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The Development of a Digital Innovation Ecosystem: The Key Role of Policymakers

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Abstract: Nowadays innovation processes are increasingly ecosystem-based. A lot of research focus on how a firm can became the hub of an innovation ecosystem, orchestrating the activities of other actors. Few studies deepen the pivotal role that policymakers can play in the development of innovation ecosystems. This study describes how a governmental organisation was able to become the hub of an ecosystem developing digital innovation in healthcare settings, and how it supported the diffusion of digital innovations through a specific set of policies. The research is longitudinal and mixes a co-authorship network analysis with the study of the policy mix that the governmental organisation adopted over time. The first assesses the evolution of the network while the second investigates the impacts of the policy mix components on the process of diffusion of digital innovations. Results highlight the relevance of platforms, the pivotal role of standards and the need to adopt policy instruments targeting processes characterised by increasing complexity.

1. Introduction

Innovation research is facing the issues related to the development of new products and services that request the contributions of different actors (Dattée, Alexy, and Autio 2018). Digital innovation is a "product, process, or business model that is perceived as new […] and is embodied in or enabled by IT" (Fichman, Dos Santos, and Zheng 2014, 330), and is disseminated among various firms (Yoo, Henfridsson, and Lyytinen 2010). The creation of value through digital innovations crosses the boundaries of the single organisation and requires the contribution of an ecosystem of actors (Parker, Van Alstyne, and Jiang 2017).
The literature stream on innovation ecosystems tend analysing this phenomenon (Dattée, Alexy, and Autio 2018) focusing on hub firms (Dhanaraj and Parkhe 2006) delineated by power and centrality, which are able to orchestrate the activities of other players. Few research deepened the pivotal role that policymakers can play in these settings (Clarysse et al. 2014).
This research aims at understanding how a governmental organisation can progressively shape an innovation ecosystem through policy making. The presence of different actors within the ecosystem and the relative multitude of objectives suggests the adoption of different policies inserted within a policy mix (Rogge and Reichardt 2013). This study is centred

on policy strategy and policy instruments, which are two components of the policy mix. More specifically, as suggested by Flanagan et al. (2011), we'll analyse the interactions among the various policy instruments regarding the different processes targeted over time.
Healthcare is selected as the context of this study because the diffusion of digital innovations in this sector calls for contributions of several actors with different goals (Agarwal, Gao, DesRoches, et al. 2010). Numerous governments are attempting to promote digital innovations in healthcare ecosystems, while results are often below the expectations (Gagnon et al. 2016; Lluch 2011).

2. Theoretical background

This paragraph is related to different literature streams and it is organised in two sections. The first describes digital innovation in healthcare ecosystems, while the second focuses on the pivotal role that policy mix plays in the development of an innovation ecosystem.

2.1 Digital Innovation in Healthcare Ecosystem

Digital innovations are adopted in several contexts and healthcare is a sector in which governments and companies are investing resources to support the diffusion of these technologies (Cohen 2016). The interest is related to the potential contribution that these technologies can provide to healthcare in terms of cost reduction and quality improvement (Agarwal, Gao, Desroches, et al. 2010). The results of governmental campaigns promoting the adoption of digital innovation were often not favourable (Gagnon et al. 2016; Lluch 2011).
Literature analysis shows that the usage of the word "ecosystem" to describe inter-organisational settings has increased in the last years (Parker, Van Alstyne, and Jiang 2017; Tiwana 2015). The literature of innovation ecosystem was investigated by Gomes et al. (2016) that highlighted five crucial elements. The first element pertains to the various actors considered (e.g., customers, suppliers, policymakers) and to their interdependencies, and roles within the ecosystem (e.g. hub firms, complementors) (Iansiti and Levien 2004). The second concerns the existence of a hub firm who defines objectives, ensures information sharing and provides physical assets (Takeda et al. 2008). The centrality of the hub firm affects the decisional process of other actors and the diffusion of technologies (Kim, Kwon, and Lee 2017). The collaborative and competitive relationship among actors constitutes the third element, while the fourth regards the development of a platform that enables the rise of complementary applications (Gawer and Cusumano 2014). The last element is related to the life cycle of the ecosystem (Dedehayir, Mäkinen, and Roland Ortt 2016; Moore 1993). Healthcare sector can be considered an ecosystem because it is characterised by different categories of interacting actors, governmental organisations that drive the activities of the actors of the ecosystem, coexistence of public and private actors which compete and collaborate for the health of patients, evolution of the sector itself (Dougherty and Dunne 2011; Gastaldi and Corso 2016).
The focus of innovation ecosystem research stream is principally on industries (Adner 2006; Moore 1993) while the role played by policymakers is underestimated (Gomes et al. 2016).
The few publications examining ecosystems' policies (Clarysse et al. 2014) and the resulting lack of frameworks (Oh et al. 2016), make the investigation of inter-organisational settings–in which governmental organisations play a crucial role– a challenging task. A peculiar context with these characteristics is the healthcare one and we believe that the framework illustrated in the next section would be a promising source to fill this gap.

2.2 The pivotal role of Policy mix

Following Scaringella and Radziwon (2017), the innovation ecosystem literature is rooted in the literature of innovation systems, which includes several concepts. One of them is technological innovation system which investigates contexts in which there are several actors and provides insights for policymakers. It is a system "focused on the development, diffusion, and use of a particular technology (in terms of knowledge, product or both)" (Bergek et al. 2008, 408). Bergek et al. (2008) and other scientists further elaborated the framework of the functional dynamics of innovation systems, that is used to qualitatively assess the performance of the system and suggest policy interventions. It considers the structural components (i.e. actors, network, institutions) and assesses the processes, i.e. the seven functions (Table 1) of the innovation system that either encouraged or restrained (i.e. blocking mechanisms) the diffusion of innovations.

Table 1. List of the seven functions

Function Number	Function
F1	Knowledge development and diffusion
F2	Influence of the direction of search
F3	Entrepreneurial experimentation
F4	Market formation
F5	Legitimation
F6	Resource mobilisation
F7	Development of positive externalities

The framework of functional dynamics is a promising tool to consider the viewpoint of policymakers. However, policies are considered as the results of the framework, and it is not clear which policy instruments are suitable for different technologies and when these instruments should be introduced over time (Hellsmark et al. 2016).
The literature revealed that only a few are the studies analysing the impact of policy interventions on the innovation ecosystem (Reichardt et al. 2016).
Rogge and Reichardt (2016, 1623) speculate that policy strategy is the "combination of policy objectives and the principal plans for achieving them" and policy instruments "constitute the concrete tools to achieve overarching objectives".
Based on Tinbergen (1952), Flanagan et al. (2011) suggested the adoption of policy mixes instead of a single policy instrument. They also proposed analysing different types of interactions, arising in different dimensions, among policy strategy and policy instruments.
The research of Rogge and Reichardt (2016) analyses policy instruments and classifies them in terms of types (i.e. information, regulation and economic instrument) and purposes (demand pull, technology push, systemic purpose).

3. Methodology

To address the research questions, we adopted an archival analysis mixing a longitudinal co-authorship network analysis and policy mix analysis.
Regarding the focus of the innovation ecosystem examined, we selected digital technologies as the knowledge field object of analysis and healthcare as the range of application. We restricted the analysis on the various digital innovations exploitable by healthcare organisations and other actors (e.g. patients, general practitioners). Regional healthcare system is the selected spatial focus.
The research is limited to the Italian regional healthcare system of Lombardy. This region manages healthcare services for almost 10 millions of citizens, with 35 public hospitals (ISTAT 2016). Barbarito et al. (2012) highlighted that Lombardy Region was able to support the diffusion of digital innovations within the region through several interventions. The reasons for this success are not yet explained. Innovation ecosystem is a promising literature stream to further investigate this topic. We aim at exploiting the opportunity offered by the case of Lombardy Region to start contributing to the innovation ecosystem literature from governmental organisation's viewpoint.
Data collection about policies was performed through the analysis of the papers related to research projects funded by Lombardy Region and a snowballing technique (Greenhalgh and Peacock 2005).
To perform data analysis, we adopted two frameworks. The first was developed by Reichardt et al. (2016), and it is useful not only to categorise policy strategy and policy instruments but also to analyse their impact on the innovation ecosystem. The second framework, developed by Flanagan et al. (2011), takes into account various processes targeted by policies over time.

3.1 Co-Authorship Network Analysis

Regarding the structural components, we conducted a co-authorship network analysis to identify the actors and the networks of the innovation ecosystem. Web of Science was adopted as the search engine to perform the research. Several keywords related to digital innovations in healthcare were selected to be searched (Table 2).

Table 2. List of keywords

digital health	emr	medical platform	mobile app	web-based
ehealth	electronic health record	medical imaging	disaster recovery	operating room
e-health	personal health record	health information technology	cybersecurity	decision support system
RIS/PACS	electronic medical record	health information exchange	genomics	tele-healthcare
Radiology Informatio n System	m-health	health analytics	cloud computing	hta
Picture archiving and communic ation system	mhealth	RIS	platform	health technology assessment
tele-care	mobile health	PACS	ICT	apps
telecare	wireless health	big data	digital technologies	software
telemedici ne	health 2.0	information system	digital innovation	business intelligence
ehr	health platform			

The selection criteria were to consider publications in which at least one of the authors is affiliated with an Italian institution, or the funding organisation was Italian (4,763 publications). The second criterion was to choose papers published in peer-reviewed journals and with English or Italian languages (2,998 publications).
Titles and abstracts were assessed to select publications related to the topic of digital innovations in healthcare, resulting in 977 publications. Information about the institutions was extracted, homogenised and cleaned through OpenRefine. We obtained 2,100 institutions after removing duplicates. Institutions were also categorised into clusters.
Italian institutions were furtherly detailed through the grouping in the various Italian Regions. In this way, we were able to identify 121 actors from Lombardy.
The analysis was focused on the 299 publications characterised by at least one actor from Lombardy. We identified the relationships among actors and their relevance. Relevance was assessed in terms of the eigenvector centrality inside the network through UCINET6 and NetDraw (Brass and Burkhardt 1993). Eigenvector centrality is the measure adopted to measure the popularity of a given actor (Borgatti, Everett, and Johnson 2013).
The year of publication of the selected documents allowed investigating how these aspects evolved. Due to the time required for publishing papers, it intrinsically provides delayed information.

3.2 Policy Mix Analysis

Data collection regarding policies was conducted through the analysis of the publications where Lombardy Region funded the research, snowballing technique. The use of these sources of information increased data reliability due to data triangulation.
The analysis of the papers characterised by Lombardy Region as funding organisation, allowed to collect data regarding digital innovations and the related process, and to investigate the typology of policy instruments adopted.
Snowballing technique was performed through the regional search engine of Lombardy related to laws and resolutions, the search engine related to the regional platform (Regione Lombardia 2017b, 2017a) and Google Search for the required document not available in the first two search engines. It was useful to identify further principal plans and policy instruments.
Data analysis regarding policies was firstly based on the frameworks developed by Reichardt et al. (2016) and Rogge and Reichardt (2016), and then on the interactions among policy instruments (Flanagan, Uyarra, and Laranja 2011).
The frameworks of Reichardt et al. (2016) and Rogge and Reichardt (2016) were helpful to:

- categorise the elements of policy strategy and policy instruments {indicated by braces};
- highlight how innovation ecosystem impacts policies (i.e., it identifies blocking mechanisms and the related functions) [indicated in square brackets];
- underline how policy strategy and policy instruments influence the innovation ecosystem (i.e., it highlights the positive or negative impact on the functions) [indicated in square brackets and preceded by "+" or "-" if the influence on the specific function is "positive" or "negative" respectively].

Given the application in the healthcare context, we categorised the elements of policy mix in terms of the processes concerning Regional Healthcare System (Flanagan, Uyarra, and Laranja 2011) and of the involved actors. Therefore, we considered time as the dimension in which policy mix interactions take place.
All the documents were useful to reconstruct the development of the analysed innovation ecosystem and identify the key events related to the introduction of new components of the policy mix. The components of the policy mix were chronologically ordered. Each component was categorised following the framework of Rogge and Reichardt (2016), detailed in terms of the actors and processes involved, of the blocking mechanism that caused the introduction of the specific component and the influence of the component on the innovation ecosystem.
A cross-component analysis was conducted following the framework of Flanagan et al. (2011).
The documents were analysed, coded, summarised and interpreted during the recurrent meetings of the authors. The meetings aimed to test the reliability of concepts, share ideas, as well as contrast critical issues associated with the components of the policy mix and the cross-component analysis. The categorisation of the components of policy mix and the results of the performed analyses were validated by academics and experts of healthcare sector.

4. Results

This chapter shows the outcomes of this research and consists of two sections. The first section outlines the structural components of the analysed innovation ecosystem, while the second depicts the evolution of the structural components and the impact of the policy mix on the seven functions over time.

4.1 Structural components

This section discusses the results of the co-authorship analysis concerning the actors and their relationships over time. Furthermore, it illustrates the data regarding the policy mix and the classification of its components.
Results of the co-authorship network analysis allow identifying actors, categories of actors, relationships among actors and the evolution of these aspects over time.
Our investigation revealed that from 1991 to mid-2017, 121 actors from Lombardy published 299 documents. The evolution of the network is displayed in Figure 1, which shows the four temporal phases that will be described in the following sections.
We assigned an ID to all actors and examined their eigenvector centrality. Among actors, Lombardy Region is the one with the highest eigenvector centrality, followed by three universities and a hospital with competencies in research. Therefore, Lombardy Region can be considered the hub of the ecosystem related to digital innovation in healthcare. However, the centrality was not sufficiently high in previous years and the hub position was therefore built over time. The lack of ties among sets of actors limits the diffusion of knowledge and slows its development. It is one of the aspects that could be improved in the future through the adoption of some policy instruments useful to enhance the connectivity between actors and grants fostering the collaboration among them.

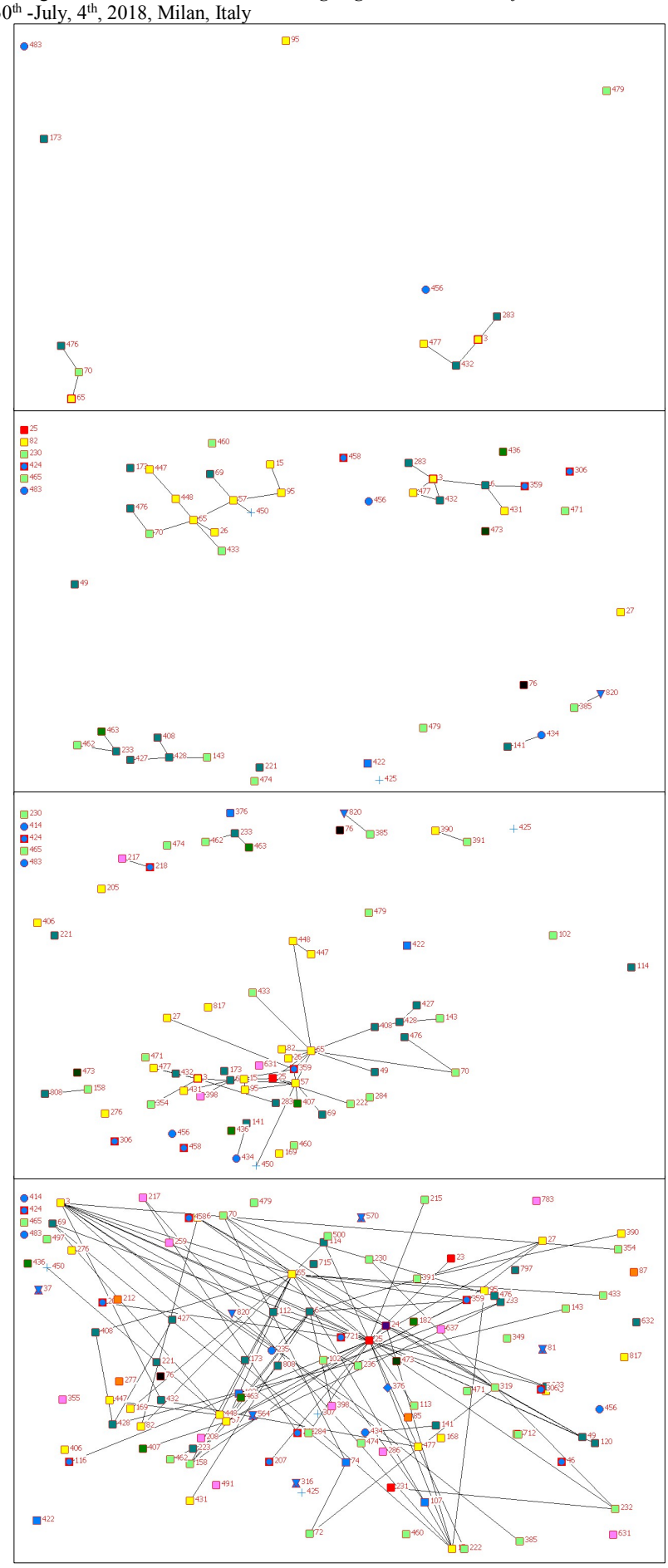

Figure 1. Networks of Internal Actors

The data related to policies gathered during co-authorship network analysis and the snowballing technique were chronologically ordered and classified (Rogge and Reichardt 2016) (Table 3). This information is used as input for the following section that investigates the influence of the policy mix on the innovation ecosystem.

Table 3. Evolution of policy mix

Policy Mix Component	Type of Policy Mix Component	Year
Regional Healthcare Strategy - SISS	Policy Strategy	1997
CRS-SISS Platform	Economic Instrument - Systemic	1999
Funded Project - CRITERIA	Economic Instrument - Technology push	2002
Funded Project - TELEMACO	Economic Instrument - Technology push	2005
SISS- Selection of Standards	Instrument - Regulation - Demand Pull	2007
SISS-Resolution 2007	Instrument - Regulation - Demand Pull	2007
Guidelines	Policy Plan	2007
Funded project - EVOLVO	Economic Instrument - Technology push	2008
Funded project - IGEA SAT	Economic Instrument - Technology push	2008
SISS - Resolutions 2009	Policy Strategy	2009
Guidelines	Policy Plan	2009
Guidelines	Policy Plan	2010
Guidelines	Policy Plan	2010
Electronic health record Project	Economic Instrument - Systemic	2010
Guidelines	Policy Plan	2011
List of Verified software	Instrument - Regulation - Demand Pull	2011
List of Verified software	Instrument - Regulation - Demand Pull	2011
Guidelines	Policy Plan	2012
Maturity Model - Assessment - Benchmarking	Instrument - Information - Demand Pull	2013
Maturity Model - Assessment - Benchmarking	Instrument - Information - Demand Pull	2014
Best practices	Instrument - Information - Demand Pull	2014
Funded project - Continuing medical education	Economic Instrument - Technology push	2014
Guidelines	Policy Plan	2014
Funded project - Telemonitoring	Economic Instrument - Technology push	2015
Funded project - Telemonitoring	Economic Instrument - Technology push	2015
Funded project - e-Learning	Economic Instrument - Technology push	2015
Guidelines	Policy Plan	2015
Funded project - HFDATA	Economic Instrument - Technology push	2015
Funded project - ONCO-CODES	Economic Instrument - Technology push	2015
Funded project - Big Data - Genomics	Economic Instrument - Technology push	2016

4.2 Evolution of the innovation ecosystem and of its policy mix

In the following sections, we will illustrate the evolution of the analysed innovation ecosystem from 1991 to 2017, in four phases.
Every section describes the condition, at the end of the considered time window, regarding the structural components of the innovation ecosystem and the impact of the policy mix. It emphasises the blocking mechanisms, the processes and digital innovations targeted by the policy interventions.

4.2.1 Experimentation era (1991-2000)

Concerning the evolution of the network of internal actors until 2000, connections were mainly among research centres and healthcare organisations. Entrepreneurial experimentation was restricted to only two IT companies but not linked to any other actor [F3] (Figure 1).
In this phase, the market of digital innovations was at an embryonal stage [F4], and projects were at an experimental level [F3].
The Regional law issued in 1997 (Regione Lombardia 1997) constituted the first contribution for the birth of this innovation ecosystem {policy strategy}. It specified the goals of the regional policy strategy regarding healthcare sector that concern the integration between healthcare and social care, expenditure control and quality of services. This law sanctioned the development of the regional digital platform called SISS (Sistema Informativo Socio Sanitario) {economic instrument – systemic purpose}. SISS platform aimed at promoting the integration of all healthcare and social care actors, citizens, and IT providers [+F2].

In 1999, Lombardy Region launched the project CRS-SISS (Barbarito et al. 2012). It started as a pilot study and constituted the starting point of regional healthcare platform of Lombardy. Interoperability standards were not yet defined (Table 4).

Table 4. Policy mix analysis (1991-2000)

Policy Mix Component	Year	Processes	Digital innovations	Actors	Type	Blocking mechanism (B) | Policy mix influence on the innovation ecosystem (+/-)						
						F1	F2	F3	F4	F5	F6	F7
Regional Healthcare Strategy - SISS	1997	Healthcare and Social care processes	Platform	All healthcare and social care actors	Policy Strategy	B	+	B	B			
CRS-SISS Platform	1999	Healthcare and Social care processes	Healthcare card	All healthcare and social care actors - Citizens - IT Provider	Economic Instrument - Systemic	B	+	B+	B+	+		+

4.2.2 SISS as a digitalisation project (2001-2007)

The Italian Government instituted incentives to encourage investments in digital technologies (Parlamento Italiano 2003) [F2, F6]. The bibliometric analysis revealed that until the year 2007 knowledge sources were restricted to research centres, universities and hospitals with competencies in research [F1] (Figure 1).
From 2006, the Lombardy Region entered within the network, but it did not collaborate with any other actor.
The analysed innovation ecosystem was still in an experimental phase during which the low level of digitalisation of documents negatively affected its growth [F4].
The lack of norms regarding tools and ways to digitalise documents, implied the development of a not orchestrated multitude of formats [F2].
In 2005, the Italian Parliament issued the law concerning digital documents (Parlamento Italiano 2005) [F5]. Subsequently, the first step of guidelines published by the Region took place in 2007 and revolved around the digitalisation of documents {policy plan} [+F5] (Lombardia Informatica 2017). It was related to clinical, administrative and social care processes, and constituted the prerequisite to sharing information among actors [+F1].
Lombardy Region also funded some projects as CRITERIA (Scalvini et al. 2013, 2009) which demonstrated the feasibility and effectiveness of using telemedicine [+F5 +F4], or TELEMACO (Bernocchi et al. 2012) which positively affected the credibility of telemedicine services and was considered as a best practice by the Italian health minister [F5].
One of the aspects that limit the diffusion of telemedicine is the lack of defined pricing (i.e. DRG) for the related services [F6] and has a negative influence on the sustainability of telemedicine services [F4]. The first step regarding the definition of DRG for telemedicine took place during TELEMACO project [+F4, +F6].
Until 2007, SISS platform lacked a defined standard which allowed interoperability and the format adopted by the various organisations limited the diffusion and development of knowledge [F1]. Furthermore, the absence of standards increased the risk for entrepreneurs [F3].
The selection of standard (e.g. HL7, DICOM) {regulation instrument with demand pull purpose} was the starting point of the communication among actors [+F1] and the evolution of the market (Bergek et al. 2008) [+F4]. It increased the legitimacy of digital innovations [+F5]; therefore, IT companies perceived a lower risk in entering in the innovation ecosystem [+F7]. It also restricted the research regarding standards [-F2] while it enabled further research on interoperability [+F2] (Table 5).

Table 5. Policy mix analysis (2001-2007)

Policy Mix Component	Year	Processes	Digital innovations	Actors	Type	Blocking mechanism (B) | Policy mix influence on the innovation ecosystem (+/-)						
						F1	F2	F3	F4	F5	F6	F7
Funded Project - CRITERIA	2002	Research/Clinical Process	Telemedicine (Communication between patient and healthcare organisation)	Healthcare Organisation - Patient	Economic Instrument - Technology push				B+	B+	B	
Funded Project - TELEMACO	2005	Research/Clinical Process	Telemedicine (Communication between patient and healthcare organisation)	Healthcare Organisation	Economic Instrument - Technology push	B+	+		B+	+	B+	
SISS- Selection of Standards	2007	Development of digital innovations - Administrative, Clinical and Social Care Processes	All digital innovations	All healthcare actors - IT Provider	Instrument - Regulation - Demand Pull	B+	+/-	B	+	+		+
SISS- Resolution 2007	2007	Healthcare and Social care processes (Public organisations)	All digital innovations	All healthcare actors - IT Provider	Instrument - Regulation - Demand Pull	+	+		B+			
Guidelines	2007	Clinical and Social Care Processes	Digitalisation of Clinical Documents	All healthcare actors - IT Provider	Policy Plan	B+	B+		B	+		B

4.2.3 SISS as a system (2008-2011)

Results of the co-authorship network analysis showed that Lombardy Region began co-operating with other actors from 2009.
There was an improvement in entrepreneurial experimentations explainable through the various synergies among some of these technologies [F3].
Until 2007, the integration with the SISS platform was not mandatory and negatively affected the connectivity [F1, F2] and the growth of the market [F4]. The resolution issued in 2007 made the integration with the SISS platform compulsory for public healthcare organisations and general practitioners [+F1, +F2, +F4] {regulation instrument with demand pull Purpose}.
The regional laws of 2009 highlighted the role of SISS platform {policy strategy} and the development of digital innovations in healthcare and social care organisations [F2] as one of the main objectives. Healthcare and social care organisations were incentivised to updating their infrastructures, processes and digital services [+F7], but the approval from the in-house company owned by Lombardy Region was required [-F7].
The diffusion and development of digital innovations were supported through the publication of guidelines. Another goal of the program was the cut of the costs associated with the procurement of digital innovation solution through a centralised purchasing [F4].
In 2009 Lombardy Region began the development of the guidelines about the electronic medical record for healthcare organisations and general practitioners {policy plan} (Lombardia Informatica 2013c, 2014b). The Region specified the requirements of electronic medical record software regarding functionalities [+F2] and quality. This plan increased the interest of firms able to develop high-quality technologies and discouraged low-quality firms [+/-F7]. Based on these requirements and the integration with SISS platform, the Region drew up a list of verified electronic medical record software {regulation instrument with demand pull purpose} (i.e. only eligible IT developers can sell software to healthcare organisations in Lombardy). The list increased the authority of recognised IT vendors [+F5] and supported healthcare organisations and general practitioners in the process of selection. It enforced the impact in terms of the entrance of new actors previously described [+/-F7], and it supported the growth of the market [+F4].
In 2010 Lombardy Region started the development of guidelines for information systems of hospitals {policy plan} (Lombardia Informatica 2013a). They described the required portfolio of applications [+F2, +F7] and the role played by information systems [+F5].
In 2010 Lombardy Region launched the regional electronic health record project (Barbarito et al. 2015) with the aim of providing a complete patient history and making it accessible at any point of care [+F1]. Electronic medical record software and the integration with SISS platform were required for nurturing electronic health record [+F2].

The Region developed the guidelines related to the management of workstations and the delivery of administrative services within healthcare and social care organisations.
They attributed the management of information systems to healthcare and social care organisations [+F2], highlighted the need for a single external IT provider and of the integration with the SISS platform [+F6]. The outsourcing of these activities supported the growth of workstation management solutions [+F4]. It reinforced the connection between the organisation and IT provider which was able to perceive the relevance of its role within the innovation ecosystem [+F5, +F7].
Regarding the projects funded by the Region of Lombardy during this phase, EVOLVO Project (Landolina et al. 2012; Zanaboni et al. 2013) revealed how tele-monitoring reduces the number of visits [+F5], IGEA SAT Project (Paneroni et al. 2015) analysed the effectiveness of tele-rehabilitation technologies for the treatment of chronic conditions [+F4, +F5] (Table 6).

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Table 6. Policy mix analysis (2008-2011)

Policy Mix Component	Year	Processes	Digital innovations	Actors	Type	Blocking mechanism (B) | Policy mix influence on the innovation ecosystem (+/-)						
						F1	F2	F3	F4	F5	F6	F7
Funded project - EVOLVO	2008	Research/Clinical Process	Telemedicine (Tele-Monitoring)	Healthcare Organisation - Research Centre - IT Provider	Economic Instrument - Technology push					B+		
Funded project - IGEA SAT	2008	Research/Administrative and Clinical Processes	Telemedicine (Tele-rehabilitation through the usage of various digital innovations)	Healthcare Organisation - - Research Centre - IT Provider	Economic Instrument - Technology push				+	+	B+	
SISS - Resolutions 2009	2009	Healthcare and Social care processes	All digital innovations	All healthcare and social care actors	Policy Strategy		B+		B+			B+
Guidelines	2009	Clinical Process	Electronic medical record (Integrated with SISS platform)	Healthcare Organisation - IT Provider	Policy Plan	B	B+			+		+/-
Guidelines	2010	Administrative and Clinical Processes	Information System (Integrated with SISS platform)	Healthcare Organisation - IT Provider	Policy Plan		B+			B+		+
Guidelines	2010	Clinical Process	Electronic medical record (Integrated with SISS platform)	General Practitioner - IT Provider	Policy Plan	B	B+			+		+/-
Electronic health record Project	2010	Clinical and Social Care Processes	Electronic health record (Integrated with SISS platform)	All healthcare actors - Citizens - IT Provider	Economic Instrument - Systemic	B+						
Guidelines	2011	Administrative process	Management of PC - Devices - Printers (Integrated with SISS platform)	Healthcare Organisation - Local Healthcare Authority (ASL) - IT Provider	Policy Plan		B+		+	B	B+	+
List of Verified software	2011	Clinical Process	Electronic medical record (Integrated with SISS platform)	Healthcare Organisation - IT Provider	Instrument - Regulation - Demand Pull				+	B+		+/-
List of Verified software	2011	Administrative process	Management of PC - Devices - Printers (Integrated with SISS platform)	General Practitioner - IT Provider	Instrument - Regulation - Demand Pull				+	B+		+/-

4.2.4 SISS as a mature system (2012- mid-2017)

In the mid-2017 the innovation ecosystem included 121 actors. The increase in the number of actors was also due to the inclusion of companies of complementary services or required to deliver digital services (e.g. telco) [F3] (Figure 1). The presence of other categories of actors started to emerge including consulting companies and venture capitalists [F1]. Until mid-2017 Lombardy Region (ID 25) increased its centrality with a gradual pace inside the network building many collaborations with some of the most central actors and involving several hospitals, firms and associations.

The development of guidelines for information systems of healthcare organisations continued and led to the development of a "maturity model", a model to assess the level of implementation regarding functionalities, diffusion and integration among the components (Lombardia Informatica 2013a). The related analysis and benchmarking {information instrument with demand-pull purpose}, performed in 2013, allowed to realise how the organisations implemented their information systems [+F2]. This analysis was adopted for the development of another document highlighting the best practices among these actors [+F5] (Lombardia Informatica 2014a). It supported the diffusion of knowledge [+F1], fostered "best-in-class" organisations to help other organisation [+F7] and identified the paths that should be followed [+F2].
Regarding the healthcare organisations, in 2012 the Region started the development of guidelines for information systems for social care organisations {policy plan} (Lombardia Informatica 2013b). The guidelines were useful for the definition of the role played by information systems inside the SISS platform [+F5] and of the required key functionalities [+F2]. These aspects increased information availability [+F1] and allowed the evolution of information systems [+F7]. Finally, the region proceeded with the definition of the related maturity model, and with the assessment and benchmarking {information instrument with demand-pull purpose}.
In 2014, Lombardy Region continued with the development of guidelines for information systems with a focus on central booking services to foster homogenisation and support the evolution of information systems [+F6], and for automatic identification and data capture technologies (e.g., barcode, RFId) {policy plan}. These technologies trace critical items and people involved in transfusion processes or management of high-value drugs (Lombardia Informatica 2015).
These guidelines regarded healthcare organisations and all the figures involved in the collection, treatment, logistics and transportation of blood outside the boundaries of the single hospital [+F2].
The research projects financed by Lombardy Region [+F6] were related to fall detection and localisation of patients (Ballardini et al. 2016; Kianoush et al. 2017), administrative data [+F2] (Ieva, Jackson, and Sharples 2017), genomics, big data solutions [+F6] (Murphy et al. 2017), computerised decision support system that also considered data related to electronic health records and evidence-based knowledge (Moja, Passardi, et al. 2016; Moja, Polo Friz, et al. 2016), web-based services (Kwag et al. 2016) [+F1] (Table 7).

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Table 7. Policy mix analysis (2012-2017)

Policy Mix Component	Year	Processes	Digital innovations	Actors	Type	Blocking mechanism (B) | Policy mix influence on the innovation ecosystem (+/-)						
						F1	F2	F3	F4	F5	F6	F7
Guidelines	2012	Administrative and Social Care Processes	Information System	Local Healthcare Authority (ASL)	Policy Plan	B+	+			+		B+
Maturity Model - Assessment - Benchmarking	2013	Administrative and Clinical Processes	Information System	Healthcare Organisation	Instrument - Information - Demand Pull	B	+			B		
Maturity Model - Assessment - Benchmarking	2014	Administrative and Social Care Processes	Information System	Local Healthcare Authority (ASL)	Instrument - Information - Demand Pull	B	+			B		
Best practices	2014	Administrative and Clinical Processes	Information System	Healthcare Organisation	Instrument - Information - Demand Pull	B+	+			B+		+
Funded project - Continuing medical education	2014	Clinical and e-Learning Processes	Web-Based Services	Healthcare Organisation – Research Centre	Economic Instrument - Technology push	+	+			+		
Guidelines	2014	Administrative process	Centralised Booking Centres	Healthcare Organisation - Local Healthcare Authority (ASL)	Policy Plan						B+	
Funded project - Telemonitoring	2015	Research/Clinical process	Telemedicine (Tele-monitoring)	Research Centre	Economic Instrument - Technology push						B+	
Funded project - Telemonitoring	2015	Research/Clinical process	Telemedicine (Tele-monitoring)	Research Centre	Economic Instrument - Technology push						B+	
Funded project - e-Learning	2015	Clinical and e-Learning Processes	Web-Based Services	Healthcare Organisation - Research Centre	Economic Instrument - Technology push	+						
Guidelines	2015	Treatment management processes	Traceability technologies - AIDC (Barcode - RFID)	Blood Donor Associations - Laboratories- Healthcare Organisation - Patient	Policy Plan		B+					
Funded project - HFDATA	2015	Research/Administrative and Clinical Processes	Administrative data - Information System - Business Intelligence	University - Research Centre	Economic Instrument - Technology push		B+					
Funded project - ONCO-CODES	2015	Research/Clinical Process	Electronic health record - Decision Support System	Healthcare Organisation - Research Centre - IT Provider	Economic Instrument - Technology push		+				B	+
Funded project - Big Data - Genomics	2016	Research/Clinical process	Big Data - Genomics Software	Healthcare Organisation - Research	Economic Instrument - Technology push						B+	

5. Conclusions and discussion

Results of the co-authorship network analysis revealed the growth of the analysed innovation ecosystem and the increasing centrality of Lombardy Region over time. It was reached through the collaboration with relevant actors and through research grants. The growth of the analysed innovation ecosystem and the increase in the centrality of the

governmental organisation suggest a potential link between these dynamics (Kim, Kwon, and Lee 2017). The growth of the ecosystem was characterised by the increase of the typologies of digital innovations adopted within it. Coherently with the policy strategy, based on the development of a multi-sided platform, and developed through the introduction of several components of the policy mix, the development and integration of these technologies were enabled by a platform allowing the interactions among healthcare and social care actors, platform owner (i.e. Lombardy Region), patients and IT providers. The second relevant aspect concerned the development of a multi-sided platform: the policy instrument that constituted the cornerstone of the entire policy strategy enabling the integration of digital innovations (Gawer and Cusumano 2014; Rogge and Reichardt 2013). Nevertheless, an effective integration required the selection of the appropriate standards. Thus, we can suggest the following proposition:

> P1: A governmental organisation can support the growth of an innovation ecosystem through a policy strategy based on a multi-sided platform and through the selection of the required standards to support the integration of the future complementary applications.

The study of the evolution of the policy mix emphasised the relevance of economic instrument with systemic purpose, i.e. platform, and regulation instruments with a demand-pull purpose related to the definition of standards.
It is a contribution to the platform literature regarding the birth of a platform and the progressive development and integration of different applications (Gawer and Cusumano 2014).
This research contributed to the debate regarding the management of digital innovations in inter-organisational contexts (Yoo, Henfridsson, and Lyytinen 2010) but applied in the public sector.

From the standpoint of the policy plans and policy instruments adopted after the selection of the standard, the initial focus was limited to clinical processes (i.e. policy plans regarding digitalisation of clinical documents and electronic medical record). It gradually went beyond the single department, reached the organisational level (i.e. policy plans regarding information systems of healthcare and social care organisations) and finally arrived at the ecosystem level (i.e. policy plan regarding traceability technologies). Therefore, we noticed that growing complexity characterises targeted processes regarding digital innovations that needed to be integrated.
Concerning the interactions among the elements of the policy mix, we can understand that increasing complexity of the processes targeted by policy plans was a crucial aspect to ensure the growth of the innovation ecosystem (Flanagan, Uyarra, and Laranja 2011). Focusing on the technologies adopted regarding funded projects, they were increasingly complex. It is showed on the following list:

- Telemedicine (Communication patient-healthcare organisation);
- Telemedicine (Tele-monitoring);
- Telemedicine (Tele-rehabilitation);
- Web-based services;
- Telemedicine (Tele-monitoring);
- Web-based services;
- Administrative data - Information system - Business intelligence;
- Adoption of electronic health record data to develop decision support system;
- Big data - Genomics - Software.

These aspects constitute a contribution to the platform literature because they describe how an actor has been managing a platform-based ecosystem since its creation (Gawer 2014).
Therefore, we recommend the following proposition:

> P2: A platform-based policy strategy, oriented to the growth of an innovation ecosystem of digital innovations, is grounded in policy plans and instruments continuously targeting and integrating processes characterised by an increasing complexity related to the variety of actors involved and of integrated digital innovations.

The growing complexity of the processes targeted by the components of the policy mix was also related to the technologies adopted in these processes (Flanagan, Uyarra, and Laranja 2011).
The adoption of the framework of the seven functions in a longitudinal study, considering the impact of the policy interventions over time, contributes to the development of technological innovation system literature (Hellsmark et al. 2016).
The research extended the fields of application of the framework developed by Reichardt et al. (2016) in the healthcare context. The research mixed quantitative aspects with qualitative elements related to the frameworks of Reichardt et al. (2016), and Bergek et al. (2008).

The limitations of the research are related to the co-authorship network analysis that did not consider all the possible digital innovations. Further research could extend the number of chosen keywords and performs different analysis (e.g. patents, interviews with experts). Regarding generalisability, the studies focused on the Italian context. Therefore, it is

the starting point to continue this research in other regions. Further analysis could test the appropriateness, in other sectors, of comparable policy strategies (Iansiti and Levien 2004).

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