upon the notions of processes of stabilization and destabilization and thresholds (as presented in the previous section) to examine the transitions of those configurations. We analyzed the processes of destabilization and stabilization underlying the emergence and evolution of each A-G configuration, how those (de)stabilization processes fed back into and shaped the A-G configuration, and the thresholds associated with the transitions to new A-G configurations. We identified eleven stabilization, nine destabilization processes, and two main thresholds (see Figure A3 in the Appendix). In the analysis of the destabilization and stabilization processes, we observed that they operated at four levels: The lowest level is each PMS and the group of pharmacies using it, the second level is all pharmacists coordinated by the CCP, the third level is the regional level where the entire Rec@t is coordinated by the CHS, and the fourth level is the national level where the project began.

5 Coevolution of Rec@t and its A-G Configurations

In this section, we analyze the evolution of Rec@t. The analysis is organized into three phases, each representing a specific A-G configuration. For each phase, we describe the events, choices, actions, and associated processes of destabilization and stabilization that produced Rec@t and its A-G configuration and emergent properties. We also describe the capacities of the A-G configuration to retroactively affect its parts and to shape the evolution of Rec@t. Figure A3 summarizes the processes of stabilization (S_i) and destabilization (D_j), and the thresholds.

5.1 Phase 1: Centralized Configuration (2000-2004)

In 2000, the Spanish Ministry of Science and Technology started a project aimed at modernizing the National Health System with IT. One of the projects involved building a common national model of electronic prescriptions that would address the fragmentation and variety of prescribing and dispensing systems that were in place at that time in the autonomous regions (S_1 in Figure A3). Several stakeholders were invited to the project, including managers of the regional health services and representatives of the professionals involved in prescribing and dispensing (i.e., the Colleges of Doctors and the Spanish Council of Colleges of Pharmacists). A draft of design guidelines for the common Spanish electronic prescription service was released in 2002. It was a one-size-fits-all model comprising a central database that would be used by both doctors and pharmacists. Some regional health services expressed their concern about the disruption that the one-size-fits-all model would cause to the Spanish decentralized healthcare system, where autonomous regions were responsible for pharmaceutical management. Moreover, the technological components (e.g., servers) of the national project were incompatible with the technological installed base of the regions (D_1 in Figure A3).

To address the destabilizing effects of the one-size-fits-all model at the regional level, the implementation of operational solutions for the common Spanish model for electronic prescriptions was delegated to the regional health systems (S_2 in Figure A3). The idea was that once the regional electronic prescription infrastructures were operational, they would interconnect with each other and coalesce into a national infrastructure. In the case of Catalonia, the Catalan Health Service (CHS) launched the Rec@t project by mid-2004. The CHS regarded Rec@t as one of the key projects of the strategic plan for pharmaceutical provision that aimed to improve the efficiency of the Catalan health system by streamlining patients' access, containing drug expenditures, and reducing prescription and dispensing errors due to lack of coordination between the agents involved in those processes.

From the outset of the project, the CHS, as its sponsor, was at the center of its governance structure, and following the recommendations of the national project, it initially set two core functional requirements. First, all the data (i.e., prescriptions, dispensations, invoices, patients, drugs, health providers, doctors, pharmacies, pharmacists) should be integrated and accessible online by all of the diverse stakeholders—CHS, doctors, and pharmacists. Second, the processes of prescribing and dispensing should run in real time; that is, medications should be dispensable at any pharmacy regardless of the location of the prescriber. To fulfill these requirements, the CHS proposed a tightly coupled architecture and top-down governance approach. The CHS-centered architecture following the national guidelines (see Figure A2 in the Appendix) consisted of a central system owned and managed by the CHS, called SIRE, with an integrated database to store all the data.

For health providers, the CHS-centered architecture preserved the interaction model between health providers and the CHS by allowing health providers to keep their internal EPR systems and practices; it only required them to create a communications module with the central server of the CHS. For pharmacies, however, the centralized architecture disrupted the operational model (D_2 in Figure A3), as it entailed significant changes in the practice of dispensing and invoicing of pharmacists (e.g., pharmacists were to connect directly to SIRE through a browser for dispensing and invoicing) and in the relationships among the CHS, Catalan Council of Pharmacists (CCP), and pharmacies. Since the new system would tighten the relationship between the CHS and individual pharmacies, the CCP's position and the pharmacists' opportunities for collective action would be weakened. In that sense, the centralized configuration enhanced the capacity of the CHS to set bilateral agreements with pharmacies in the future, thus bypassing the traditional central mediating position of the CCP (as specified in the pharmaceutical agreement). As envisioned, the system gave the CHS a powerful instrument for shaping the evolution of pharmacists' professional practices.

The CCP strongly opposed the centralized configuration, framing it as a serious threat to the existing pharmacy model. The centralized configuration fragmented the pharmacy model by downplaying the role of the CCP. Moreover, the centralized configuration was viewed as a possible catalyst for the deregulation of the pharmacy sector, which would open it up for the entrance of new actors (e.g., pharmacy chains) and potentially disrupt the existing pharmacy model. As resistance from the CCP intensified, the project was expanded to include the CCP (Threshold 1 in Figure A3).

5.2 Phase 2: Dual Configuration (2005-2009)

When the CCP formally joined the project, it started emphasizing the idea that the professional development and the economic survival of the pharmacy model relied on enhancing the collective capacities of pharmacists by building an architecture for Rec@t that mirrored the pharmacy model (S_3 in Figure A3). A vice-president of the CCP related the pharmacy model to the architecture of Rec@t in the following terms:

> *We are a network [the pharmacy model in Catalonia] that needs a network [the VPN] … Politicians argue for a capillary pharmacy model; that is, that pharmacies are spread throughout the country. We must transfer this*

> *network of pharmacies to the electronic world. It cannot happen that what is there physically does not exist electronically.*

Accordingly, the CCP proposed a dual architecture where the central server of the CHS-centralized architecture would be replicated by another architecture, which would be connected to pharmacies (see Figure A2). The dual architecture implied the inclusion of another central node, called SIFARE, which duplicated the data of the CHS node, SIRE, required by pharmacists (i.e., data related to prescriptions, dispensations, and catalogues). It also implied that health providers and pharmacies would connect to separate networks. Pharmacies would connect to the Pharmaceutical Network, giving them access to SIFARE (see Figure A2). The CCP (and in turn, pharmacists) would own the Pharmaceutical Network and SIFARE, and SIFARE would synchronize in real time with SIRE, thus still conferring real-time visibility of the dispensing data to the CHS. Moreover, the dual architecture was framed as an opportunity for improving pharmaceutical care. In an official response to the presentation of Rec@t that the health minister gave at the Eighth European Pharmacy Meeting, the CCP stated,

> *The Rec@t project does not have to be simply an electronic invoicing tool but a tool for professional development, and therefore, that it takes into account, in the current legal framework, the access to the necessary patient data to be able to realize a better pharmaceutical care.*

At first, the CHS objected to this proposal because it introduced unnecessary redundancy, putting the real-time requirement at risk and decreasing the robustness of the solution. The IT consultant of the CCP interpreted the opposition of the CHS as follows:

> *There was much reluctance on the part of the CHS. The CHS initially said no to the model proposed by the CCP ... It seemed essential for the CHS to have information online ... and I think the CHS had the image that SIFARE [the CCP's server] would generate a delay in the communication and that could be dramatic. I also understand that the CHS wants to have more control of the pharmaceutical expenditure and this means having online information and a direct relationship with pharmacists.*

However, after several rounds of negotiations between the CHS and the CCP, the former realized that the latter's opposition to the centralized configuration could ultimately jeopardize the success of the project. Also, the CHS recognized that the dual configuration would reduce the organizational complexity of the project, as it distributed responsibility for the project among more actors (e.g., the CCP, PMS vendors) and better accommodated the interests of the CPP and pharmacists (S_4 in Figure A3). Thus, the CHS finally approved the dual configuration.

The CCP wanted to avoid the need for pharmacists to discontinue using the existing PMSs.[2] Accordingly, they decided that pharmacies should access SIFARE through their PMSs instead of web browsers (S_5 in Figure A3). To manage the integration and communication between SIFARE and the PMSs, the CCP set up an advisory committee for technology and communications that brought together the CCP and the PMS vendors. Under this structure, the CCP revamped a recognition program for PMS vendors that was launched in early 2004. The initial scope of that program was the use of patient health cards in the dispensing of drugs and the transmission of data related to invoicing. The recognition program was extended to include Rec@t. The new program defined a minimum set of functional and technical requirements that PMSs should fulfill. PMS vendors were tasked with integrating their solutions with SIFARE in a way that minimized changes to pharmacist practices. Those vendors who passed the recognition program received the API from the CCP, enabling them to interconnect their PMS solutions with SIFARE. This meant that the functionalities of the PMS would be homogenized at the level of pharmacists (S_6 in Figure A3) but destabilized at the level of each PMS vendor and the pharmacists using the PMS (D_3 in Figure A3).

The architectural changes enabling the dual architecture also entailed changes to the governance of Rec@t. The CCP was given the main responsibility of developing the SIFARE server and the required functionalities for pharmacies. The CHS set up a project for developing SIRE, and the CCP set up a similar project for developing SIFARE. They created a steering committee and an executive committee, in which diverse members of the CHS, CCP, health providers, and other stakeholders were represented. Likewise, a number of working groups were created to establish overall requirements and design specifications for various domains (prescribing and dispensing by active ingredient, prescribing and dispensing of narcotics, applying professional filters, communicating to the population, analyzing legal requirements, etc.). Further, an amendment to the pharmaceutical agreement between the CHS and the CCP was signed by both parties. The amendment defined the clauses for the development of the pilot for Rec@t and made the role of the CCP explicit. Later in

[2] In 2004, when the Rec@t project was about to begin, there were about 35 different types of PMSs.

2007, the passing of a decree that regulated Rec@t consolidated the dual configuration (S_7 in Figure A3).

Based on the dual configuration, Rec@t was built and a pilot was completed in 2008. A phased rollout was conducted, with each phase involving different geographical locations. The rollout thus entailed a destabilization of the infrastructure at the level of pharmacists (D_4 in Figure A3) because the number of health providers, PMS vendors, pharmacies, patients, and transactions significantly increased at each phase. This triggered an adaptation of the dual configuration—for example, with new releases of the API for the PMSs, processing, storage, and bandwidth capacity was increased, and an IT operations center and a helpdesk service was created to support pharmacists and address technical and functional issues (S_8 in Figure A3).

In the development, pilot, and rollout of the dual configuration, the focus was on an initial closed set of functional requirements established by the CHS and the CCP. However, as the adoption and use of the initial version of Rec@t gained momentum and became more stable, the CCP and the PMS vendors turned their attention toward the development of new services to support pharmacies. Therefore, the solution was destabilized in the sense that it was opened up for the inclusion of new functionalities that destabilized (parts of) the existing dual configuration (D_5 in Figure A3). The generation of new ideas for pharmacist services led to the gradual enhancement of SIFARE and improved the practice and professional development of pharmacies (Threshold 2 in Figure A3).

5.3 Phase 3: Platform Configuration (2010-2014)

The CCP embarked on various strategies (or tactics) for achieving platform configuration (S_9 in Figure A3). In 2010, the CCP started to extend Rec@t functionality by developing a number of apps on top of SIFARE that were available to pharmacies through web browsers to support various activities, such as quality monitoring, management of alerts, management of users at pharmacies and user permissions, management of digital signatures, and the invoicing, reporting, and analytics of dispensing. Additional examples include apps for citizens that provide information about the location, opening hours, and services offered at pharmacies, and apps for specific patient groups (e.g., apps that provide information related to pharmacy services such as colon cancer screening and at-home HIV testing). Moreover, the CCP also leveraged the Pharmaceutical Network and became a virtual network operator, enabling it to start providing integrated mobile and landline telephone services for pharmacies.

After developing a number of simple apps, the CCP also saw an opportunity to enhance pharmacists' practices and broaden their scope by relying on PMS vendors to add features and services to their PMS solutions utilizing the data and services available at SIFARE. The CCP supported this strategy by developing additional web services and new versions of the API for PMS vendors. This implied a de facto change in strategy: rather than viewing SIFARE and PMSs as a mere distributed system interacting to support a closed set of functionalities offered to pharmacies (where all functions were specified in collaboration among the CHS, the CCP, and PMS vendors), SIFARE gradually became redefined as a platform offering a set of digital resources that PMS vendors could utilize to develop additional services (in collaboration with their customers) running at the periphery of the system. Thus SIFARE went from being one component in the overall solution to becoming a platform on which new services could be developed.

Another relevant event that had a destabilizing effect on Rec@t was the 2008 financial crisis, which generated several pressures coming from exterior relations that propagated across levels and eventually contributed to the stabilization of the platform configuration. First, the economic crisis in Spain became a major destabilizing force for pharmacists and Rec@t, particularly from 2010 onward. As a result of the pressure from the EU to reduce the deficit, the Spanish Ministry of Health and Social Security adopted a measure to reduce the pharmacy profit margins on publicly funded drugs (D_6 in Figure A3). Second, starting in 2012, the central and regional governments approved new copayment reforms, which stimulated a fall in drug consumption and a corresponding fall in pharmaceutical expenditures. This put more pressure on pharmacists who also experienced a decrease in revenue[3] (D_7 in Figure A3). Third, the impact of those events on Rec@t was compounded by political tensions between the Spanish government and the regional governments. The autonomous regions, Catalonia among them, lost direct access to financial markets and the Spanish government became the only source of funding for the regions. The Spanish government leveraged that new scenario to put pressure on the autonomous regions in order to reduce the deficit (D_8 in Figure A3). As a result, beginning in 2010, the CHS started to default on its payments to pharmacies (D_9 in Figure A3). This created challenges regarding the funding of Rec@t and slowed down its evolution. In other words, the

[3] Paradoxically, those copayment reforms could be easily implemented because of the dual configuration.

destabilizing effects of the economic crisis reverberated through EU, global financial market, national, and regional entities, decelerating the flow of invoices, reimbursements, and funding, which ultimately had a destabilizing effect on Rec@t, particularly regarding pharmacies. Obviously, pharmacies could scarcely continue to financially support the system given that their profits had significantly decreased.

The CCP viewed the new Rec@t platform as a powerful resource for developing new digital services in collaboration with PMS vendors that would both reduce operational costs at pharmacies and offer new services to increase their income (S_{10} in Figure A3). Thus, in 2013 the SIFADATA initiative was launched, aiming to redesign and digitalize a range of processes that pharmacists could carry out daily by leveraging SIFARE and the Pharmaceutical Network. This included the management of recipe and narcotics records and the pricing of magistral formulas.[4] Although most of the PMSs already stored recipe and narcotics records, pharmacists still had to periodically print them and physically deliver them to the Department of Health. As part of SIFADATA, this process was redesigned so that data would not be locally stored in pharmacies' PMSs but in SIFARE (the core of the new platform). Pharmacists would use their swipe cards to sign the records and submit them (stored at SIFARE) to the Department of Health without any need to print them. PMS vendors would have to add features and services to their PMS solutions to utilize the data and services available at SIFARE. Thus, the CCP developed additional web services and new versions of the API for PMS vendors (see SIFARE API 5.0.0 in Figure A1).

The changes of SIFARE that led toward a platform configuration also entailed a redefinition of decision rights pertaining to the PMS solutions and changes in the governance structure. For instance, the SIFADATA initiative required the cooperation and involvement of PMS vendors, who then had to adapt their solutions to the new services. However, the SIFADATA services were not mandatory by law. Thus, to enroll PMS vendors, the CCP reoriented the relational processes and focus of the recognition program. As the project manager of the CCP noted:

> *With PMS vendors we hold meetings every three months to talk about the current situation and especially the future … We present them [with] ideas and designs and ask them to analyze and see whether those ideas and designs are in line with their developments … With the SIFADATA project we want a recognition program that is oriented to professional services, which are highly formalized. Here we do not want to leave an open door for every PMS to do whatever they want … In this project, the PMS vendors are not our suppliers, they are suppliers of the pharmacies. [So] it is a very weak relationship and we have to take good care of them … In the future, all the new services will have to go through PMS, so we must have a very good feeling with them.*

As a result of this reorientation, the relational and technical linkages between CCP and PMS vendors were strengthened (i.e., CCP's SIFARE and PMS solutions become more tightly integrated), and the SIFARE platform architecture offered a more balanced distribution of decisions rights among the CCP and PMS vendors (S_{11} in Figure A3). Moreover, additional elements were added to the governance structures. These included new working groups on invoicing, quality indicators, functional requirements involving CCP and pharmacists, and PMS vendors. Overall, the platform configuration had a restabilizing effect for pharmacists using the infrastructure because it enabled new ideas and domains of use.

6 Discussion

The preceding section recounts the dynamics of the A-G configuration of a digital infrastructure called Rec@t. Corresponding to existing conceptualizations in the literature (Plantin et al. 2018; Tilson et al. 2010), we regard Rec@t as a digital infrastructure since it constitutes the sociotechnical foundation for a set of essential information services necessary for prescribing and dispensing medications in a regional health system. From a technological perspective, Rec@t involves the interoperation of multiple heterogeneous systems and networks (Plantin et al. 2018). Rec@t also interacted with other infrastructures at regional (e.g., a regional shared medical record infrastructure), national (e.g., an infrastructure that enabled the consolidation of regional data about drugs prescribed and dispensed), and European (e.g. the EPSOS infrastructure) levels. Moreover, Rec@t was promoted top-down by public agencies and managed in a collaborative manner involving the CHS, health care providers, EPR vendors, CCP, pharmacies, and PMS vendors.

6.1 Conceptualizing the Architecture-Governance Configurations

When conceptualizing A-G configurations, two issues must be addressed: the relationship between an A-G

[4] A magistral formula is a drug manufactured for a specific patient by a pharmacist according to the instructions of the prescribing doctor and following the instructions of pharmaceutical standards.

configuration and the overall infrastructure it belongs to, and the relationships between the architecture and the governance structure, which includes defining the relationships between the different elements of the architecture and the different elements of the governance structure. First, within the framework of assemblage theory, an A-G configuration represents the *form* of its infrastructure. The form of an assemblage gives it certain properties and capacities. In our case, Rec@t's form, i.e., its A-G configuration, endows Rec@t with certain properties, such as its distributedness geographically across Catalonia and organizationally across health care institutions and pharmacies. Rec@t's degree of distributedness gives it certain capacities to interact with healthcare institutions, pharmacies, and patients in a way that enables their collaboration in drug prescribing and dispensing. These properties of Rec@t's form, in combination with its material properties, such as its computational power and storage and transmission capacities, allows Rec@t to facilitate information sharing and exchange among Rec@t users. Characterizing the A-G configuration as the form of Rec@t implies that the relationship between Rec@t and its A-G configuration is a part-whole one: i.e., "assemblages emerge from interactions between their parts" (upward causality), and "once an assemblage is in place it immediately starts acting as a source of limitations and opportunities for its components (downwards causality)" (DeLanda 2016, p. 21).

Regarding the relationship between the architecture and governance structures of a digital infrastructure, an A-G configuration can be seen as an assemblage composed of two constituents: the architecture and the governance structures, each having certain properties as well as capacities to interact with each other, giving the A-G configuration specific properties and capacities to interact with other assemblages—in the case of Rec@t, the health care and pharmacy assemblages in Catalonia. In short, the A-G configuration is an intertwined intermediate-scale entity of the infrastructure that constitutes what is bounded and that describes its form and defines the potential evolutionary trajectories of the infrastructure.

6.2 Types of Stabilization and Destabilization Processes

We now examine different types of stabilization and destabilization processes occurring in the Rec@t case. DeLanda (2006, 2016) describes a number of stabilization processes: *territorialization*, making the border between an assemblage and its outside sharper; *homogenization* of the components, making them more similar; *coding* the assemblage, e.g., in terms of specifications of software components, written documents, or legal contracts; and *interlocking* heterogonous components by increasing their interdependencies and integration. Each of these stabilization processes has an opposite destabilization process.

As the Spanish government sought to create a common national prescription service, the centralized configuration was increasingly stabilized. This occurred as agreements were reached, decisions were made about the more detailed design of the envisioned solution, and specifications were worked out. During that process, more and more components were included in the specifications; at the same time, however, the modules depended on each other for making the whole solution work. Thus, the various components were interlocked with each other.

When the CHS sought to implement a Catalan solution based on the national specification (or standard) and started assembling Rec@t, they had to include the CCP and the pharmacies. That implied that the assemblage (which included the CHS and the national standard) was destabilized when its borders were opened up (i.e., de-territorialized) to allow the CCP and the pharmacies to become part of the assemblage. This also implied that the variety of included components increased while the homogeneity of the assemblage decreased. In this way, the centralized configuration was destabilized.

This led to the emergence of the dual configuration. Important early steps in the stabilization of this configuration and the whole Rec@t infrastructure (first version) were taken as the CHS, the CCP, and the working groups involved agreed on the functionality of Rec@t (i.e., territorializing the solution in terms of functions the role each actor would perform). Further, at a lower scale, the dual configuration was increasingly stabilized at an increasingly more detailed level as its design was worked out and specified. During this process, the components of the dual configuration became coded (i.e., its behavior as specified by designers was consolidated) and increasingly interlocked. The dual configuration was also stabilized because of the harmonization and mutual interlocking of the architecture and governance, which, in turn, became further stabilized through the coding represented by the contracts and agreements signed between the CHS and the CCP, between the CCP and the PMS vendors, between the CCP and CATCert, between the CCP and the telecom services provider, etc.

Rec@t was further stabilized and closed (i.e., territorialized) regarding its functionalities throughout the development, pilot, and rollout phases. But the end of the rollout triggered some new destabilization processes regarding the dual configuration. In particular, the growth in the number of users increased transactions, meaning that the technical architecture had to eventually be upgraded to handle this growth.

At the same time, as more computers and software modules connected to each other, the costs and coordination work required to switch to a new version of the system increased. Similarly, as the rollout gained momentum, the CCP and the PMS vendors turned their attention toward the development of new services supporting pharmacies, meaning that the solution was destabilized by being opened up (i.e., de-territorialized) for the inclusion of new functionalities. This destabilized (parts of) the existing dual configuration, which led to the emergence of the SIFARE platform configuration (and the subsequent adoption of new add-ons). Throughout the whole process, the dual configuration at the macrolevel became increasingly stabilized, primarily because more components were included in the assemblage in line with this configuration, increasing the number of components connected to and interacting with each other. As a result, individual components and the whole assemblage became increasingly interlocked.

6.3 Iterations of Stabilization and Destabilization Processes

Our analysis shows that the evolution of Rec@t and its A-G configuration followed various paths or trajectories, unfolding as a number of related stabilization and destabilization processes (see Figure A3). Over time, the evolution of Rec@t along a specific trajectory led to the destabilization of its A-G configuration, followed by the emergence of a new configuration and its stabilization. The stabilization of the new configuration, then, motivated Rec@t to evolve along a new trajectory. In this way, Rec@t and its A-G configuration were in flux, continuously going through processes of destabilization and stabilization. Destabilization processes operate centrifugally, opening the infrastructure for change, while stabilization processes operate centripetally, endowing the infrastructure with persistence.

Core components of the centralized A-G configuration (Phase 1) included the Ministry of Health (MoH) at the national level and the CHS at the regional level. This configuration emerged, first, because the project seeking to develop a national infrastructure was initiated and managed by the National Health System. Accordingly, the architecture and functionality included in the national standard were heavily influenced by the National Health System's perspective and needs. The CHS' interests and perspective were well aligned with those at the national scale, so they viewed translating the national standard to the regional scale as fitting their needs well and started to work out more detailed plans and specifications. This configuration conferred upon the CHS the capacity to monitor and control pharmacies in a way that, at least in the CCP's view, could have led to deregulation of the pharmacy sector to the detriment of existing pharmacists. Further, the centralized configuration would have constrained the CCP's capacities to shape the infrastructure and their involvement in the processes supported by Rec@t, in particular invoicing. For these reasons, when the CCP was invited into the project they made it clear that the centralized configuration was not well aligned with their perspective and interests, leading to the emergence of the dual configuration.

The dual configuration (Phase 2) gave the CCP and pharmacies a high degree of autonomy regarding how to develop the pharmaceutical components of Rec@t in a way that better aligned with their interests. This is illustrated by the decision allowing pharmacies to connect to Rec@t through their PMSs instead of browsers, and the creation of a new Pharmaceutical Network controlled by the CCP as the centralized configuration rather than the internet. The dual configuration also constrained the capacities of the CHS to interact directly with pharmacies and influence their practices.

The dual configuration implied that some of Rec@t's emergent properties (e.g., its complexity and couplings) were different compared to those envisioned in the centralized configuration. The introduction of SIFARE added extra technological complexity. However, the loose coupling between SIRE and SIFARE also meant that the organizations building the Rec@t parts used by health care institutions and the CHS, on the one hand, and the parts used by pharmacies and the CCP, on the other, were also loosely coupled. This reduced the organizational complexity of Rec@t and, accordingly, the dual configuration facilitated a smooth and successful development, rollout, and adoption of the infrastructure.

The replacement of browsers with PMSs and the involvement of PMS vendors had implications for the further evolution of Rec@t. As the initial version of Rec@t stabilized and was successfully adopted, ideas emerged among the CCP, pharmacies, and PMS vendors regarding how Rec@t could be leveraged as a resource for building new services and further improvement of pharmacies' practices beyond what Rec@t initially supported and far beyond the CHS's original intentions. Over time, more ideas for how to do this emerged—the CCP first developed some simple apps themselves, and PMS vendors then modified and extending SIFARE APIs to support additional PMS vendor innovations and other functions, which led to the emergence of the SIFARE platform configuration (Phase 3).

In other words, the system evolution moved from a scenario where SIFARE and PMSs interacted to support a closed set of functionalities offered to pharmacies (and where all functions were specified in collaboration among the CHS, the CCP, and PMS vendors) toward one where SIFARE was redefined as a platform offering a set of digital resources that PMS vendors could utilize to develop additional services (in collaboration with their customers) running at the periphery of the system. As such, SIFARE went from being one component in the overall solution to becoming a platform on which new services could be developed. It is worth noting that the emergence of the SIFARE platform configuration was enabled by and took place within the overall dual configuration and actually strengthened and further stabilized this configuration.

The dynamics of the A-G configuration (see Figure 2) show that, on the one hand, destabilization processes are followed by stabilization processes that reconstitute the A-G configuration. On the other hand, stabilization processes lead to new destabilization possibilities for the A-G configuration. Therefore, our analysis foregrounds co-constituting processes of destabilization and stabilization of the A-G configuration. This iteration of destabilization and stabilization processes occurs within the same level and across levels (see arrows in Figure 2) and is characterized by thresholds and critical junctures. For instance, the continuous adoption and use of Rec@t (with the dual configuration) increasingly stabilized the system while simultaneously triggering the generation of new ideas for new services for pharmacists that then began to destabilize Rec@t. However, these destabilizations did not have any apparent effect on the dual configuration or on Rec@t itself until they reached a certain *threshold* (e.g., in terms of the number of ideas and requirements generated and the intensity of pressure from PMS vendors and pharmacists to implement them). As that threshold was crossed, SIFARE became an open platform for PMS vendors, allowing them to develop new services and innovations for pharmacists. In short, these destabilizing events had the character of *a gradual accumulation of events*, but a (qualitative) change in the system did not happen until the number/intensity of destabilizing events reached a certain threshold (DeLanda, 2006). Crossing that threshold of destabilization triggered major restabilization processes that transformed the A-G configuration, leading to the emergence of a new configuration.

Stabilization of the A-G configuration may also represent critical junctures. One important critical juncture was definitively the Rec@t building agreement based on the dual configuration. This was also the case with the decision to allow pharmacies to connect to Rec@t through their PMSs, the decision to involve PMS vendors, and the decision to implement the Pharmaceutical Network. As our analysis shows, when a critical juncture is crossed, an assemblage will begin to evolve along a different path. For instance, the dual configuration decision clearly led Rec@t to evolve along a path very different from the one originally envisioned.

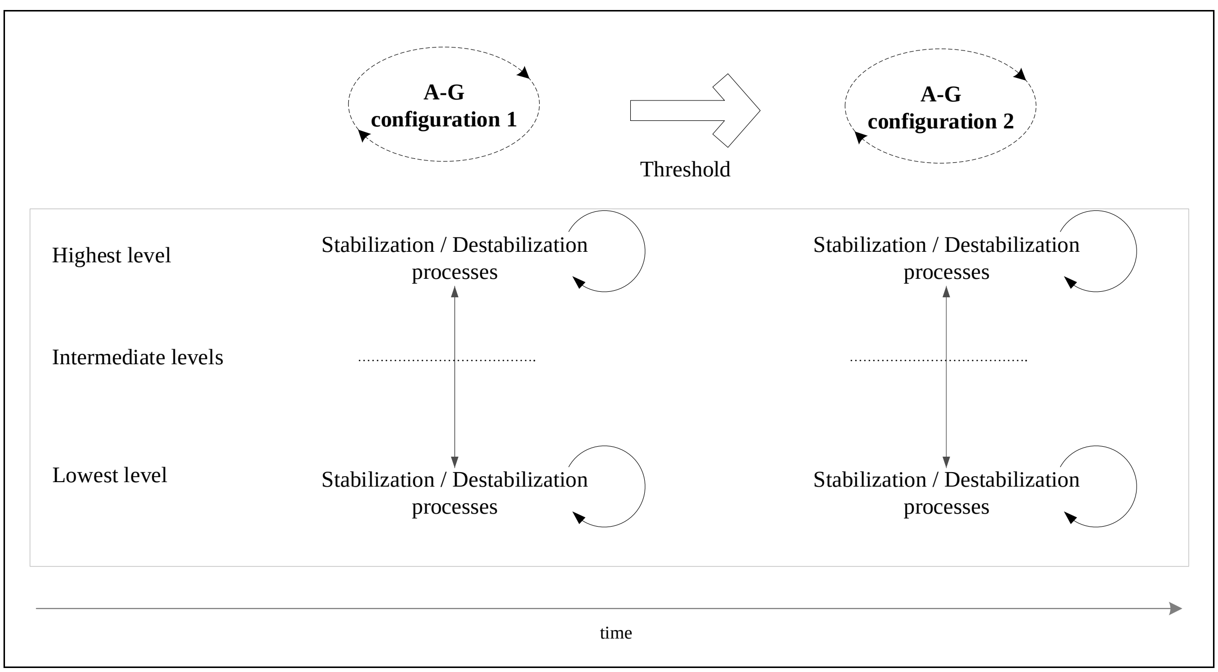

Figure 2. Model of the Dynamics of A-G Configurations

7 Implications and Conclusions

7.1 From Stability/Change to Stabilization/Destabilization

The case study of Rec@t illustrates, like previous IS studies (Hanseth & Lyytinen, 2010; Henfridsson and Bygstad 2013; Tilson et al. 2010), that contemporary large-scale solutions are characterized by constant evolution, loosely defined boundaries, and growing complexity. Rec@t has continuously evolved; it has grown and adapted throughout its history. Different evolutionary patterns or processes are described in the literature. Rec@t bootstrapped (Hanseth & Lyytinen, 2010, Aanestad et al., 2017) in the sense that it started on a small scale with a limited set of functionalities that were first adopted by a small group, before diffusing more widely. And, as it was adopted, more functions were added, in a process that was at least partly self-reinforcing. In addition to adoption, Rec@t evolved through self-reinforcing scaling and innovation processes, as described and theorized by Henfridsson and Bygstad (2013). Likewise, our study reports two of the growth tactics of digital infrastructures identified by Koutsikouri et al. (2018). For instance, the SIFADATA initiative in the platform configuration is an example of "inventing process" tactics that aimed to extend the scope of the Rec@t infrastructure beyond the initial scope for pharmacists. Examples of "providing interfaces" are found in the dual and platform configurations, as the CCP gradually opened digital resources for PMS vendors to adapt and enrich solutions for pharmacists.

As reported by previous IS research (Reimers et al., 2014; Tilson et al. 2010), we view the evolution of Rec@t as shaped by tensions, which, in turn, are shaped by its A-G configuration. In our case, each A-G configuration represents a specific mixture of and balance between modularization and integration (or loose and tight couplings) of technological components and between control and autonomy (or centralized and decentralized control). Our results show how specific balances between these tensions shaped the evolution of a system in terms of "determining" the tension between stability and change regarding various components. But more importantly, our research demonstrates the *dynamics of tensions*—i.e, how the balance between tensions represented by a specific A-G configuration shapes the balance between the stability and change of a system's components, which again leads to (emergent) changes in the balances between modularization/integration and autonomy/control. Further, the multilevel analysis of the dynamics of A-G configurations represents an analysis of the interactions and mutual shaping of tensions across levels. First, this upward and downward movement allows us to display stability not as a state of digital infrastructures but as a prolonged effort to stabilize relations among components across levels. Accordingly, instead of stability and change, the processes of stabilization and destabilization become the object of study. Second, as our analysis shows, those processes of stabilization and destabilization are interdependent, mutually enabling, and mutually constitutive. We maintain that the processes of stabilization and destabilization offer an analytical apparatus for future studies on the evolution of digital infrastructures. Finally, the fact that the processes of destabilization and stabilization of the A-G configuration operate across different levels demonstrates that scholars cannot assume a single and stable level of analysis when studying digital infrastructures. In that sense, we consider further longitudinal and multilevel studies on the evolutionary dynamics of digital infrastructures to be a fruitful direction for future work.

7.2 Architecture-Governance Configurations

In line with extant IS research (Henfridsson & Bygstad, 2013; Tiwana, 2014), our analysis highlights the important role of architecture and governance in the evolution of digital platforms and infrastructures. We treat the A-G configuration as a valid unit of analysis for the study of the evolution of unbounded large-scale systems over time. We conceive the A-G configuration as representing the form of a system as a whole. In addition, we view an A-G configuration as an assemblage in itself, meaning that it consists of different interacting component parts. Digital platform and infrastructure studies assume that there is a relation between architecture and governance structures but they neither conceptualize nor study that relation in detail (Hanseth & Lyytinen, 2010; Henfridsson & Bygstad, 2013; Rodon & Silva 2015; Wareham et al., 2014). An exception is Tiwana (2014), who conceived architecture and governance as

> *mutually reinforcing each other … both are affected by each other and affect each other. It is not only platform architecture that determines feasible governance strategies but also governance choices by platform owners that lead to architectures evolving along different trajectories over time. We therefore must think in terms of the codesign and coevolution of architectures and governance* (p. 205).

Similarly, our results reflect how architecture changes influenced shifts in decision rights and vice versa. Moreover, because we view the A-G configuration as a multilevel entity, we show that despite the multiple interdependencies between the actors and systems, the transitions to new A-G configurations occurred without major difficulties because governance was nested in a series of levels (Constantinides & Barrett, 2014)—in the Rec@t case, changes at the level of the whole coordinated by the CHS, at the level of all the pharmacies coordinated by the CCP, and at the level of PMS vendors and pharmacies using PMS solutions. Moreover, the fact that Rec@t governance was polycentric—that is, "characterized by multiple governing units at different scales rather than a monocentric unit" (Constantinides & Barrett, 2014, p. 13)—enabled the coexistence of different framings of Rec@t at different levels. For instance, at the regional level, Rec@t was framed as a tool to improve the efficiency of the health system, while, at the level of pharmacists, it was framed as a tool for professional development. However, more research is still needed on this multilevel and bidirectional relationship between architecture and governance.

Although IS studies on digital platforms and infrastructures acknowledge the dynamism of evolution, they tend to emphasize the stability of the overall architecture and governance (Eaton et al., 2015 is an exception but focuses on adjusting architecture and governance at the level of interfaces only). Those studies treat architecture and governance as enduring entities that may change in certain qualities but remain recognizable and stable over time. Our process analysis enabled us to identify three main A-G configurations in the evolution of an infrastructure. Such a process orientation on the A-G configuration highlights the importance of destabilization because architecture and governance are continually in a state of becoming. Becoming represents a particular point of view in which the infrastructure constantly goes through processes of destabilization and stabilization that temporarily consolidate a specific A-G configuration.

Further, as mentioned above, infrastructure research has mainly conceived A-G configurations in terms of mainly loose or tight couplings and central or distributed control (Henfridsson & Bygstad, 2013; Lyytinen et al. 2017). In contrast, platform research focuses on one specific overall configuration involving the split between platform core and apps and between platform controller and app developers (Tiwana, 2014). We contribute to research on infrastructures, then, by demonstrating the role played by specific A-G configurations that allowed Rec@t to grow, evolve, and successfully support an ever-expanding community of users, offering them a continuously increasing number of useful services. In short, Rec@t has proven to be a *generative infrastructure*, at least during the period in which we studied it, according to both Zittrain's (2006) original definition and Lyytinen et al.'s (2017) definition, which is more adapted to the case of infrastructures.

What makes Rec@t generative is, first of all, its dual configuration. This configuration mirrored the existing structure of the field with health care providers on one side and pharmacies on the other. Despite the fact that the SIFARE hub created a significant degree of redundancy, which was perceived as a source of inconsistency that could lead to anomalies in the functioning of the system, it mobilized the user community of pharmacies during the development, deployment, and use stages of the system; it also enabled pharmacies to shape the evolution of the system according to their future interests. In that sense, we believe a design principle of large-scale information systems (Hanseth & Lyytinen, 2010) could be formulated as "one user community, one hub." Through this principle, we emphasize the idea that, in the case of systems serving several user communities, using one hub to serve only one user community helps prevent potential discrimination against the interests of that user community. At the same time, it gives that user community the capacity to self-organize for collective decisions and actions that are likely to support the bootstrapping and adaptability of the system.

This principle is, for instance, reflected in the domain of programmatic advertising (Alaimo & Kallinikos, 2018), where suppliers of advertising space (i.e., publishing organizations) are connected to "supply-side platforms" and advertisers to "demand-side platforms." These platforms connect through what are called "ad exchanges," which coordinate real-time auctioning processes each time someone accesses an online publication. We argue that the overall infrastructure involved in this advertising domain is based on a kind of dual architecture quite similar to Rec@t's. Further research is needed to refine and test the effect of the "one user community, one hub" design principle on digital infrastructures that support the activity of user communities.

Our analysis also highlights how the transformation of the dual configuration into a platform configuration by opening SIFARE contributed to making Rec@t highly generative. This evolution of Rec@t demonstrates that different A-G configurations are required to keep an infrastructure generative during the different phases of its evolution. Here, we acknowledge that our study focuses on a digital infrastructure supporting two main user groups—doctors and pharmacists—each of which has an organization that coordinates their activity. In our study, we consider the dual configuration to be well aligned with the structure of its user communities. Although as noted above, we believe that such a dual configuration may be relevant in other contexts, future research should identify specific A-G configurations adequate for different phases of evolution of other classes of digital infrastructures. Moreover, we note that the granularity of the A-G configurations that we present is at a relatively high level. We acknowledge that there is a multiplicity of overlapping configurations of architecture and governance at lower levels. Thus, further research might consider other levels of granularity for the A-G configuration.

Our study has several practical implications. First, it reveals a distributed nature of design. The A-G configuration decision of the infrastructure may have been made by a group of designers (and managers) in a boardroom, but that was just one event in many events that affected the form of the architecture and governance, shaped by relations between multiple components at different levels, including prior decisions to implement a pharmaceutical network, experimentation with other apparently unrelated IT projects, knowledge about the outcomes of other technological projects, calls for deregulation coming from EU, and so forth. This leads us to suggest that practitioners should view A-G configurations not only as the product of rational actions during the design and implementation of the system, but also as the outcome of different flows, events, and decisions occurring at different spatiotemporal levels that designers cannot control or foresee. Second, our study also suggests that, rather than being mainly preoccupied with stability and consistency, practitioners should also recognize the possibilities of the interactions between architecture and governance, the emergent effects of those interactions on the evolution of systems, and the potential of intermediary outcomes of evolution. In that respect, this research subscribes to a view in which the design and management of IT systems are concerned with imagining futures and drawing transitions from what is currently in place toward those futures. Third, related to the previous point, our study highlights the critical role of thresholds in the transition to new A-G configurations. In that respect, managers of digital infrastructures should consider tactics that enable them to identify and change the thresholds if possible, examine which transformations of A-G configuration are opened when a threshold is crossed, and evaluate how those transformations can be used strategically.

References

Aanestad, M., Grisot, M., Hanseth, O., & Vassilakopoulou, P. (2017). *Information infrastructures within European health care: Working with the installed base*. Springer.

Alaimo, C., & Kallinikos, J. (2018). Objects, metrics and practices: an inquiry into the programmatic advertising ecosystem. *Proceedings of IFIP 8.2 Working Conference on Information Systems and Organizations*, 110-123.

Anderson, B., Kearnes, M., McFarlane, C., & Swanton, D. (2012). On Assemblages and Geography. *Dialogues in Human Geography*, *2*(2), 171-189.

Arthur, W. B. (1994). *Increasing returns and path dependence in the economy*. University of Michigan Press.

Cecez-Kecmanovic, D., Galliers, R. D., Henfridsson, O., Newell, S., & Vidgen, R. (2014). The sociomateriality of information systems: Current status, future directions. *MIS Quarterly*, *38*(3), 809-830.

Ciborra, C. U., Braa, K., Cordella, A., Dahlbom, B., Failla, A., Hanseth, O., Hepsø, V., Ljungberg, J., Monteiro, E., & Simon, K. A. (Eds.). (2000). *From control to drift: The dynamics of corporate information infrastructures*. Oxford University Press.

Constantinides, P., & Barrett, M. (2014). Information infrastructure development and governance as collective action. *Information Systems Research*, *26*(1), 40-56.

Constantinides, P., Henfridsson, O., & Parker, G.G. (2018). Introduction: Platforms and infrastructures in the digital age. *Information Systems Research*, 29(2), 381-400.

DeLanda, M. (2000). Deleuze, diagrams, and the genesis of form. *Amerikastudien/American Studies*, *45*(1), 33-41.

DeLanda, M. (2006). *A new philosophy of society: Assemblage theory and social complexity*, Bloomsbury Publishing.

DeLanda, M. (2010). *Deleuze: History and science*, Atropos Press.

DeLanda, M. (2016). *Assemblage theory*. Edinburgh University Press.

Deleuze, G., & Guattari, F. (1987). *A thousand plateaus: Capitalism and schizophrenia* (Trans. Brian Massumi). University of Minnesota Press.

Doolin, B., Lamprou, E., Mitev, N., & McLeod, L. (Eds.). (2014). *Information systems and global assemblages: (Re)configuring actors, artefacts, organizations—Proceedings of IFIP WG 8.2 Working Conference on Information Systems and Organizations*. Springer.

Eaton, B., Elaluf-Calderwood, S., Sørensen, C., & Yoo, Y. (2015). Distributed tuning of boundary resources: The case of Apple's IOS service system. *MIS Quarterly, 39*(1), 217-244.

Farjoun, M. (2010). Beyond dualism: Stability and change as a duality. *Academy of Management Review*, *35*(2), 202-225.

Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing information infrastructure: The tension between standardization and flexibility. *Science, Technology, and Human Values*, *11*(4), 407-426.

Hanseth, O., Jacucci, E., Grisot, M., & Aanestad, M. (2006). Reflexive standardization: Side effects and complexity in standard making. *MIS Quarterly*, *30*(SI), 563-581.

Hanseth, O., & Ciborra, C. (2007). *Risk, complexity and ICT*. Edward Elgar Publishing.

Hanseth, O., & Lyytinen, K. (2010). Design theory for dynamic complexity in information infrastructures: The case of building internet. *Journal of Information Technology*, *25*(1), 1-19.

Hanseth, O., & Bygstad, B. (2015). Flexible generification: ICT standardization strategies and service innovation in health care. *European Journal of Information Systems*, *24*(4), 645-663

Henfridsson, O., & Bygstad, B. (2013). The generative mechanisms of digital infrastructure evolution. *MIS Quarterly*, *37*(3), 907-931.

Hepsø, V., Monteiro. E., & Rolland, K. (2009). Ecologies of eInfrastructures. *Journal of the AIS*, *10*(5), 430-446.

Iansiti, M., & Levien, R. (2004). *The keystone advantage: what the new dynamics of business ecosystems mean for strategy, innovation, and sustainability*. Harvard Business Press.

Jackson, S. J., Edwards, P. N., Bowker, G. C., & Knobel, C. P. (2007). Understanding infrastructure: History, heuristics, and cyberinfrastructure policy. *First Monday*, *12*, Article 6.

Kallinikos, J. (2012). Form, function, and matter: Crossing the border of materiality. In P. Leonardi, B. Nardi, & J. Kallinikos (Eds.), *Materiality and organizing: Social interaction in a technological world* (pp. 67-87). Oxford University Press

Kazan, E., Tan, C. W., Lim, E. T., Sørensen, C., & Damsgaard, J. (2018). Disentangling digital platform competition: The case of UK mobile payment platforms. *Journal of Management Information Systems*, *35*(1), 180-219.

Koutsikouri, D., Lindgren, R., Henfridsson, O., & Rudmark, D. (2018). Extending digital infrastructures: a typology of growth tactics. *Journal of the Association for Information Systems*, *19*(10), 1001-1019.

Langley, A. (1999). Strategies for Theorizing from Process Data. *Academy of Management Review*, *24*(4), 691-710.

Leonardi, P. M., Nardi, B. A., & Kallinikos, J. (2012). *Materiality and organizing: Social interaction in a technological world*. Oxford University Press.

Lessig, L. (1999). *Code and other laws of cyberspace*. Basic Books.

Lyytinen, K., Sørensen, C., & Tilson, D. (2017). Generativity in digital infrastructures: A research note, In R. D. Galliers & M.-K. Stein (Eds.), *The Routledge Companion to Management Information Systems* (pp. 253-275). Routledge.

MacCormack, A., Rusnak, J., & Baldwin, C. (2008). *Exploring the Duality between Product and Organizational Architectures: A Test of the Mirroring Hypothesis* (Working Paper 08-039). Harvard Business School.

Markus, L., & Bui, N. (2012). Going concerns: Governance of interorganizational coordination hubs. *Journal of Management Information Systems*, *28*(4), 165-199.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative analysis: An expanded sourcebook.* SAGE.

Morris, C. R., & Ferguson, C. H. (1993). How architecture wins technology wars. *Harvard Business Review*, *71*(2), 86-96.

Orlikowski, W. J. (2009). The sociomateriality of organisational life: Considering technology in management research. *Cambridge Journal of Economics*, *34*, 125-141.

Plantin, J-C., Lagoze, C., Edwards, P. N., & Sandwig, C. (2018). Infrastructure studies meet platform studies in the age of Google and Facebook. *New Media & Society*, *20*(1), 293-310.

Reimers, K., Johnston, R. B., & Klein, S. (2014). An empirical evaluation of existing IS change theories for the case of IOIS evolution. *European Journal of Information Systems*, *23*(4), 373-399.

Rodon, J., & Silva, L. (2015). Exploring the formation of a healthcare information infrastructure: Hierarchy or meshwork?. *Journal of the Association for Information Systems*, *16*(5), 394-417.

Rolland, K. H., & Monteiro, E. (2002). Balancing the local and the global in infrastructural information systems. *The Information Society*, *18*(2), 87-100.

Ross, J. W., Weill, P., & Robertson, D. (2006). *Enterprise architecture as strategy: Creating a foundation for business execution*. Harvard Business Press.

Rukanova, B., de Reuver, M., Henningsson, S., Nikayin, F., & Tan, Y. H. (2020). Emergence of collective digital innovations through the process of control point driven network reconfiguration and reframing: The case of mobile payment. *Electronic Markets*, *30*, 107-129.

Sørensen, C., de Reuver, M., & Basole, R.C. (2015). Mobile platforms and ecosystems. *Journal of Information Technology*, *30*(3), 195-197.

Tallon, P. P, Ramirez, R.V., & Short, J. E. (2013). The information artifact in IT governance: Toward a theory of information governance. *Journal of Management Information Systems*, *30*(3), 141-178.

Tilson, D., Lyytinen, K., & Sorensen, C. (2010). Research commentary—Digital infrastructures: The missing IS research agenda. *Information Systems Research*, *21*(4), 748-759.

Tiwana, A., Konsynski, B., & Bush, A. A. (2010). Platform evolution: Coevolution of platform architecture, governance, and environmental dynamics. *Information Systems Research*, *21*(4), 685-687.

Tiwana, A. (2014). *Platform ecosystems: Aligning architecture, governance, and strategy*. Morgan Kaufmann.

Tiwana, A. (2015). Evolutionary competition in platform ecosystems. *Information Systems Research*, *26*(2), 266-281.

Wareham, J., Fox, P. B., & Cano, J. L. (2014). Technology ecosystem governance. *Organization Science*, *25*(4), 1195-1215.

Woodard, C. J. (2008). Architectural control points. *Proceedings of the 3rd International Conference on Design Science Research in Information Systems and Technology*, 359-363.

Yin, R. K. (2009). *Case study research: Design and methods*. SAGE.

Zittrain, J. (2006). The generative internet. *Harvard Law Review*, *119*, 1974-2040.

Appendix

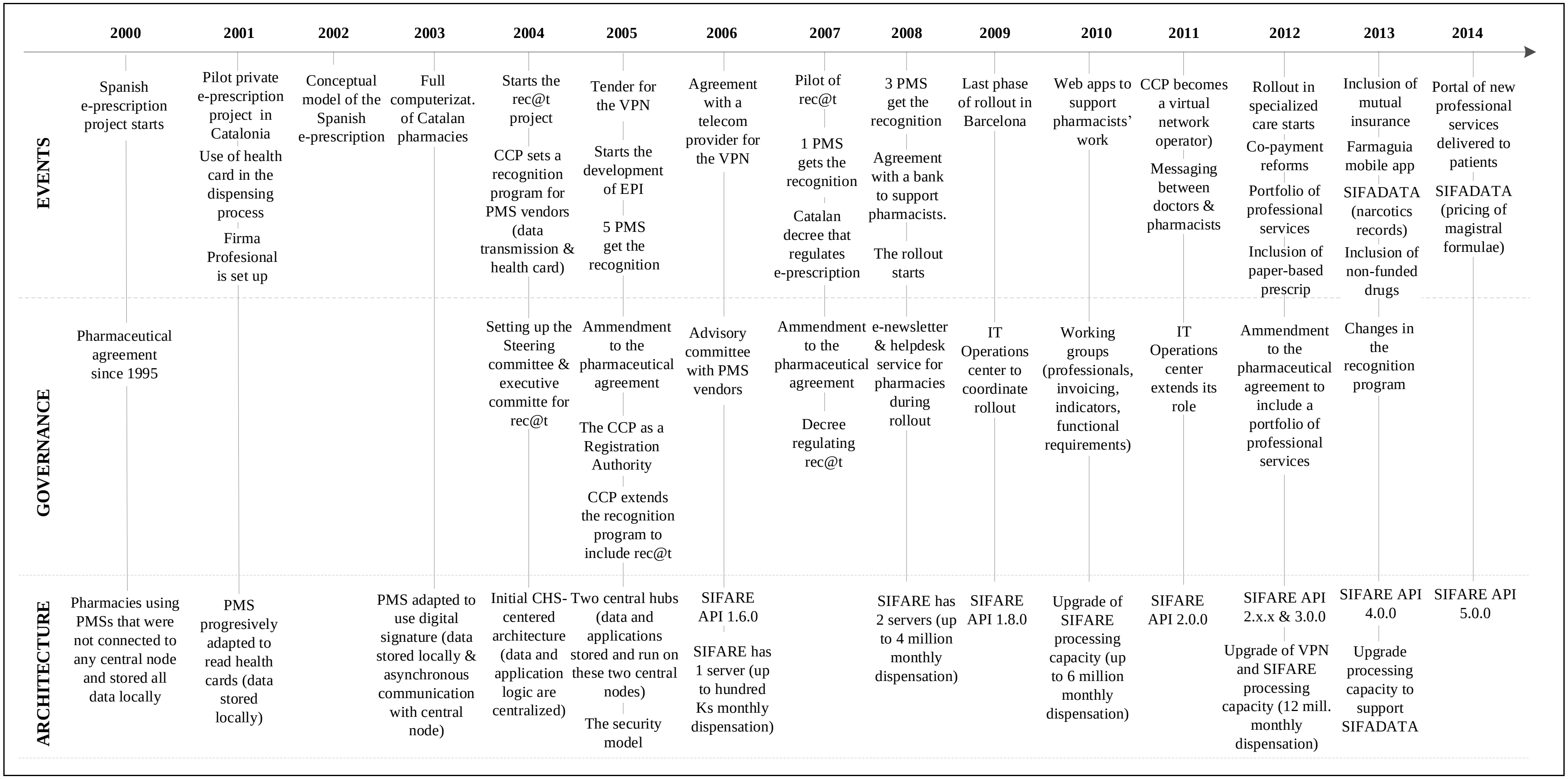

Figure A1: Chronology of Events and Related Changes to the Architecture and Governance of Rec@t

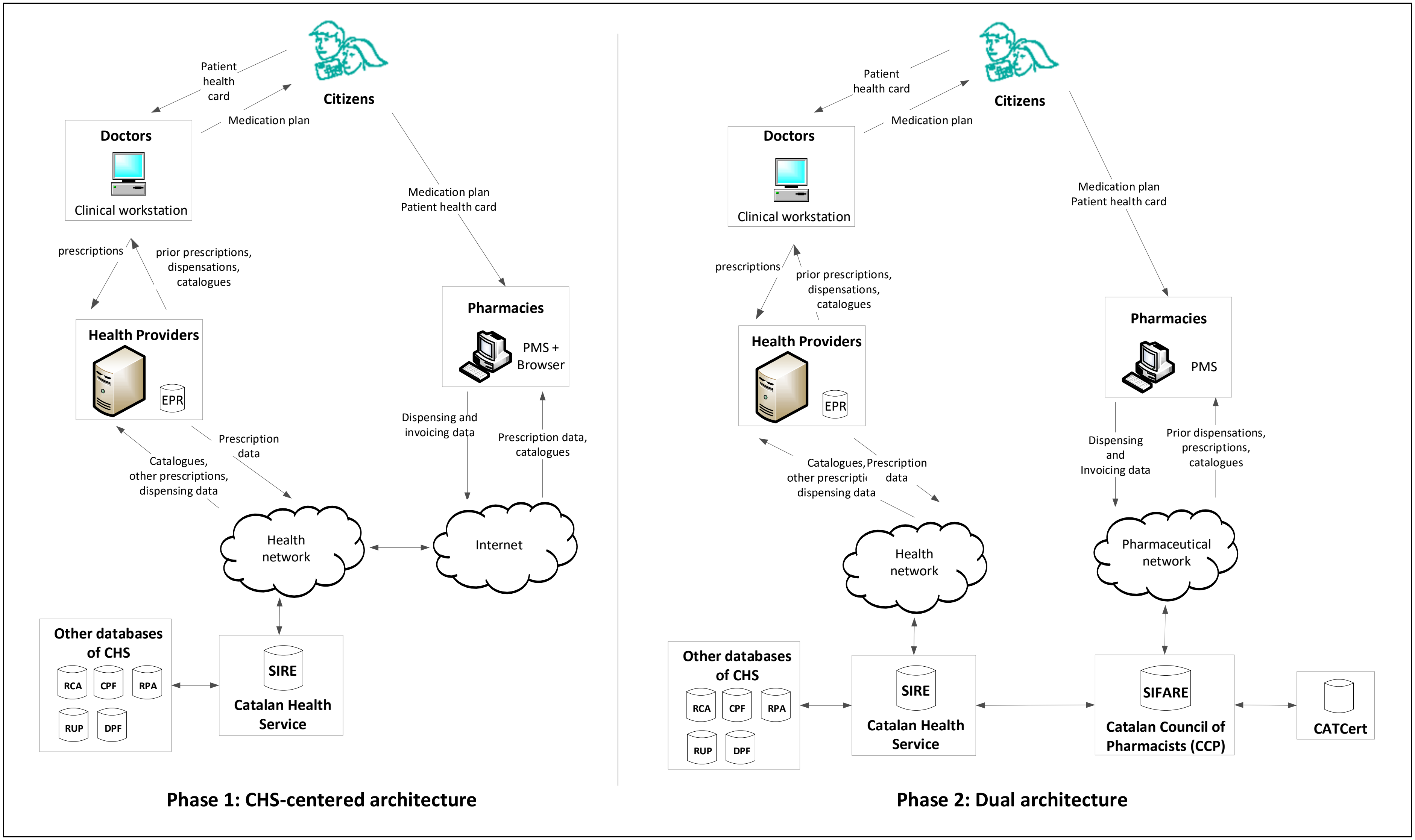

Figure A2. Architecture of Rec@t During the Design

	PHASE 1 Centralized configuration	*Threshold 1* → **PHASE 2** Dual configuration	*Threshold 2* → **PHASE 3** Platform configuration
Level: National	S_1: Initial design of the National project territorializes prescription		D_6: EU forces the Spanish government to reduce deficit
Level: Regional (coordinated by CHS)	D_1: National project destabilizes regional health service and triggers changes to the technological installed bases S_2: Fixing the scope of the project at the Regional scale (CHS-centered architecture territorializes prescription at regional level)	S_4: The dual configuration reduces the complexity of the project S_7: Passing the degree of electronic prescription & amendment to the pharmaceutical agreement	D_8: Regional governments receive pressure to reduce deficit & Catalonia's government is banned from direct access to financial markets D_9: CHS started committing repeated defaults to pharmacists
Level: pharmacists (coordinated by CCP)	D_2: The centralized configuration disrupts the pharmacy model (bypassing the CCP). Resistance from the CCP.	S_3: The dual architecture mirrors the pharmacy model (reinforces role of pharmacists and consolidates CCP) S_6: The recognition program homogenizes the working of all PMS D_4: The phased rollout entangled new users and transactions S_8: Increasing processing, storage and bandwidth capacity and adjusting governance structure D_5: Emergence of new ideas about extending Rec@t beyond dispensing and invoicing	S_9: New applications run on and data reside at the core of the platform (SIFARE) D_7: Pharmaceutical bill decreases due to approval of co-payment reforms S_{11}: Increasing interlocking between SIFARE and PMS
Level: PMS vendor and pharmacists using the PMS		S_5: The dual architecture gives continuity to pharmacists' installed base (e.g., PMS) D_3: Deterritorializing the former use of PMS by each pharmacy	S_{10}: Homogenizing the processes running on PMS associated with SIFADATA initiative

S_i: Stabilization process i
D_j: Destabilization process j

Threshold 1: The amount of resistance from the CCP (as spokesperson of pharmacists)
Threshold 2: The number of ideas and amount of pressure from PMS vendors and pharmacists to implement those ideas

Figure A3. Evolution of the A-G Configuration in Terms of the Destabilization and Stabilization Processes

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