UNIVERSITÀ DEGLI STUDI DI PALERMO
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INTER-ORGANIZATIONAL NETWORKS FOR INNOVATIONS AND SUSTAINABILITY

IL DOTTORE
JELENA MAZAJ

IL COORDINATORE
PROF. ANDREA CONSIGLIO

IL TUTOR
PROF. ARABELLA MOCCIARO LI DESTRI

CO-TUTOR
PROF. MICHELE TUMMINELLO

CICLO XXXIII
ANNO CONSEGUIMENTO TITOLO 2021

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LIST OF ABBREVIATIONS

CSO – Civic Society Organization

EC – European Commission

ERA – European Research Area

EU – European Union

FP – Framework Program

H2020 – HORIZON 2020 (8th EU Framework Program)

HES – Higher Education Establishments

NGO – Non-governmental Organization

OTH – Other Entities

PIC – Participant Identification Code

PPPs – Public-Private Partnerships

PRC – Private for-profit Companies

PUB – Public Bodies

R&D – Research and Development

R&I – Research and Innovation

REC – Research Organizations

RRI – Responsible Research and Innovation

SDG – Sustainable Development Goal

SME – Small and Medium Enterprise

SNA – Social Network Analysis

SVN – Statistically validated network

WHO – World Health Organization

"A successful sustainable development agenda requires partnerships between governments, the private sector, and civil society. These inclusive partnerships built upon principles and values, a shared vision, and shared goals that place people and the planet at the center, are needed at the global, regional, national and local level."

The United Nations, 2015

SUMMARY

The present Thesis is structured as a collection of three essays linked by one core idea: contributing to research knowledge on inter-organizational network dynamics in the context of innovation and the promotion of sustainability.

In this Thesis, the author takes a systemic perspective and analyses the interactions between diverse groups of stakeholders, aiming to identify and interpret the logic underlying the formation of inter-organizational partnerships to promote innovation and sustainability. The dynamics of inter-organizational networks are influenced by several internal and external factors, such as strategic cooperation with stakeholders, structural changes (such as an R&I policy change), and exogenous shocks (such as COVID-19). The present work's value is developing research inputs and providing empirical ground and methodological support for innovation management framed by inter-organizational networks and mission-oriented public policy evolution. The present work is divided into three main chapters, and their abstracts are presented below. Finally, the Thesis ends with conclusions that summarize the outputs of the empirical works.

CHAPTER 1

An appropriate starting point to comprehend the inter-organizational networks for sustainability is to deepen the research knowledge on stakeholders' role in sustainable innovation and disentangle the antecedents, management, and potential sustainable innovation outcomes.

Using the Scopus database, we collected papers that represent works carried out in the field of sustainable innovation and stakeholders' involvement in organizational practices for these innovations. Based on the data process selection method, we carry out a literature review of the 59 selected papers. This literature review aims to describe the sustainable innovation phenomena and offer a comprehensive overview of the knowledge produced on the theme to practitioners and policymakers

So, this chapter presents an interpretative framework of extant literature and discuss the following questions related to the inter-organizational resource-management of sustainable innovation: (a) with whom to work; (b) when to work; (c) how to work together; (d) what challenges should organizations learn to face. Theoretical and practical business implications of the proposed framework are discussed.

CHAPTER 2

This chapter aims to analyze the inter-organizational R&I collaboration network dynamics at a mesoscopic level as a consequence of an external environment change. In particular, the study's

empirical setting is the policy change that occurred when passing from the EU 7th Framework program (FP7) to the HORIZON 2020 program (H2020). This change's effect on the patterns of evolution of the inter-organizational networks between financed actors is stressed. In such R&I context, inter-organizational networks play a particularly critical role as innovation catalysts.

Using a dataset of more than 22,228 unique projects in FP7 and 22,153 in H2020, we constructed two collaboration networks. We apply network analysis as a research instrument to identify and measure the fundamental structural properties of networks. At the mesoscopic level, the resulting communities for both networks have been analyzed and compared. Results show that under a policy change, the Horizon 2020 network becomes more assortative than the FP7 network. Preferential attachment (reach-club phenomenon) between leading R&I institutions is demonstrated within the system. The network is supported by the sporadic participation of (many) new actors. Also, the work outcomes demonstrate three different architectures of inter-organizational connections that can define network dynamics: (i) persistent stability or knowledge concentration, (ii) expansion of clusters or knowledge spread, and (iii) merging effect or knowledge aggregation. With these results, we contribute to organizational and network theories by detecting and identifying structural patterns for innovation links in such a complex system as the EU framework program stressing the policy's impact on them as a dynamics booster.

CHAPTER 3

The last chapter examines the impact of an exogenous shock on an inter-organizational R&I network. We concentrate on healthcare public-private partnerships and investigate the history dependencies[1] within them and how an exogenous shock such as COVID-19 fosters an evolution of the complex R&I network. In total, data of 2087 funded projects (FP7, HORIZON 2020, and Innovative Medicines Initiative) are involved in this study to understand the evolution process(es) these types of networks manifest under emergency conditions. The results demonstrate that the present crisis's urgency shifts the healthcare sector to test new working paths. Two opposite behaviors of the actors in these networks are observable: (i) highly innovative partnerships and (ii) strong lock-in effects. Additionally, we state that non-EU countries demonstrated strong cooperation and co-creation openness under this exogenous shock. Furthermore, the urgency conditions in COVID-19 push policymakers to demonstrate vital flexibility and adaptability of the EU R&I call to the societal needs.

Finally, it is possible to underline that network analysis is a powerful research tool for

[1] History dependency refers to prior ties existing between organizations.

developing new knowledge regarding R&I cooperation evolution under external factors. Accordingly, this work provides a theoretical and an empirical framework for managing the inter-organizational innovation network based on a dynamic complex system theory perspective (Simon 1996; Sawyer, 2005). In particular, it is possible to mention the newly developed insight capable of describing the network's dynamics through the meso and micro levels of analysis.

INTRODUCTION

Scholars argue that sustainability science and practice should be based on four core aspects: rigor, relevance, dynamic and normative aspects (Baumgartner, 2011). Thus, sustainability is promoted and framed by the EU R&I policy frameworks and instruments. Answering these calls for action and focusing on sustainable development, organizations show wiliness for innovative performance-based on collaborative practices. All this promotes interaction between diverse groups of stakeholders and a final co-creation output, such as sustainable innovation. The approach chosen to investigate the "Inter-organizational networks for innovations and sustainability" topic is based on the three main pillars: complex systems, innovations, and sustainability.

1. COMPLEX SYSTEMS AND MANAGEMENT

Research literature presents a wide range of studies focused on analyzing social, economic, and historic phenomena based on a systemic view. This approach is deeply rooted in various studies. Main contributions are made starting from the 1940s by L. von Bertalanfty (biologist), Lawrence J. Henderson (physiologist, chemist, and biologist), W.G. Scott (economist), D. Katz (psychologist), and R. L. Kahn (psychologist and social scientist), and other scholars. The online etymology dictionary describes a system (n) as an "organized whole, a whole compounded of parts" (from *greek* – systema)[2], which for management studies means an understanding of the links and interactions between the single elements that compose all the defined system. According to Kast and Rosenzweig (1972), a system can be considered in three ways: (i) closed, (ii) open, or (iii) open-closed. The last one represents complexity "to defend one or other in an absolute way." Due to specific interaction characteristics and composition, overall, systems can be divided into three groups (Amaral and Ottino, 2004):

(i) simple systems are constructed of a small number of components that function in compliance with well-defined rules;

(ii) complicated structures with a large number of components that are controlled by specific rules and play specific roles;

(iii) complex systems represent the self-organized system with many actors, nonlinearly (Kwapień and Drożdż, 2012) interacting with each other and with the surrounding environment. The common complex systems' characteristic and a difference from other mentioned systems is that these systems are based on performance without any external organizing principle being applied between actors. Openness and constant alteration of

[2] Meaning of a system (n), *source*: Online Etymology Dictionary: https://www.etymonline.com/word/system.

the internal structure and patterns of operation in the process of self-organization characterize such a system (Kwapień and Drożdż, 2012).

Incoherence with the management field, being composed by people, an organization, can be aligned with a complexity concept. According to Sawyer (2005), an organization is a complex arrangement of several individuals engaged in overlapping and interlocking patterns of relationship with one another. The systems theory defines an organization as an open system with a minimum of two interacting components, sub-groups, dynamic relationships, boundaries, ongoing change, and high complexity. It underpins the importance of interrelation and interdependence in management (Kast and Rosenzweig, 1972). In the management area, a complex structure can emerge between (i) interplaying agents (people, groups, or organizations) based on non-linear (Ladyman *et al.*, 2013) and invisible (Sawyer, 2005) interactions; and (ii) based on work on limited and local knowledge that is linked to chaos but supported by feedback system (Ladyman *et al.*, 2013), defined by a long list of the manifolds. Furthermore, at the same time, they can demonstrate high flexibility and adaptation to changing external conditions (Kwapień and Drożdż, 2012). If the multivariate data recorded to describe a system and its evolution are highly heterogeneous, display a high degree of spatial and temporal dependencies, and present emergent structures, then it can be called complex (Ladyman, Lambert, and Wiesner, 2013).

It is essential to underline that complex system is highly diverse due to:

(i) the unit level (as units have complex internal structures, are not identical, and are not linked by strictly defined roles);

(ii) and the nature of the interactions between units (strong non-linear character) (Amaral and Ottino, 2004; Kwapień and Drożdż, 2012).

The core of this research work is based on the research of organizational behavior in networks. As organizations (processes and practices inside) are viewed as complex systems, scholars agree that the complexity of the phenomena can be researched through:

(i) Complexity theories, which are used widely to understand the phenomenon of organizational changes (Perello-Marin *et al.*, 2013);

(ii) Network theory is one of the most important frameworks for the quantitative study of complex systems (Lyneis *et al.*, 2001; Amaral and Uzzi, 2007).

The last one is dominating in this work and is applied in all the three chapters of this Thesis, which are dedicated to (i) understanding of stakeholders' network for sustainable innovation; (ii) the analysis of the organizational dynamics in the EU R&I funded projects under a policy change; and (iii) under an exogenous shock.

2. SUSTAINABILITY IN A NUTSHELL

During the last three decades, sustainability has become an increasingly essential phenomenon for management scholars. Thousands of publications, books, and media stress that fast technological progress and a linear economic model[3] pushed the planet into a critical situation (Diesendorf, 1999; EU, 2019). It exceeds its limits, and new initiatives should be fostered to ensure future generations' well-being, targeting sustainability as a core issue of the century. In this work, sustainability acts as a merging element of all three parts of the Thesis.

As a starting point, it is worth highlighting this phenomenon's origins and explaining the nature of the "sustainability" construct to introduce and clarify its nature. The nowadays pathway for sustainability is addressed by the 2030 Agenda for Sustainable Development, adopted by the United Nations Member States in 2015, and its 17 Sustainable Development Goals (SDGs) (Fig. 1).

Fig. 1 Sustainable Development Goals (Source: UNESCO)

These goals require new ideas and unorthodox approaches to address their dynamic and changing combination of technological and social elements (Eisenhardt *et al.*, 2016). The SDGs have been rooted firmly in different organizational/policy strategies and research frameworks, making them a center of attention and addressing them with the "triple bottom line" of society, environment, and economy (Elkington *et al.*, 2007). Also, considering sustainability a new development and collaboration path which might solve various crises (Grin *et al.*, 2010).

Nerveless, sustainability is not a new concept in research. Search in "Scopus," carried out in February 2020, presents more than 215,884 document results for "sustainability" and

[3] *Linear economic model* refers to the traditional economic model, which is based on a take-make-consume-throw away pattern. It relies on large quantities of energy, cheap and easily accessible materials. Source: EU Parliament, Circular economy: definition, importance and benefits (https://bit.ly/3daLdzu)

276,882 document results – "sustainable development." The wide use of the concept requires a more systematic approach in the generalization of its originality. Millar *et al*. (2012) state that the initial idea of "sustainability" is linked to the environmental movement in the 1960s. After a decade, the first international conference that addresses business models and global ecology took place in Stockholm in 1972, putting organizational studies scholars' attention on sustainable development. The World Commission on Environment and Development (WCED) developed the concept of sustainable development and its guidelines in 1987, which was a step forward. The concept, which is used today, was presented as a development that meets the presents' needs without compromising future generations' ability to meet their own needs. A progressive transformation of the economy and society is necessary (Imperatives, 1987). Sustainability presented extreme attention to the bottom-up approach and invites to think globally but act locally (Colombo, 2001). So far, a context-specific understating remains an open concept with diverse interpretations and use (Purvis *et al.*, 2019). However, it is widely accepted that "sustainability" reflects on environmental issues and/or on "the ability to be maintained at a certain rate or level or the ability to continue or be continued for a long time" (Oxford English Dictionary[4]). Nerveless, scholars agree that sustainability and sustainable development, which often serves as a synonym for the concept, has three main pillars: social, economic, and environmental (Diesendorf, 1999; Purvis *et al.*, 2019). This requires changes in organizational structure and operations from the organization and management studies point of view. As an example, Brown (1991) stresses that sustainable social and economic development depends on effective local organizations, links between sectors, and national policy. In other words, sustainability depends on social and institutional factors and not on economic and technical problems, which receive most of the attention in the literature. Broadly speaking, sustainability is supported by values and shared visions, heterogeneity of actors, and external threats. According to Baumgartner (2011), sustainable development is about growing the potential for change in life equality for all people on the planet. It is about respecting and working inside an ecosystem's boundaries. Even more, Roscoe *et al.* (2015) stress that sustainability is a public concern. Still, it has a powerful considerable impact on corporate brand and profitability due to customers and stakeholders' increased interest in sustainable brands. To summarising, sustainable development involves different levels of stakeholder aggregation. Specifically, Hinterberger *et al*. (1997) indicate four levels: (i) the micro-level (including enterprises and consumers), (ii) the mesolevel (including institutions and their networks), (iii) the macro-level (including fiscal, monetary, and distribution conditions), and the (iv) meta-level

[4] Meaning of a sustainability (n), *source*: Oxford Learners Dictionaries: https://www.oxfordlearnersdictionaries.com/definition/english/sustainability .

(including social aims).

Notably, sustainability gets a stronger position in policy planning and implementation. Following this direction, management scholars have begun associating sustainability with grand challenges (George *et al.*, 2016). Being complex, uncertain, and evaluative, these challenges go beyond a single organization/community's boundaries, affecting organizational systems and networks. Grand challenges often "require collaboration across organizations to achieve significant breakthroughs" (Eisenhardt *et al.*, 2016, p. 1115). Different researchers state that solutions for these challenges are based on multiple organizations and individuals who act as change agents mobilizing different cooperation types toward an articulated problem (Ferraro *et al.*, 2015; George *et al.*, 2016), challenging helix innovation models. As so, innovations play a significant role in reaching sustainability goals.

From a policy-making perspective, innovation is understood as a crucial element for socio-economic growth, which should propose answers to many societal challenges (Scherngell and Barber, 2011). These societal challenges, influenced by rapid technological growth, overpopulation, climate change, and digitalization, demonstrate greater importance at the local level (for example, community management). They foster changes in the overall organizational environment, such as more robust networks for innovation between diverse formal and informal knowledge actors. The role of networks in innovation and sustainable development has received increasing attention in the latest literature. As a result**,** innovation and sustainability correlate strongly with each other and challenge managerial society to analyze and create new organizational practices on social issues more complexly and intensively. According to Aka (2019), managers have to deal with tensions between transforming a classical solution into a sustainable solution, interacting, negotiating with stakeholders, and proposing changes for the market over time in a physical and virtual environment. In the mentioned conditions, innovations are forced to change their format and become sustainable innovations. The main driving force of innovativeness is supported or shaped by societal values, believes, (perceived) future threats, exogenous shocks, and not primary profitability or domination in the market. Kirschten (2005) adds that sustainable innovations need to be integrated into existing systems and linked to existing structures.

In such conditions, social, economic, political, and technical problems become more complex and multidimensional. These external factors push organizations to be more reactive to these new challenges, stressing the need to recognize them, reflect and solve them quickly, and adapt to the market's new requirements and rules. Thus, the proposed Thesis focuses on the networks' research, as a complex system, for innovations and explicitly supports SGD17 – partnerships for sustainable goals.

3. INNOVATIONS FOR SUSTAINABILITY

Scholars have recognized sustainability as a "central" subject in the strategic management discussion (Lüdeke-Freund, 2010), almost as an oxymoron in the age of temporary competitive advantage (Dagnino, Picone, and Ferrigno, 2021). Introducing sustainability in the business world implies taking the stakeholders' perspective seriously (i.e., focusing beyond the market value). It contemplates the primary view of stakeholders who seek to meet their long-term expectations. "Concretely identifying to whom they are responsible, and how far that obligation extends" represent the hidden challenges for organizations (McGahan, 2020; O'Riordan and Fairbrass, 2014, p. 123). Furthermore, sustainability calls attention to the planetary system's well-being and healthiness (George *et al.,* 2016), positioning itself in research as a multi-level concept (Figge *et al.*, 2002).

Prior literature shows that the quest for sustainability frequently requires combining and recombining resources among multiple knowledge actors and developing strategies with a long-term perspective (Schmidthuber and Wiener, 2018; Ketata *et al.*, 2014). Also, as a consequence of this, we have assisted to increased requests for innovation partnerships in the business world (Janssen and Moors, 2013; Manning and Roessler, 2013; Reypens *et al.,* 2016), blending competition and collaboration practices. In this context, each organization may act as a change agent by activating new resource orchestration processes in solving an articulated problem (Ferraro *et al.,* 2015; George *et al.,* 2016). This reasoning line introduces de facto the helix innovation model (involving business, university, and government) and stresses the centrality of coordination among heterogeneous stakeholders in igniting sustainable innovation.

In the past decade, scholars have conceptualized an advancement of the Triple Helix innovation model, i.e., the Quadruple Helix model, by adding civil society into the list of knowledge actors (Carayannis *et al.*, 2012). This more advanced version of the Triple Helix leverages knowledge dispersed among stakeholders, fostering high degrees of democracy in knowledge exchange and innovation and power relations changes in this context (Jensen and Sandström, 2011). Recently, scholars also updated the Quadruple Helix Model by including ecological content in it. An additional new model is named the Quintuple Helix Model (Carayannis *et al.*, 2012). It highlights stakeholders' involvement in co-creation and responsibility in promoting and implementing sustainable innovation and invites scholars to provide new research inputs for the model.

Overall, prior studies acknowledged that the organizations' dialogue with stakeholders facilitates sustainable innovation (Ayuso *et al.,* 2006). With more emphasis, Breukers *et al.* (2014) argue that innovation can be successful only if supported (or at least accepted) by relevant stakeholders. Nonetheless, sustainable innovation literature is fragmented, and, as a consequence, it is challenging to link and map diverse norms and "glocal" actions. Additionally, it is unclear how to improve the existing governance and participation gap, allowing to leverage diverse expertise and flexible, decentralized structures (Bäckstrand, 2006). The first chapter of the thesis provides an overview of the academic literature regarding the typology of the stakeholders involved in organizational performance-oriented to sustainable innovations, presents examples of cooperation practices, and expresses the challenges of such cooperation.

4. THE PAST, PRESENT, AND FUTURE OF THE EU R&I NETWORKS IN BRIEF

Kastrinos and Weber (2020) stress that the Framework Programme 9 - Horizon Europe is directly linked to the Sustainable Development Goals. It requests a systemic change and a new governance approach. So, the new program promotes the perspective of transition management. According to the authors, this transition requires ongoing adaptation processes and learning from the glocal[5] to the global context, reflexive governance, deliberative politics for managing transitions, and the development of robust knowledge on sustainability. Thus, it provides a solid field for analyzing the dynamics between heterogeneous actors for innovations and sustainability.

Today, the program celebrates 37 years, and it is promoted as the most significant research and innovation (R&I) policy instrument globally, a vital element of EU research and innovation (EU, 2015). The start of the program is linked to the rising necessity of developing the European industry's international competitiveness. As so, in 1984, Europe launched the first framework program to promote scientific research and technological development.

4.1. HISTORY INSIGHTS

Framework Programme, which covered five years till the Framework Programme 6 (FP6) and a wider seven-year implementation period of the FP7, aims to coordinate the EU Member States' research policies and pools research funding for diverse areas. It concentrates on creating R&I excellence clusters, fostering public-private partnerships, and knowledge exchange between formal and informal knowledge actors[6]. Cooperation among them is based on a project idea (generally) within an international consortium, in other words, within an inter-organizational network. The project actors join efforts for a limited time period and a specific research purpose, manage organizational capacities and strategies for constant participation in this policy tool. The funding tool is recognized as a highly prestigious and competitive R&I ecosystem at the national, regional, and EU policy levels.

[5] According to the Oxford Dictionary, the term *glocal* means reflection of features or being related to factors that are local and contribute to global level.
[6] Formal knowledge actors represent a group having an explicit legal authority (policy makers, research organizations, business), informal knowledge actors – opposite (for example: citizens, media, community groups, NGOs).

The European Commission's technology program was created to address the "technology gap" between Europe and the USA and was based on a technology push (Reillon, 2017). In the beginning, the implementation of the framework programs was represented by specific excellence organizations. Over time, applying diverse policy instruments for openness and innovation stimulation, this program became an embraced issue of wide-range heterogeneous actors.

The roots of the European multilateral cooperation in research are grounded in post-war decades, with the establishment of two most significant economic and political communities linked to energy issues: ECSC (European Coal and Steel Community) in 1951 and Euratom (European Atomic Energy Community) in 1958, and other research cooperation initiatives between the EU countries, for instance, CERN (European Organization for Nuclear Research) in 1954, ESO (European Southern Observatory) in 1962, EMBO (European Molecular Biology Organization) in 1964, EMBL (European Molecular Biology Laboratory) and ESF (European Science Foundation) in 1974 (Reillon, 2017; Kastrinos and Weber, 2020). The intergovernmental framework, called European Cooperation in Science and Technology (COST, 1971), fostered exchanges on diverse research fields, opening a platform for cooperation between the EU and non-EU countries. In 1974, the European Community established a sub-committee of its medium-term economic policy committee to deal with science and technology, as well as a community policy for research and development (R&D), and internalized the funding function in the Commission (Arnold, 2012).

Also, in 1973, the EU research policy targeted the creation of a single EU science area, aiming at (i) efficient coordination of national policies to avoid replications, (ii) cooperation and competition between the EU knowledge entities, such as universities, research centers, and researchers, (iii) and carrying out R&I with a rationalization of efforts and greater efficiency. Finally, in 1981 the EC proposed a strategy for the framework program. It was presented as a research and development concentration mechanism for EU competitiveness, definition of shared priorities, and mapping of national policies and efforts. In 1982, the EC adopted guidelines for the first framework program (FP1), rooting this financial and competitiveness mechanism for future decades. The pathway of the program is summarized in Table 1.

All the FPs are implemented under regular revision, structured around specific and transversal R&I objectives, focusing on bottom-up proposals and supporting the functioning of a unified European Research Area (ERA) and a single market for people's movement goods/services and capital (Reillon, 2017). The Commission was given the duty of leading the coordination of state RTD plans and expanded the scope of basic research in the FPs with the Maastricht Treaty (1993). The program's dynamics, rules, and priorities are under continuous revision due to reflecting on economic, technological, and societal challenges and planning to overcome them. The functioning of the FPs is based on several assessments[7], such as (1) impact assessments, (2) interim evaluations, (3) ex-post assessment, (4) regular monitoring on implementation, (5) horizontal and thematic evaluation studies, and as a cross-cutting pillar - regular consultations with heterogeneous stakeholders and citizens (this started with the H2020). Based on the experts' findings and evidence, the processes' modification is proposed for the following program (or updates of the ongoing work program). Based on this, funding is planned for the specific R&I areas (Fig 2).

Table 1. The Framework programs evolution, timeline, budget, and main components[8]

Framework Programme (FP)	Life span	Budget, M Euros	Main components[8]
FP1	*Preparation started in 1981* 1984-1987	Around 3.750	Six thematic objectives (agriculture, industrial competitiveness, raw material, energy, development aid, and living conditions).
FP2	*Preparation started in 1985* 1987-1991	Around 5.400	Thematic objectives resemble the FP1, a particular focus on access and support to research infrastructure, research worker mobility, support for actors in the innovation process, including small and medium-sized enterprises (SMEs) and the involvement of non- Community European countries in the program.
FP3	*Preparation started in 1989* 1991-1994	Around 6.600	Five thematic areas and a transversal priority on human capital and mobility. The increasing importance of new technologies such as ICT, biotechnologies and new materials. FP3 introduced the idea of multidisciplinarity and the concept of addressing technological challenges.
FP4	*Preparation started in 1992* 1994-1998	Around 13.100	Seventeen specific programs Topics: ICT, industrial technologies, environment, life sciences, agriculture and fisheries, life sciences, nonnuclear energy and transport. The novelty was the introduction of targeted socio-economic research. The establishment of FP4 also required the adoption of rules on participation and dissemination.
FP5	*Preparation started in 1996* 1998-2002	Around 14.960	The Commission proposed three thematic programs under the first activity, shaped no longer as topics but as challenges: unlocking the resources of the living world and the ecosystem, creating a user-friendly information society, and promoting competitive and sustainable growth. The three other activities were also renamed as confirming European research's international role, innovation and participation of SMEs, and improving human potential.
FP6	*Preparation started in 2000* 2002-2006	Around 17.500	Greater focus on interactions between science, society, and citizens. The previous four-activity structure was replaced entirely by a new one with three programs.70 Under the first program, 'Focusing and integrating Community research', seven thematic topics were defined, covering the same areas as in the previous FP with space and a topic on citizens and governance in a knowledge-based society. Support for policy development for SMEs and international cooperation was also included in this program. The second program, 'Structuring the ERA', covered support for innovation, human resources, research infrastructure and the topic 'Science and society'.
FP7	*Preparation started in 2004* 2007-2013	Around 50.000	Four objectives:

[7] Source: EC. Impact assessment, evaluation and monitoring of EU research and innovation programmes: https://bit.ly/3dSnPpC .
[8] Developed based on: JEUPISTE -Historical timeline of the Framework Programme; Burgos (2020); Horizon Europe; and Reillon, 2017)

Framework Programme (FP)	Life span	Budget, M Euros	Main components[8]
			• Cooperation: support for transnational research projects in 10 thematic areas, with security as a new area and space as an area on its own; • ideas: supporting bottom-up research projects with individual grants via the establishment of the European Research Council (ERC); • people: strengthening human capital in research and support mobility; • capacities: supporting key aspects of European research and innovation capacities (infrastructures, regional clusters, SMEs, international cooperation).
FP8 or Horizon 2020	*Preparation started in 2011* 2014-2020	Around 80.000	Three pillars and two specific objectives corresponding to its main priorities: • Excellent Science • Industrial Leadership • Societal Challenges • Specific objective - Spreading excellence & widening participation • Specific objective 'Science with and for society
FP9 or Horizon Europe	*Preparation started in 2016* 2021-2027	Around 100.000	Three pillars: excellent science; global challenges and EU industrial competitiveness; and innovative Europe. Five mission areas: • Adaptation to climate change, including societal transformation; • Cancer; • Climate-neutral and smart cities; • Healthy oceans, seas, coastal and inland waters; • Soil health and food

This specific ecosystem's activation and funding potential for innovations has significantly spurred collaboration networks and competition between firms and other knowledge actors. Tomasello *et al.* (2014) state that being a part of such R&D network means "sharing of the reputational effects, technological risk sharing and resource pooling" and having access to the so-called "circles of influence (groups of firms sharing the same membership attribute)" (Tomasello *et al*., 2014).

With the establishment of the FPs, the European community follows the general objective of the R&I system based on strengthening the scientific and technological bases of European industry and contributing to the quality of citizens' life (Arnold *et al.*, 2005; Bruce *et al.*, 2004) and development of better EU sectoral policies and their funding (Laredo, 1998). Based on the policy agenda, the dedicated funding to sectoral policies changes within FPs (Fig. 2). The program is functioning as a strategic tool for implementing specific scientific and societal goals, which are research outcomes subject to the: i) assessment, ii) monitoring, and iii) evaluation by specialized executive agencies established by the European Commission. Indeed, these three processes together represent "a mandatory exercise foreseen in the Decisions of the Council of Ministers concerning the Framework Programmes" (Arnold *et al.*, 2005, p.1).

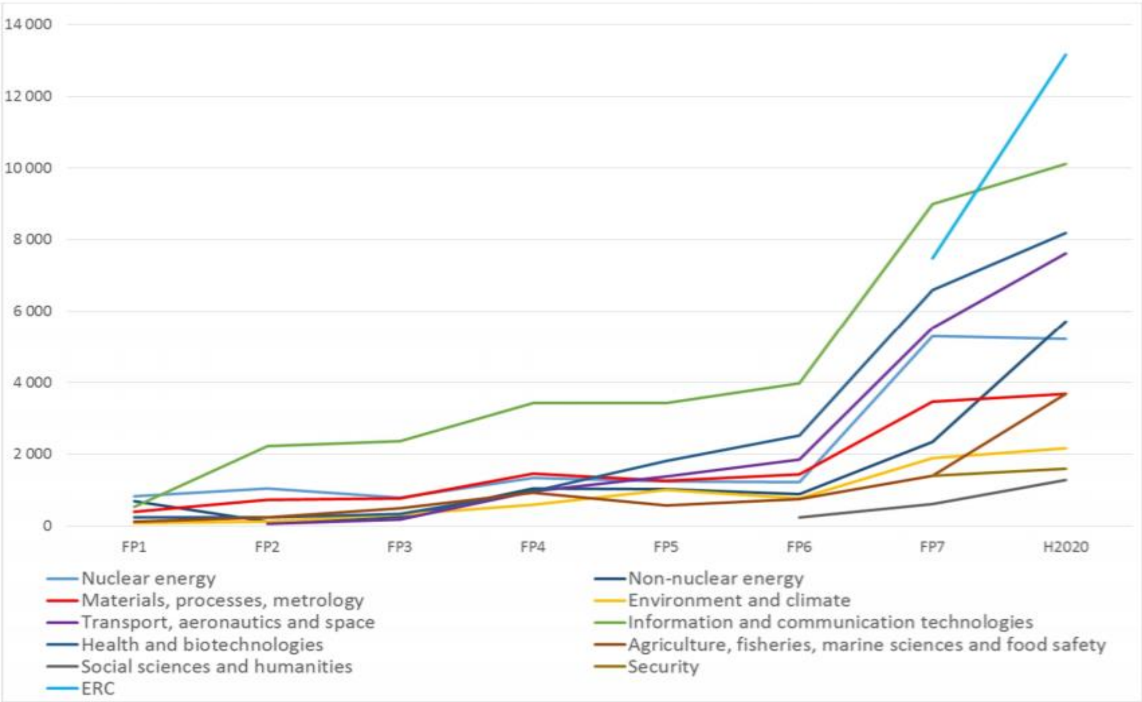

Fig. 2 Evolution of the support provided by the framework program for the various thematic activities (in a million ECU/€)[9]

The program's future belongs to Horizon Europe (2021-2027), which will be presented publicly in June 2021 during the EU Research and Innovation Days[10]. According to the EC Press corner[11], the new FP will strengthen excellence and support top researchers and innovators to foster systemic changes for a green, healthy, and resilient Europe. Novelties are several. Within all the sub-frameworks, the program will foster excellence. It will fund outstanding academics and innovators to help bring about the structural reforms that are required to "ensure a green, healthy, digital, and resilient Europe." For example, among the changes to mention, "regions, voluntarily, can transfer part of their regional funds to Horizon Europe to be used in research and innovation activities in their region." Other changes cover modification of the application forms – minimization of the total number of the proposal's pages, the blind evaluation process for two-stage proposals, and a more reflective evaluation process of the applicant and the project content. A simplified project evaluation process within the newly established European Innovation Council is also introduced. It provides faster access to SMEs and start-ups, aiming to boost local innovation capacities. All these changes aim to stimulate innovation potential further, powerfully compete with worldwide R&I leaders (the USA and China), and boost research potential to foster gender equality[12].

[9] Source: Reillon (2017), p. 27
[10] Source: European Research and Innovation Days, https://research-innovation-days.ec.europa.eu/
[11] Source: Commission welcomes political agreement on Horizon Europe, the next EU research and innovation programme, https://ec.europa.eu/commission/presscorner/detail/en/IP_20_2345
[12] Source: Launch ceremony of the European Innovation Council, https://www.youtube.com/watch?v=UeB-wPksDxk

4.2. FPS' FUNDING MECHANISMS

Currently, the framework program is implemented by the European Commission through the Directorate-General for Research and Innovation & Directorate-General for Communications Networks, Content and Technology, and Executive Agencies, such as the Research Executive Agency (REA), the Executive Agency for SMEs (EASME), and the ERC Executive Agency (ERCEA). Implementing the FPs is a direct responsibility of the Directorate-General Research and Innovation. This Commission department is responsible "for EU policy on research, science, and innovation, intending to help create growth and jobs and tackle our biggest societal challenges." It implements three main policy goals for EU research and innovation: open innovation, open science, and open to the world[13] through the overall coordination of evaluation, planning and system design for R&I.

Like the Horizon 2020 program, Horizon Europe is based on pillars (Fig. 3) through Work Programmes, which set up funding opportunities for R&I activities. Pillars within FPs are changing based on policy directions. However, the second pillar always represents inter-organizational collaborative projects, the analysis of which is at the core of the studies presented in chapter 2 and chapter 3 of the Thesis.

Participation in these collaborative projects and funding schemes are available for five types of knowledge actors: REC - research organizations; HES - higher education establishments; PRC - private for-profit companies; PUB - public bodies; and OTH - other types of entities. Before participation in a specific pillar and work program, a potential participant should pass an identification and registration process on EU Participant Portal. After a successful application, each one receives a unique 9 - digit Participant Identification Code (PIC). This number supports identification, individual visibility, and monitoring of actions of each R&I knowledge actor. Nowadays, these actors can represent[14] : (i) the Member States of the European Union; (ii) the associated countries (for example, Iceland, Norway, Albania, Bosnia and Herzegovina, Macedonia, Montenegro, Serbia, Turkey, Israel, Moldova, Switzerland, Faroe Islands, Ukraine, Tunisia, Georgia, and Armenia); and (iii) the countries with joint agreements on co-funding mechanisms, for example, Canada, China, India, Russia, The USA, Mexico, and Japan. Although the latter makes the program open for international cooperation, the concentration is primarily on the EU R&I potential. Participants can apply for funding based on the rules provided in the Work Programmes. They are divided into Calls, which provide funding for diverse Topics and represent societal challenges (Fig. 4).

[13] Source: Goals of research and innovation policyhttps://ec.europa.eu/info/research-and-innovation/strategy/goals-research-and-innovation-policy_en

[14] Source: https://www.apre.it/en/international-cooperation/horizon-2020-is-open-to-the-world/#:~:text=There%20are%20sixteen%20countries%20associated,%2C%20Tunisia%2C%20Georgia%2C%20Armenia

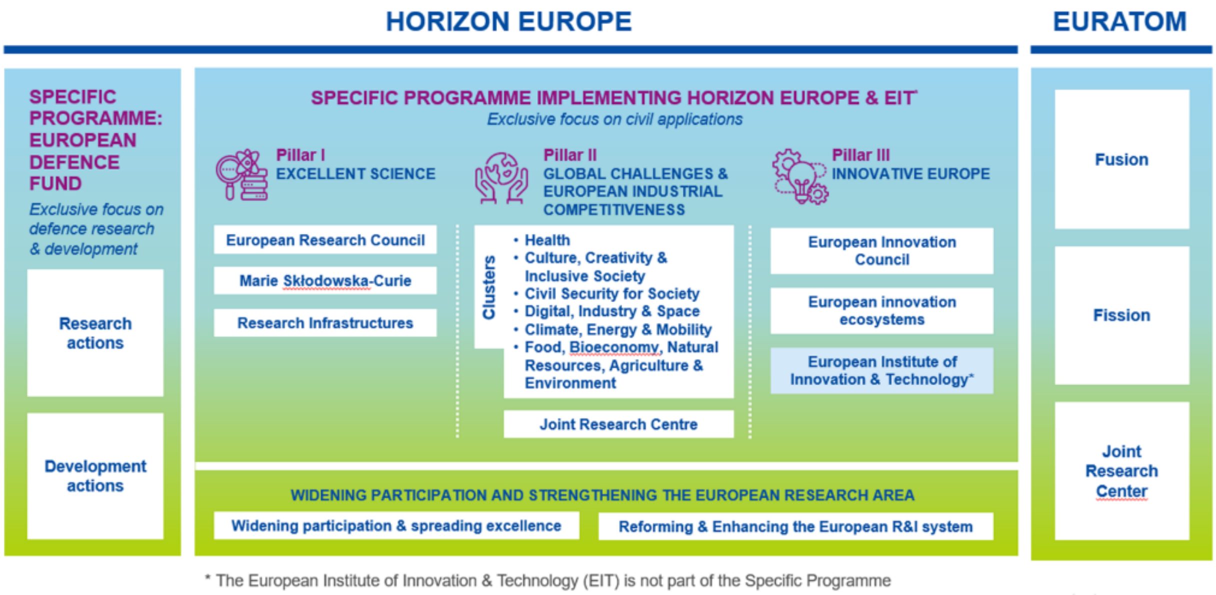

Fig. 3 Horizon Europe program (Source: EC, https://tinyurl.com/2t2xf8fe)

Usually, a detailed Call for action with the Topics are published three months before the project's presentation deadline. However, the draft version is known earlier. Answering the specific challenges presented in a given Topic and complying with all the eligibility and admissibility conditions, potential participants present their project proposals to the Commission via the Participant Portal. Then, an external group of experts organizes the evaluation of the proposal.

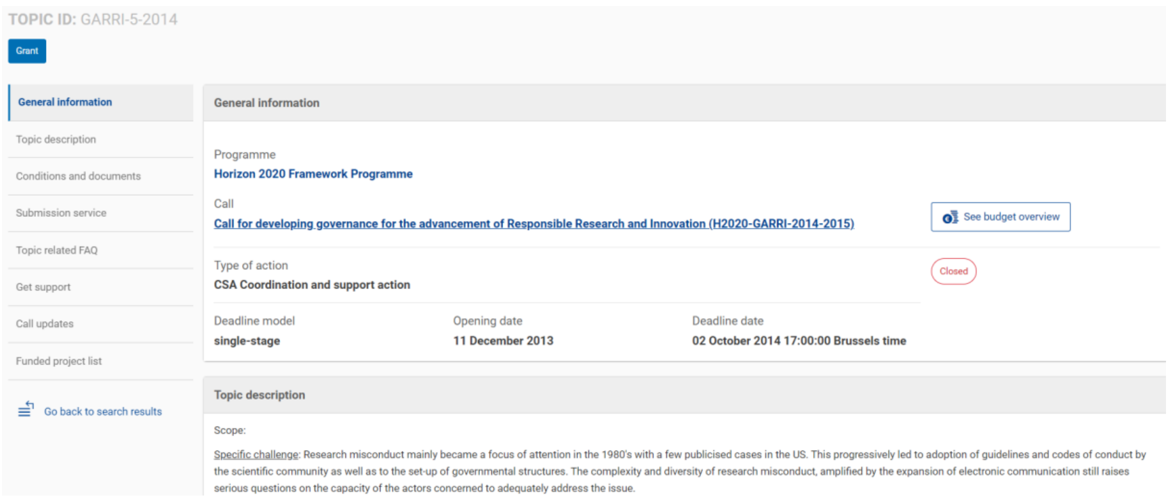

Fig. 4 Example of the H2020 Call and Topic description on the EC Funding and Tender Portal

There are two types of proposals: one-stage and two-stage proposals. One-stage proposals mean that applicants should provide a full project description. An evaluation of such a proposal takes about five months. Instead, two-stage proposals require: an early presentation of the project idea in brief, and three months are dedicated to evaluating this project idea. If the idea receives a positive evaluation, it passes to the second stage, which requires a full project description. Such preparation takes about three months period. After this, a complete evaluation will be provided in five months. The evaluation of a proposal takes five to eight months, depending on the type of Call (i.e., one-stage or two-stage application). After the evaluation, the consortia receive the project evaluation. The evaluation form provides a detailed assessment of the project idea based on several criteria[15]. Below we present the evaluation criteria of a Horizon 2020 collaborative proposal:

1 – Excellence: the following aspects are considered. "Clarity and pertinence of the objectives; Soundness of the concept and credibility of the proposed methodology; Extent that proposed work is beyond state of the art, and demonstrates innovation potential (e.g., ground-breaking objectives, novel concepts and approaches, new products, services or business and organizational models); Appropriate consideration of interdisciplinary approaches and, where relevant, use of stakeholder knowledge and gender dimension in research and innovation content."

2 – Impact: "the extent to which the outputs of the project would contribute to each of the expected impacts mentioned in the work program under the relevant topic; Any substantial impacts not mentioned in the work program that would enhance innovation capacity, create new market opportunities, strengthen competitiveness and growth of companies, address issues related to climate change or the environment, or bring other significant benefits for society; Quality of the proposed measures to – exploit and disseminate the project results (including management of IPR), and to manage research data where relevant; and communicate the project activities to different target audiences."

3 – Quality and efficiency of the implementation: "Quality and effectiveness of the work plan, including the extent to which the resources assigned to work packages are in line with their objectives and deliverables; Appropriateness of the management structures and procedures, including risk and innovation management; Complementarity of the participants and extent to which the consortium as a whole brings together the necessary expertise; Appropriateness of the allocation of tasks, ensuring that all participants have a valid role and adequate resources in the project to fulfill that role."

Other: Scope of the proposal, Operational Capacity, Exceptional funding of third-country participants/international organizations; Exceptional financing for third-country participants/international organizations; Use of human embryonic stem cells.

Each of the (1-3) sections is evaluated by scores (in the range 0-5, 5 is max). The

[15] Source: EUROAXECC, https://cdn3.euraxess.org/sites/default/files/news/day201_proposal_preparation_and_submission_dalibor.pdf

Commission will consider a consortium potentially eligible for funding if the proposal reaches a minimum threshold of 10. The maximum evaluation is 15. The proposals with the highest evaluation receive the funding, which is limited by the budget allocated for each specific Call presented within a Work Programme.

If the project is funded, a Grant Agreement will be prepared in three months, and the consortium will start the implementation phase. To finalize, if we calculate all the time dedicated to the project development, evaluation, and Grant Agreement preparation, the project's implementation can start almost one year after the Call is published. In our opinion, the dedicated time does not correlate with the realization of the innovative ideas, as after one year, it can lose its innovativeness for the dynamic market. Moreover, within the implementation phase, the project is framed by a robust bureaucratic apparat. It concentrates on the administrative process strongly rather than evaluating the objectives and their impact on the EU market. Thus, limiting the R&I system for self-organization mechanisms.

Framed by numerous rules and processes, managed by diverse institutions, and implemented by heterogeneous actors, this program represents a complex system based on inter-organizational links. Thus, this system invites scholars to reflect on the dynamics and processes underlying inter-organizational networks to stimulate the research inputs' development to understand and manage better such a heterogeneous system.

To sum up, Chapter 1 supports scholars in developing a shared understanding of sustainability links within the innovation systems and the main elements of stakeholders' involvement in collaborative practices for sustainability with organizations. This chapter also provides a framework for sustainable innovation, elements of which are carefully considered in the following chapters. Indeed, Chapter 2 and Chapter 3 of this Thesis concentrate on two aggregation levels within inter-organizational networks for R&I, the mesoscopic and microscopic level, respectively, and provide insights into the policy impact on the network's dynamics (Ch 2) and reaction to exogenous shocks (Ch 3).

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CHAPTER 1. STAKEHOLDER INVOLVEMENT IN SUSTAINABLE INNOVATION: TOWARDS AN INTEGRATED CONCEPTUAL FRAMEWORK

Keywords: Sustainability, Stakeholders, Sustainable innovation, Stakeholder involvement

1.1 INTRODUCTION

Organizations have become progressively more sensitive to these social and environmental issues than in the past, as "sustainability is becoming a driving force of economies and societies" (EC, 2019, p. 3). Consequently, organizations have increasingly focused on formulating, developing, and managing a sustainability strategy, learning that this implies facing different complex challenges (Hall and Vredenburg, 2003). Arguably, the ongoing process of globalization is amplifying the attention paid to stakeholders' expectations. "Globalization changes the power relations" among organizations and "brings with it new dimensions of responsibility" (Jensen and Sandström, 2011, p. 474). This responsibility will be satisfied with the appropriate organizational strategies that leverage innovation capabilities (Pandza and Ellwood, 2013) and may support the Quintuple Helix Model. In the mentioned model, the socio-ecological transition of society and economy, the role of stakeholders, understanding of local realities are seen as drivers for knowledge generation and innovation (Carayannis *et al.,* 2012), consequently, also a driver for sustainability. According to the authors, this model represents "a win-win situation between ecology, knowledge, and innovation, creating synergies between economy, society, and democracy" (Carayannis *et al.*, 2012, p. 2). Applying the stakeholder theory in this model may support the development of the knowledge base for studies of sustainability management (Hörisch *et al.,* 2014) and sustainable innovations.

This chapter summarizes the existing knowledge on main cooperation objectives with stakeholders and their involvement and develops *a framework of sustainable innovation practices*. To achieve our goal, we structure research into four main steps. First, we briefly present the concept of sustainable innovation. Second, we illustrate the methodology applied to address our research question. Third, we provide descriptive statistics underlying the main directions and tendencies of research on this issue. Forth, we systematize and describe the main findings of our research. Finally, we summarize the critical implications of our study.

1.2 SUSTAINABLE INNOVATION: A CLOSER LOOK

In 2007, Savitz and Weber proposed to study sustainability as an issue of "shared value" between financial stakeholders and the publics' interests (or, so-called, non-financial stakeholders). After a decade, sustainable development appears to be a crucial point in many organizations' innovation processes (Altenburger, 2018), challenging an innovation concept.

The initial conceptualization of sustainable innovation is rooted in Kanter's (1999) article "From spare change to real change: The social sector as a beta site for business innovation." In this paper, the author calls attention to the importance of cooperation practices between businesses and the social sector for innovations, sustainability, and replicability of new outcomes aiming to reach common welfare. Stemming from Kanter's pioneering study (1999), the number of conceptual and empirical contributions on sustainability has been increasing (El-Kassar and Singh, 2019), and arguably they stress that sustainability depends on innovation (Kusi-Sarpong *et al.*, 2018). From a complementary perspective, innovation literature demonstrates the importance of sustainability on organizational outcomes. Nonetheless, a complete agreement on a definition and sphere of sustainable innovation applicability is still missing (Candi *et al.*, 2018; Cillo *et al.*, 2019).

Extant literature provides a wide range of conceptual connections between sustainability and innovation that can be found in research literature, for example: eco-innovation, mainly focused on integration of environmental requirements into all stages of innovation management (Aagaard, 2019), sustainability innovation (Horng *et al.*, 2018; Juntunen *et al.*, 2018; Dyck and Silvestre, 2018), sustainable development innovation (Hall and Vredenburg, 2003), sustainable innovation (Kusi-Sarpong *et al.*, 2018; Delmas and Pekovic, 2016), sustainability – driven innovation (Kiron *et al.*, 2013), environmental innovation (Wagner, 2007; Yu *et al.*, 2017; Delmas and Pekovic, 2016; Watson *et al.*, 2017), (open) eco – innovation (González-Moreno *et al.*, 2019; Sarkar and Pansera, 2017), green innovation (Hall *et al.*, 2017; El-Kassar and Singh, 2019; Kusi – Sarpong *et al.*, 2018; Flammer *et al.*, 2019; Fliaster and Kolloch, 2017), responsible innovation (Rodríguez *et al.*, 2013; Pandza and Ellwood, 2013), partly even – social innovation (Candi *et al.*, 2018; Phillips *et al.*, 2017); explorative and exploitative innovation (Nielsen *et al.*, 2019). Summarizing, Alkemade and Suurs (2012) found a red-line among such concepts and state that these innovations require significant investments with high risks and a long-term horizon. All the different related constructs that emerge in sustainable innovation research confirm that "*sustainable innovation is a very recent and fragmented topic*" (Cillo *et al.*, 2019, p. 1014).

Drawing on the multiple views of sustainable innovation, we infer that the definition proposed by Juntunen *et al.* (2018, p. 331) is the most appropriate for our research because of its inclusiveness: "*[sustainable] innovations are aimed at improving the environmental, social, and economic performance of the innovated solution.*"

1.3 METHOD

Our literature review aims to describe the sustainable innovation phenomena and offer a comprehensive overview of the knowledge produced on the theme to practitioners and policymakers (Tranfield *et al.*, 2003; Cillo *et al.*, 2019). According to Fink (2005), the quality of a literature review is an outcome of two factors: the completeness of studies reviewed and the reproducibility of the analysis procedures. For this reason, we offer a detailed view of the data collection process. In line with Tranfield *et al.* (2003), we describe the process of paper selection through the following steps:

(i) *step zero*, a selection of the database of articles. We collected papers available on Scopus, Elsevier's abstract, and citation database. This database provides access to the most authoritative journals relevant to our field of study;

(ii) *step one*, we search in title, abstract, and keywords the following strings: ("sustainable innovat*") or ("innovat*" and "triple bottom line") or ("innovat*" and "hybrid organi*") or ("innovat*" and "hybrid corporation") or ("innovat*" and "quadruple bottom line") or ("innovat*" and "quintuple bottom line") or ("innovat*" and "stakeholder*"). Since Scopus includes papers published from the year 1966 and our research focus (i.e., "innovations related to sustainability") is a relatively new topic in management (Cillo *et al.*, 2019), we do not apply a right truncation; a left truncation includes the year 2019. The overall outcome reached more than 1400 information sources;

(iii) *step two*, we use the following criteria to focus our research: (1) Subject Area: Business, Management, and Accounting; (2) Language: English; (3) Document type: Article, (4) Source type: Journal, (5) Publication stage: Final;

(iv) *step three,* we restrict our analysis to articles published in journals with at least three stars of the Academic Journal Guide[16] 2018 (AJG 2018). The overall outcome was 360 papers;

(v) *step four*, we read all the abstracts to select only the papers that explicitly contribute to understanding stakeholders' role in sustainable innovation processes. This stage requires careful analysis and double-checking due to the phenomena complexity in the information sources' final list. At the end of the mentioned process, we selected 59 papers. All the articles in the sample by journal and publication year are presented in Table 1.1. At this point, we perform the analysis of our database by identifying for each paper: publishing year, authors, journal, conceptual perspective(s), the concept of innovation, list of stakeholders, research method, sample, and findings.

[16] This guide is based on peer review, editorial and expert reasoning following the evaluation of publications, and is supported by statistical data relating to citation.

A significant variation between the initial database and the final result is visible from the above-described data collection procedure. This difference appears because the bulk of the articles explore sustainability's conceptualization but do not focus on our research topic, i.e., the stakeholders' involvement in innovation processes. Fig. 1.1 shows the data-selection process.

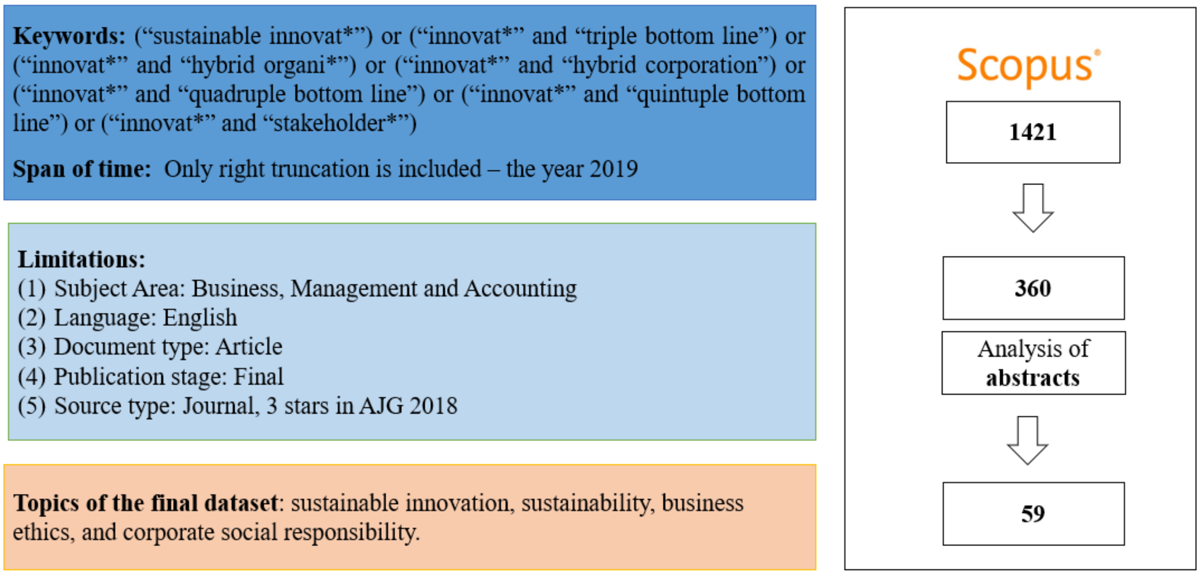

Fig. 1.1 Data process selection

The section presented below underlines the descriptive characteristics of the analyzed research material. It is essential to depict the pioneers of research on the phenomenon under scrutiny and address its principal aspects: leading countries, sectors involved, publishing directions, and others.

Table 1.1 Articles in the sample by journal and publication year

Journals/Periods	2004-2005	2006-2007	2008-2009	2010-2011	2012-2013	2014-2015	2016-2017	2018-2019
California Management Review	-	-	-	-	-	-	O'Rourke and Strand (2017)	-
Industrial Marketing Management	-	-	-	-	-	-	Reypens *et al.* (2016)	-
International Journal of Contemporary Hospitality Management	-	-	-	-	-	Wong and Gao (2014)	-	Horng *et al.* (2018); Raub and Martin-Rios (2019)
International Journal of Production Economics	-	-	-	-	Klassen and Vereecke (2012)	-	-	Tuni and Rentizelas (2019)
International Journal of Production Research	-	Evans *et al.* (2007)	-	-	-	-	-	Vos *et al.* (2018); Kusi-Sarpong *et al.* (2018)
Journal of Business Ethics	-	-	Mena et al. (2009)	-	Manning and Roessler (2013)	Garriga (2014); O'Riordan and Fairbrass (2014); Dibrell *et al.* (2014); Rühli *et al.* (2015)	Delmas and Pekovic (2016); Longoni and Cagliano (2016); Phillips et al. (2017)	Albertini (2018); Candi *et al.* (2018)
Journal of Business Research	-	-	-	-	-	Lai *et al.* (2015)	Herrera (2016)	-
Journal of Product Innovation Management	-	-	-	-	-	-	Watson et al. (2017)	Juntunen *et al.* (2018)

Journals/Periods	2004-2005	2006-2007	2008-2009	2010-2011	2012-2013	2014-2015	2016-2017	2018-2019
Journal of Sustainable Tourism	-	-	-	-	Albrecht (2013)	-	Gronau (2016)	Knowles (2019)
Long Range Planning	-	-	-	-	-	-	Olsen *et al.* (2017)	-
Organization Studies	-	-	-	-	-	-	-	Dyck and Silvestre (2018)
R and D Management	-	-	-	-	-	Ketata *et al.* (2014)	Fliaster and Kolloch (2017)	-
Research Policy	-	Wagner (2007)	-	Romijn and Caniëls (2011)	Pandza and Ellwood (2013); Rodríguez *et al.* (2013)	Colvin *et al.* (2014)	Manning and Reinecke (2016)	Andries *et al.* (2019)
Small Business Economics	-	-	-	-	-	-	Leyden (2016); Hall *et al.* (2017)	-
Strategic Management Journal	-	-	-	-	-	-	-	Flammer *et al.* (2019)
Supply Chain Management	-	-	-	-	-	Graham et al. (2015)	Furlan Matos *et al. (2017)* Alves *et al.* (2017)	-
Technological Forecasting and Social Change	-	-	-	Quist *et al.* (2011)	Alkemade and Suurs (2012); Janssen and Moors (2013)	Breukers *et al.* (2014); Smith *et al.* (2014)	Yu *et al.* (2017); Sarkar and Pansera (2017)	El-Kassar and Singh (2019); Elzen and Bos (2019); González-Moreno *et al.* (2019); Moradi and Vagnoni (2018); Nielsen *et al.* (2019); Pancholi *et al.* (2019)
Technovation	Brennan and Dooley (2005)	-	-	-	Sarpong and MacLean (2012)	-	-	-

1.4 EXPLORATORY ANALYSIS OF LITERATURE

From a total number of 59 selected articles published between 2005 and 2019, only four papers were published before 2011, corresponding to 7% of the total. In 2014 a high interest in the theme emerged, and eight articles were published. The number of publications on the topic reached a peak in 2018 when ten selected articles were published, corresponding to 17% of the total selected articles. Fig. 1.2 shows the publishing year of the selected papers.

A temporal analysis of our database shows that sustainability and sustainable innovation have started to be more prevalent in the research literature since the beginning of the last decade. We interpret the growing interest in sustainability as linked to two specific issues. First, worldwide debates on planetary limits started in the middle of the 1990s with the acceleration of the Environmental Action Programs in Europe. Second, several public instruments for sustainability integration emerged; for example, the acceptance of the Sustainable Development Goals (SGDs) by the United Nations in 2015 and the integration of a cross-cutting concept of Responsible Research and Innovation (RRI) in Research and Development (R&D).

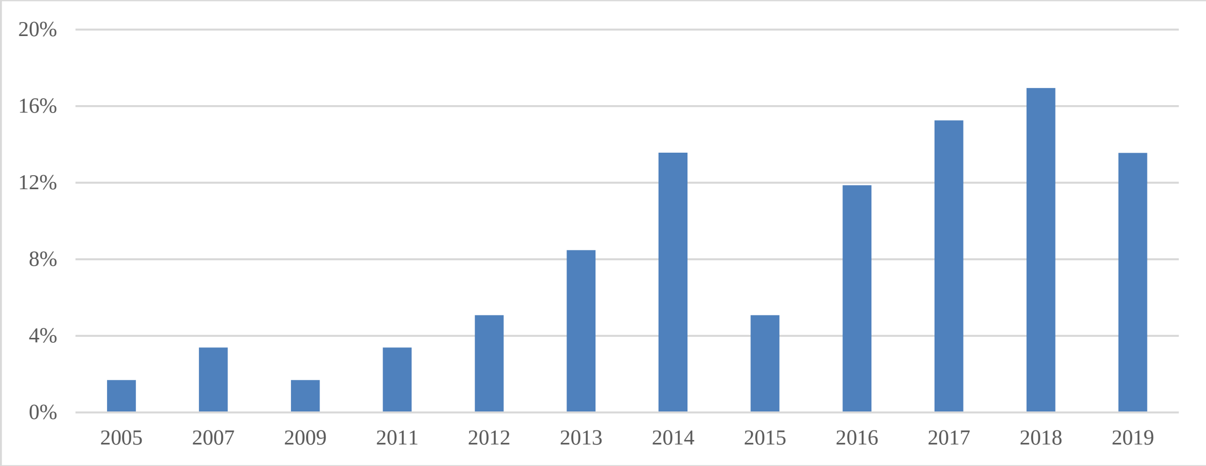

Fig. 1.2 Publishing year of the selected publications

The highest number of publications represent journals that publish articles from a wide variety of methodological and disciplinary perspectives concerning: (i) ethical issues related to business, (ii) social, environmental, and technological factors, and (iii) challenges (such as policy, management, organizational or other) posed by technology, R&D and science. These are the *Technological Forecasting and Social Change* and the *Journal of Business Ethics*, which published 13 and 11 articles. Both journals combined correspond to 23% of the total number of selected papers. The third-highest number of publications have been published by *Research Policy*, which counts seven articles, equivalent to approximately 7% of our dataset (Fig. 1.3).

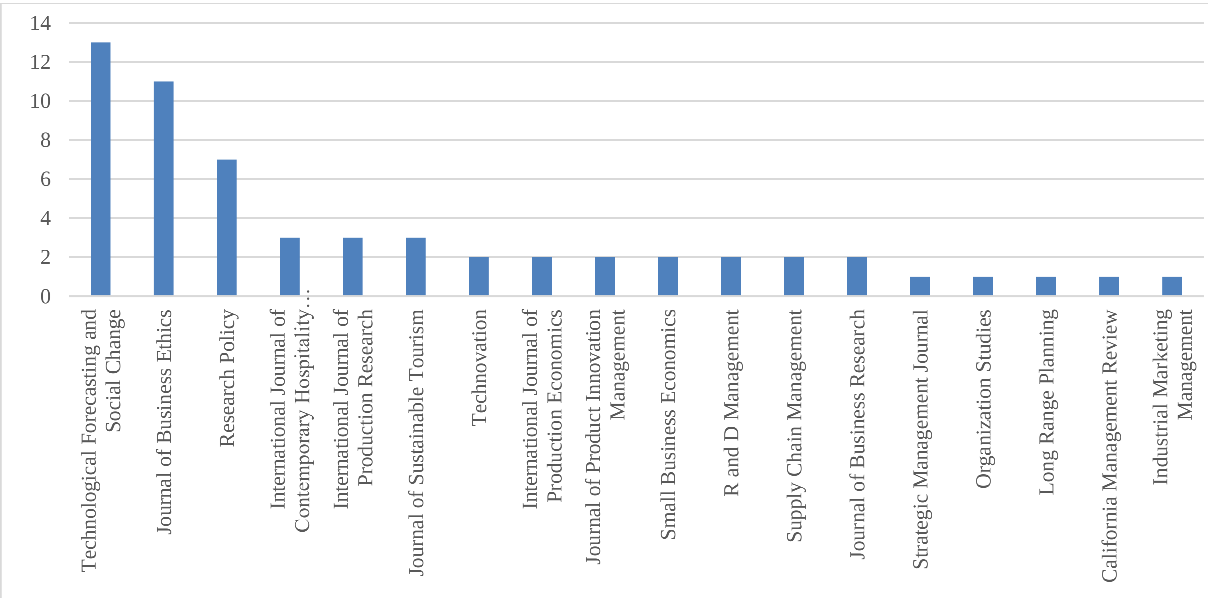

Fig. 1.3 Journals of the selected publications

A total number of 13 industries represents the empirical contexts of sustainability and sustainable innovation studies in published articles (Fig. 1.4). Simultaneously, a different group identifies papers that refer to more than one industry (mixed). The industries most represented are the Tourism and Manufacturing industries, covering about 12% of each of the selected publications. Other sectors, namely the Energy and Resources industry and the Food industry, cover approximately 8% of publications, while Health industries cover around 7 % of the dataset. 15% of the articles correspond to mixed industries, and 14% refer to a non-specified industry, as shown in Fig. 1.4.

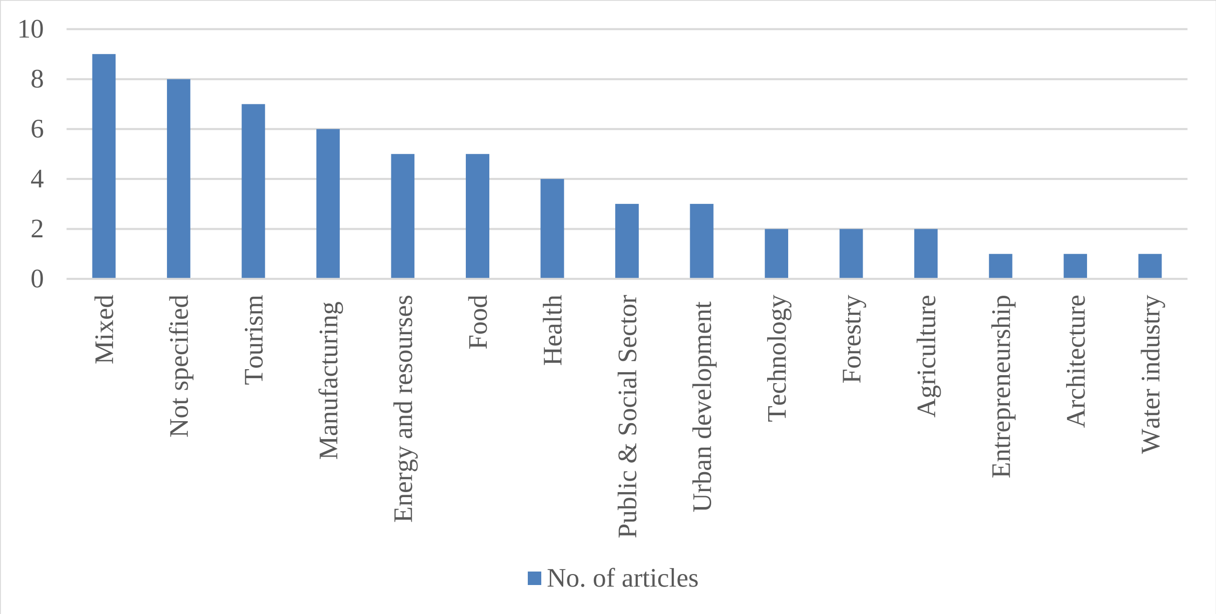

Fig. 1.4 Industries represented by the publications

The selected articles represent diverse case studies linked to six groups of actors (Fig. 1.5): a single country (EU or non-EU), multiple countries (EU or non-EU), and mixed EU and Non-EU countries.

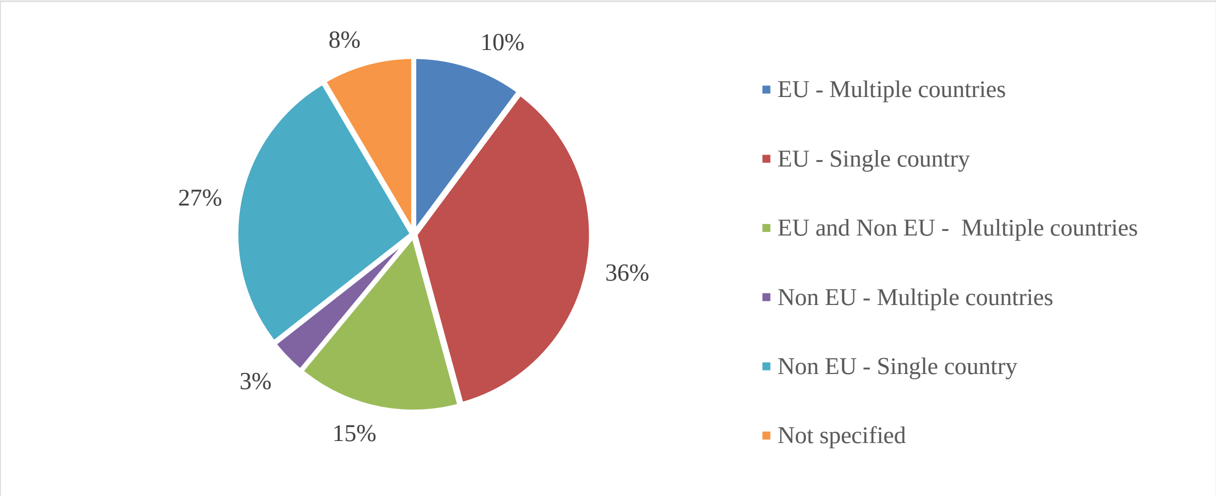

Fig. 1.5 Case studies of the countries represented by the selected publications

Groups related to EU countries cover 46% of the total number of publications. Indeed, 34% of the papers are related to the EU – single country, while 10% of papers are related to the EU – Multiple countries. The highest number of publications involves the UK (11 papers), the Netherlands (8 papers), the USA (7 papers), Germany (7 papers), and Italy (5 papers). This list represents the leading countries in developing responses and political frameworks for the promotion and the support of sustainability. For 8% of the papers in our dataset, equivalent to

5 papers, the country(s) considered is not specified.

The bulk of literature considers sustainability direct link to open innovation (Olsen *et al.,* 2017; González-Moreno *et al.,* 2019), business ethics (Candi *et al.,* 2018), corporate social responsibility (Klassen and Vereecke, 2012; Wong and Gao, 2014; Garriga, 2014; O'Riordan and Fairbrass, 2014; Lai *et al.,* 2015; Flammer *et al.,* 2019). Additionally, sustainability is explored from multiple theoretical angles, for example, stakeholder theory (Rühli *et al.,* 2015; Reypens *et al.,* 2016; Fliaster and Kolloch, 2017; Knowles *et al.* 2019), organizational learning, and ambidexterity theory (Vos *et al.,* 2018), contingency theory, dynamic capability view, and resource-based view (Dibrell *et al.,* 2014; Yu *et al.,* 2017).

1.5 A PROPOSED CONCEPTUAL FRAMEWORK

Our conceptual framework is composed of three main blocks derived from the literature review and framed by the stakeholders' theory. The mentioned theory invites scholars to reflects on dynamics between an organization and the stakeholders, aiming to understand the conditions under which a dialog between the two mentioned knowledge actors is established. (Freeman, 1984). The dialog is based on a resource-based view, business ethics, and organizational management. Thus, from right to left, the first block represents the *antecedents of sustainable innovation*. They include the pressure of external factors, as sustainable innovation is promoted and supported by a wide range of policy instruments for Sustainable Development Goals (SDG) that change organizational behavior due to a mix of pressure that emerges due to policy, technology, society, and the environment. Indeed, according to Juntunen *et al.* (2018), the challenge of sustainable innovation is related to the frame of ecological or social problems as a source of inspiration for innovation. Additionally, we recognize a set of organizational drivers of sustainable innovation.

The second block of our conceptual framework is the *management of sustainable innovation*. We consider both the *organizational* resource-management of sustainable innovation and the *inter-organizational* resource-management of sustainable innovation. However, as it is possible to see in Fig. 1.6, our framework offers substantial attention to the inter-organizational *resource*-management of sustainable innovation. Different aspects of sustainable innovation's broad theme bring a diverse-stakeholder focus and require a certain level of critical collaboration and in/out process within the organization, stimulating and supporting such activity. Summarizing the involvement practices, Juntunen *et al.* (2018) argue that some common work elements are necessary to obtain effective outcomes. These elements correspond to a balanced number of stakeholder groups integrated into cooperation activities and the quality of organizational engagement in creating and maintaining a productive relationship (Herrera, 2016). Stakeholder integration requires timing to acquire and use external knowledge in product and service development (Graham *et al.*, 2015). For this reason, a dominant part of the interpretative framework focuses on inter-organizational resource-based management. Specifically, we address the following questions: (a) With whom to work, (b) When to work, (c) How to work together, (d) What challenges should organizations learn to face.

Finally, we disentangle the primary *outcomes of sustainable innovation.* We divide the outcomes of sustainable innovation based on two factors: dimensions and organizational level. We argue that sustainable development makes sense if all three *dimensions* are simultaneously pursued (Raub and Martin-Rios, 2019; Nielsen et al., 2019; Manning and Reinecke, 2016): (i) economic sustainability (Fliaster and Kolloch, 2017); (ii) environmental sustainability (Vachon and Mao 2008); and (iii) social sustainability (Klassen and Vereecke 2012; Candi *et al.*, 2018). Regarding the *organizational level,* we distinguish between process sustainable innovation and product sustainable innovation (Vos *et al.*, 2018) and organizational sustainable innovation. Moreover, we stress that sustainable innovation is an outcome of social innovation and technological innovation.

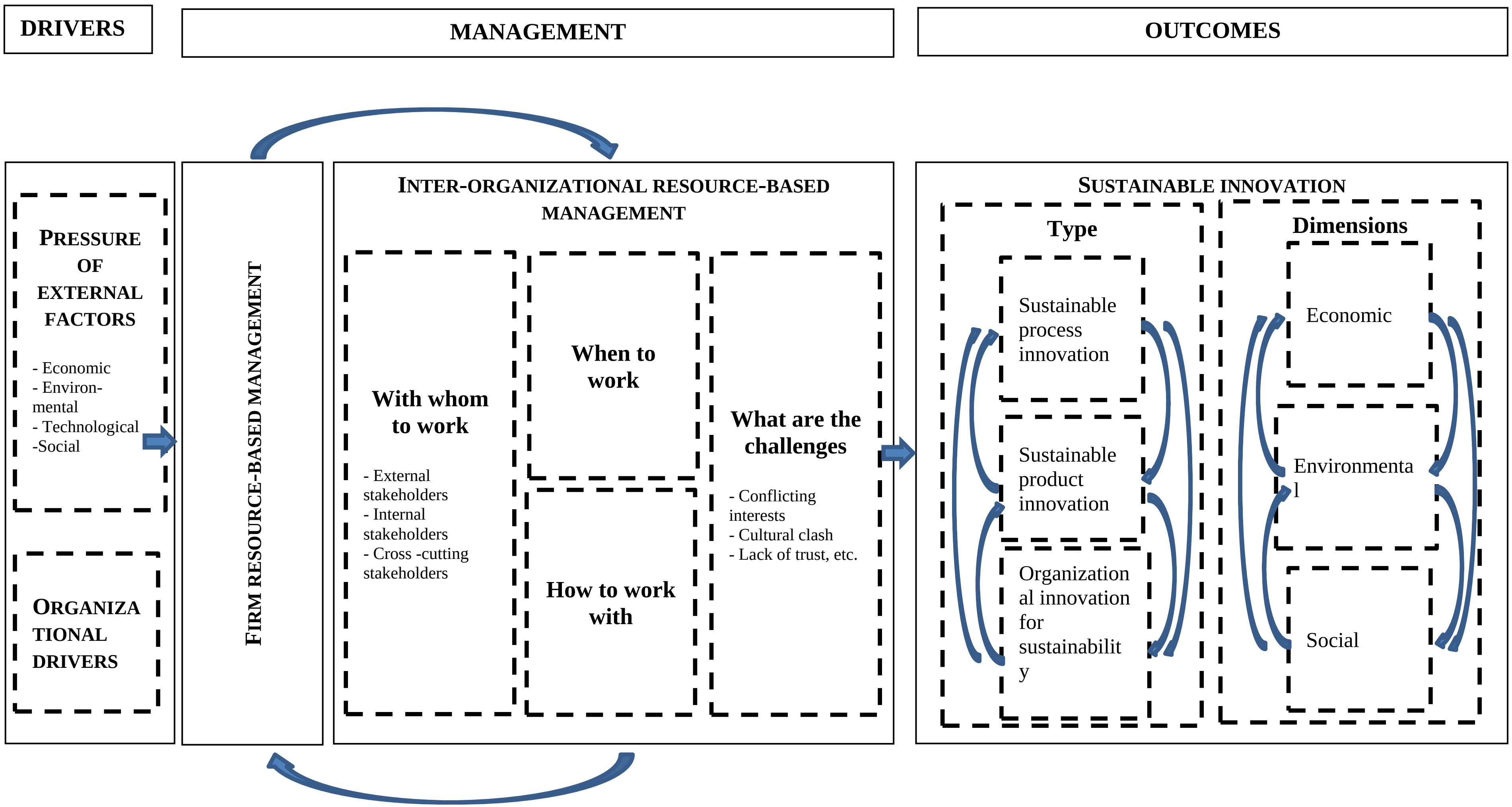

Fig. 1.6 Framework on stakeholders' involvement in sustainable innovation practices

1.6 DRIVERS OF SUSTAINABLE INNOVATION

1.6.1 The pressure of external factors

External events, such as adopting sustainability policy frameworks, strongly impact internal organizational structure changes and processes, adapting them to the organizational context (Alves *et al.*, 2017). The analyzed literature has focused mainly on identifying the external drivers of sustainable innovation. External drivers include demand-driven threats (which can drive strategic priorities) and pressure-driven threats (Ketata *et al.*, 2014; Candi *et al.*, 2018). Table 1.2 presents the most common examples considered in existing literature based on four types of external factors.

Table 1.2 Groups and examples of external drivers presented in the reviewed literature

Type	Drivers	Examples in the literature
Economic	Policy, regulation, fiscal incentives	Candi *et al.*, 2018; Dyck and Silvestre, 2018; González-Moreno *et al.*, 2019; Moradi and Vagnoni, 2018.
	Legislation	O'Rourke and Strand, 2017.
	Competition on the market	Candi *et al.*, 2018; Vos *et al.*, 2018.
	Financial availability for innovation and R&D investment	Kusi-Sarpong *et al.*, 2018.
Environmental	Environmental challenges	Albertini, 2018; Horng *et al.*, 2018; Olsen *et al.*, 2017; Knowles, 2019; Moradi and Vagnoni, 2018; Tuni and Rentizelas, 2019.
	Inter end intra-organization collaboration/competition	Candi *et al.*, 2018; Kusi-Sarpong *et al.*, 2018; Lai *et al.*, 2015.
	Designing products to reduce their impact on the environment	Kusi-Sarpong *et al.*, 2018; Flammer *et al.*, 2019.
Technological	Technology push/turbulence	Lai et al., 2015; Candi *et al.*, 2018; González-Moreno *et al.*, 2019.
	Policy for technological change	Hall *et al.*, 2017.
Social	Reducing inequality and social exclusion and other local challenges	Andries *et al.*, 2019; Phillips, Alexander, and Lee, 2017.
	Behavioral change and compliance with customer /pressure/requirements/market demand	Albertini, 2018; Candi *et al.*, 2018; Tuni and Rentizelas, 2019; El-Kassar and Singh 2019; Furlan Matos Alves *et al.*, 2017; González-Moreno *et al.*, 2019; Gronau, 2016.
	Implementation of socio-eco policies in organizations for sustainability	Kusi-Sarpong *et al.*, 2018; Elzen and Bos, 2019.
	Enhancing the social image of the organization	Kusi-Sarpong *et al.*, 2018; Longoni and Cagliano, 2016.
	Corporate social initiatives	Kusi-Sarpong *et al.*, 2018; Longoni and Cagliano, 2016.
	Cultural, social values and norms	Longoni and Cagliano, 2016; Kusi-Sarpong *et al.*, 2018; Pancholi *et al.* 2019.

1.6.2 Organizational drivers

The first and probably the essential internal driver of sustainable innovations is related to the quest for competitive advantage (Dibrell *et al.*, 2014; Yu *et al.*, 2017) and reduction in product cost (Kusi-Sarpong *et al.*, 2018).

Furthermore, sustainable innovation is a process of change that entails both employee and organizational involvement. Indeed, sustainable innovation's internal drivers are linked to multiple stakeholders' actions, such as shareholders, managers, and employees (Watson *et al.*, 2017; Longoni and Cagliano, 2016; Horng *et al.*, 2018; Herrera, 2016). From this perspective, we agree with Flammer *et al.* (2019), who affirm that social topics help direct managers' attention toward stakeholders' interests. These interests may be less critical in the short term but become crucial in the long term. Definitively, a long organizational planning horizon for sustainable innovativeness and acceptance of uncertainty (Longoni and Cagliano, 2016) appear to be the roots of an organization's long-term economic performance (Vos *et al.*, 2018).

Moreover, employees who usually care about negative externalities play an essential role in promoting sustainability. So, diverse forms of social interactions support innovativeness in sustainability (Delmas and Pekovic, 2016; Watson *et al.*, 2017). Sustainability epitomizes a part of the formal and regular employee review process in more advanced settings, such as support provided by leaders and senior management, compensation plans, written employee manuals (El-Kassar and Singh, 2019; Watson *et al.*, 2017), and training practices, such as knowledge management/environmental programs (Garriga, 2014).

1.7 ORGANIZATIONAL RESOURCE-BASED MANAGEMENT

During the last decades, several policy interventions (e.g., SDGs, EU Sustainable Development Strategy, national tax policy, and green budgeting for circular economy) fostered significant changes in organizational innovation processes, supporting the development and implementation of sustainability strategies. Nonetheless, to exploit sustainable innovation, organizations need *resources* (physical and financial resources), *capabilities* (technology sensing/response, relationship building, and shared vision), and *tactics* (eco-friendly policies, practices, and procedures). Furthermore, learning from the past and increasingly adopting innovative initiatives and radical innovations is crucial for introducing sustainable innovations (Longoni and Cagliano, 2016). From the organizational side, sustainability requires opening the organizational boundaries, strategizing supplier operations transparency, managing a risk (Kusi-Sarpong *et al.*, 2018).

Additionally, since organizations have shown limited capacity to develop sustainable innovations productively, it has been argued (Schmidthuber and Wiener, 2018) that a transition pathway and the adoption of multi-actor processes may be beneficial (Quist *et al.,* 2011; Janssen and Moors, 2013; Colvin *et al.,* 2014). Sustainable innovation calls for interactions between heterogeneous stakeholders, understanding cultural differences, and working in a specific policy framework (Moradi and Vagnoni, 2018). Consequently, organizations should also acquire operational capabilities that provide instruments to collaborate effectively with stakeholders, such as open innovation tools[17]. Olsen *et al.* (2017) underline that sustainable innovation requires collaborative efforts. In turn, such efforts foster the existing exchange of expertise and collaborators that can provide efficient communication and coordination capacities. For organizations to co-create value and learn from involvement practices, such capacities should cover: "complex first-order dynamic capabilities to manage the engagement (engagement management capabilities); and second-order dynamic capabilities" (Watson *et al.*, 2017, p. 265).

1.8 INTER-ORGANIZATIONAL RESOURCE-BASED MANAGEMENT

1.8.1 Stakeholders involvement: with whom to work

Stakeholders represent groups or individuals able to influence or affect organizational objectives (Freeman, 1984) and contribute to the organizations' value creation process (Garriga, 2014). As so, drawing on the Quintuple Helix Model, we argue that working with multiple stakeholders and their management helps establish a set of primary incentives to induce and follow sustainability policies (Dyck and Silvestre, 2018). According to Raub and Martin-Rios (2019, p. 9), a goal of the stakeholder management is to ensure that organizations strategically take into consideration the requirements and interests, even values, of individuals and/or groups that may be "affected by or have an effect on any project, initiative, intervention, or effort the organization engages in." In some cases, stakeholders' management guarantees the organizational capacity to reduce inequality and access to vulnerable groups and respond to basic needs (Andries *et al.*, 2019). In this debate, we underscore the importance of considering two contexts. First, the *local context* impacts a selection of relevant stakeholders (Raub and Martin-Rios, 2019). Thus, there is a definite need for contemplating local needs by carefully addressing their socio-cultural issues (Dyck and Silvestre, 2018). The local context can be supported efficiently by entrepreneurs, as they (i) contribute to generating social capital that fosters innovation (Leyden, 2016), and (ii) lead a transition towards more sustainable production and consumption models through the

[17] Open innovation provides a 'floor' for action in the sustainability context. If organizations use external knowledge, the return on investment in intellectual capital and knowledge will be much higher (González-Moreno *et al.,* 2019).

delivery of glocal knowledge and sustainable socio-technical solutions to many societal challenges, such as those regarding food and healthcare, for example (Janssen and Moors, 2013; Sarkar and Pansera, 2017). Local contexts imply that a “one size fits all” solution will not be effective, and opening a dialogue with local stakeholders is a critical issue (Evans *et al.*, 2007). Second, the *industry* and public context support understanding of which actors should be included in the innovation process (Jensen and Sandström, 2011).

In addition to the distinction between local and industry context, our literature review supports developing a more detailed knowledge regarding different stakeholders. Based on Freeman’s (1984) stakeholder approach, organizational stakeholders can be divided into external and internal groups based on their interests: institutions/organizations and personal with professional and/or social interests. Such division is essential because, although being a part of the institution and following institutional directions, individuals can have opposite visions, values, and interests. Potentially there may be hidden conflicts of interest involving the relationship between institutions and stakeholders, as insiders may have different professional and social roles. As a unique stakeholder, we also consider media that strongly influences opinion-making, decision formation, poses pressure on both of the previously mentioned groups, and provides visibility to the topic of sustainability. Therefore, it fills in Freeman’s stakeholder taxonomy as a third, cross-cutting, stakeholder group: media (Table 1.3). Media support opinion formation and provide visibility to the topic of sustainability. Of course, mass media simultaneously affects and is affected by society. Ideally, media should be an independent player, providing information, creating awareness, monitoring, and evaluating policy changes. However, it may play an instrumental role, forging opinions for both groups of stakeholders, contributing or hindering to guarantee accountability and democracy. Consequently, it fills Freeman’s stakeholder taxonomy as a separate cross-cutting group of sustainability actors.

All the aforementioned groups of stakeholders may be categorized based on long- and short-term interests regarding sustainability. They represent public and private interests and partly values. Finally, each considered group represents a specific strength due to its nature, depending on the manifested pressure and power to pose on the topic of interest. Among all the mentioned actors, the policy level actors take a leading role in promoting sustainability due to their initial power to develop based new policy agendas and financial instruments for balancing forces and interests of public and private sectors, for example, based on public-private partnerships.

Definitively, an answer to the question *“who”* depends on organization size and industrial industry in which it operates; moreover, the degree of organizational openness for collaboration with stakeholders depends on already established processes and practices and relationships with the stakeholder network (González-Moreno *et al.*, 2019). Dyck and Silvestre (2018) stress that sustainable innovations are more likely to be adopted and diffused in settings where meta-standardization of local experimentation mechanisms are in place, such as those embedded in local innovation systems. Finally, González-Moreno *et al.* (2019) posit that collaboration between several organizations and stakeholders should be high for sustainable innovations. Such intensity will help generate trust, reduce the initial cognitive distance between partners, and contribute to coping with the required knowledge base's complexity for interaction. Moreover, it supports the development of shared visions to frame priorities and reduce uncertainties (Schmidthuber and Wiener, 2018). Juntunen *et al. (*2018) add that stakeholders can play a catalyst role or be an obstacle. According to the authors, being a catalyst means creating awareness about SDGs at the local level and supporting the chosen SDG's specific actions based on available expertise, human and financial resources. Stakeholders will be an obstacle when they create legal barriers, weaken the trustworthiness of initiatives through communication, or push to implement the most economically challenging sustainability interventions. O'Rourke and Strand (2017) add that lack of decision-making may exist in companies with high democracy and transparency, as internal stakeholders are afraid to make decisions, becoming a sustainability barrier.

Table 1.3 Taxonomy of stakeholders

Sustainability: interests and power forces	**Private interests**	**Public interests**	**Long term interests**	**Short term Interests**	**Pressure & Power forces**
An external group of stakeholders					
Government (Alkemade and Suurs, 2012; Manning and Roessler, 2013; Watson *et al*., 2017; Yu *et al.*, 2017); **Policymakers** (Moradi and Vagnoni, 2018; Schmidthuber and Wiener, 2018; Gronau, 2016); **Regional administration** (Gronau, 2016); applications (Hall *et al.*, 2017; Raub and Martin-Rios, 2019); **Intergovernmental organizations** (Fliaster and Kolloch, 2017);		X	X		Strong
Customers/consumers/users (Watson *et al.*, 2017; Flammer *et al.*, 2019; Olsen *et al.*, 2017; Yu *et al.*, 2017; Ketata *et al.*, 2014; Moradi and Vagnoni, 2018); **Investors** (Klassen and Vereecke, 2012; Garriga, 2014; Fliaster and Kolloch, 2017); **Suppliers** (Watson *et al.*, 2017; Olsen *et al.*, 2017; Yu *et al.*, 2017; Ketata *et al.*, 2014);	X			X	Medium
SMEs (Breukers *et al.*, 2014);	X			X	Medium
Research institutions (Reypens *et al.*, 2016; Schmidthuber and Wiener, 2018); **Universities** (Schmidthuber and Wiener, 2018); **Scientific communities** (Moradi and Vagnoni, 2018); **Think tanks** (Reypens *et al.*, 2016; Schmidthuber and Wiener, 2018; Albrecht, 2013);		X	X		Strong
Citizens (Schmidthuber and Wiener, 2018);					

Sustainability: interests and power forces	Private interests	Public interests	Long term interests	Short term Interests	Pressure & Power forces
Civil society (Manning and Roessler, 2013; Watson *et al.*, 2017; Olsen *et al.*, 2017);		X	X		Medium
NGOs (Garriga, 2014; Manning and Roessler, 2013; Smith *et al*., 2014; Watson *et al.*, 2017; Dyck and Silvestre, 2018; Olsen *et al.*, 2017; O'Rourke and Strand, 2017; Ketata *et al.*, 2014; Alkemade and Suurs, 2012);		X	X		Medium
Residents' associations/local groups (Fliaster and Kolloch, 2017; Graham *et al.*, 2015);		X	X		Medium
Social movements (Moradi and Vagnoni, 2018);		X	X		Medium
Advocacy groups (Flammer *et al.*, 2019; Fliaster and Kolloch, 2017);		X	X		Strong
Other societal stakeholders are linked to the vulnerable profile of the challenge, for example, inequality and social exclusion (Andries *et al*., 2019).		X	X		Medium
An internal group of stakeholders					
Owners (Juntunen *et al.*, 2018) and S**hareholders** (Raub and Martin- Rios, 2019; O'Rourke and Strand, 2017);	X		X		Medium
Entrepreneurs (Janssen and Moors, 2013; Sarkar and Pansera, 2017; Leyden, 2016; Breukers *et al.*, 2014; Alkemade and Suurs, 2012);	X		X		Medium
Managers (Raub and Martin-Rios, 2019);	X		X		Medium
Employees/ workers (Brennan and Dooley, 2005; Ketata *et al*., 2014; Juntunen *et al*., 2018; Longoni and Cagliano, 2016; Raub and Martin-Rios, 2019; Horng *et al.*, 2018; O'Rourke and Strand, 2017; Herrera, 2016; O'Riordan and Fairbrass, 2014; Wong and Gao, 2014).	X	X	X		Law
Cross-cutting stakeholder					
(Social) media (Juntunen *et al.*, 2018; Raub and Martin-Rios, 2019; Herrera, 2016).	X	X	X		Medium

1.8.2 Stakeholder involvement: when to work together

As regards the "*when,"* we acknowledge that sustainability could be studied as a transition pathway (Moradi and Vagnoni, 2018) due to the complex multi-level processes it implies (Manning and Reinecke, 2016; Gehman et al., 2020). Social learning processes (Smith *et al.*, 2014), social initiatives in education, promotion of smartness in communities, and corporate citizenship strengthen understanding of shared values and co-creation between an organization and stakeholders (Herrera, 2016). Based on a regime change study, Elzen and Bos (2019) provide a list of involvement activities with stakeholders based on a transition path. These activities include (a) development and inspiring communication designs with a heterogeneous set of relevant stakeholders; (b) development of sustaining network(s) and creation of (private/ public) coalitions that actively strive for follow-ups in practice; (c) design of space for niche experiments, including partnerships and funding; (d) stimulation uptake of "partial innovations;" i.e., specific elements from the new designs; (e) creations of an exemplary new production and process system. In some cases, social media and collaboration platforms play a significant role in stakeholder empowerment, develop healthy relationships, and improve understanding of market trends and opportunities (Herrera, 2016). However, physical place-making is essential to support co-creation and knowledge for sustainable growth (Pancholi *et al*., 2019). Meantime, Fliaster and Kolloch (2017) underline that collaboration with environmental non-governmental organizations (NGOs) is vital for corporate environmental entrepreneurship. For example, in a specific case of NGO and their facilitation of sustainable innovation processes in low-income countries, Dyck and Silvestre (2018) propose a TCOS framework (the acronym stands for Technological, Commercial, Organizational and Societal uncertainties):

a) *technological feasibility*. It refers to the uncertainty associated with the existence (or not) and the possibility of developing the required technology. As so innovations must be demonstrably technologically feasible, based on existing capabilities;

b) *commercial viability* refers to the uncertainty associated with the existence (or not) and the possibility of creating a market for innovation. Innovations must be commercially viable;

c) *organizational appropriability* refers to the uncertainty associated with the potential to appropriate the innovation benefits and how easily it could be imitated. The development and exploitation of the innovations should be congruent with its strategy to address this uncertainty;

d) *societal acceptability* refers to the uncertainty associated with the potentially detrimental societal side effects (including environmental, social, cultural, or political patterns). These potential side effects must be recognized and addressed.

Collaboration strategies and processes are visible in involving with stakeholders, which creates a background for improving risk and reputation management. Such collaboration strategies contribute to the solutions of challenges and reach objectives that are unattainable for single organizations. Furthermore, they provide access to such resources as knowledge, new people, financial incomes, technology, a better understanding of the operating environment, and fostering product and process improvements. Overall, the context and learning processes play a crucial role in all the processes, supported by organizational policies, the facilitation of infrastructure and skills, and the co-responsibility with collaboration (Colvin *et al.*, 2014).

1.8.3 Stakeholders involvement: how to work with

Regarding "*how"*, Juntunen *et al. (*2018) state that two stakeholder integration initiatoves lead to a high sustainability performance of innovation. The first integration strategy is related to *openness* and entails including the early integration of secondary stakeholders (Herrera, 2016).

Arguably, an open innovation strategy strongly supports sustainability integration in the innovation process (Ketata *et al.*, 2014; Juntunen *et al.*, 2018; Gonzalez-Moreno *et al.*, 2019). Organizations have a period of trial and error. They learn how to obtain information from an outside source and how many contacts are necessary to enhance their efficiency and capacity to innovate (Gonzalez-Moreno *et al.*, 2019). This period requires considerable effort in building up a sufficient understanding of the norms, organizational rules, and everyday patterns of the different channels (Gonzalez-Moreno *et al., 2019*). In these conditions, participatory processes become essential factors for the identity of piloting territories, which is used for external communication and recognition of the pilots (Nielsen *et al.*, 2019). Such cooperation is not feasible without local empowerment, which requires changes in the mindset and in the local culture, effort from all interested parties and the stability of business operations' societal context (Mena *et al.*, 2009).

According to Juntunen et al. (2018), the second integration strategy is related to *limited openness* in terms of selective integration with only a few stakeholders (selective) or integration of primary stakeholders after the fine-tuning phase. Such a particular strategy is based on a combination of a narrow stakeholder network and deep organizational engagement. The fine-tuning approach relies on stakeholders' deep organizational engagement from the innovating organizations' value chain for both primary and secondary stakeholders. Only one or a few innovation phases are opened for input from these primary stakeholders, typically after the fuzzy front end when the concept has been defined and engineering work has started. Following this approach, organizations prefer to refine the solutions' eventual acceptability with stakeholders' help instead of introducing a new product or service fundamentals.

1.8.4 Stakeholders involvement: what are the challenges

To comprehend the stakeholders' role in sustainable innovation, it is also crucial to understand the significant challenges such cooperation faces. This recent literature research has outlined several barriers (Hörisch *et al.*, 2014). First, the lack of appropriate cooperation partners is an essential innovation barrier (González-Moreno *et al.*, 2019). We call specific attention to the lack of trust and cultural differences (Tuni and Rentizelas, 2019). Moreover, stakeholder interests are so heterogeneous that they may conflict with each other. This creates obstacles for collaborative practices and limiting the envisioning of a potential solution (Flammer *et al.*, 2019; Fliaster and Kolloch, 2017; Romijn and Caniëls, 2011). Even more, the involvement context is framed by diverse patterns, such as socio-economic and political processes, physical and spatial factors, the relationship between actors and conflicting agendas, and power inequalities between them (Romijn and Caniëls, 2011; Nielsen *et al.*, 2019).

1.9 THE INTERPLAY BETWEEN INTER-ORGANIZATIONAL AND ORGANIZATIONAL RESOURCE-BASED MANAGEMENT

It is worth considering that an organization can cover different and diverse phases and sustainability elements through interaction with stakeholders. Indeed, networking is a critical organizational innovation capability – where an organization can play different roles, such as those of the broker, the transformer, the loner, and the augmenter (Phillips *et al.*, 2017). According to Watson *et al.* (2017), stakeholder involvement for innovation represents a dynamic organizational capability, demonstrating an ability to involve and reconfigure both internal and external competencies to respond to a changing environment. Specifically, organizations need the value framing capabilities that help minimize these differences between value systems and use them to reorganize problems, distribute capabilities, and co-create innovative outcomes (Watson *et al.*, 2017). Additionally, organizations need to build structures (including digital ones) and processes that help support “learn to learn” procedures from their stakeholders (Delmas and Pekovic, 2016). Schmidthuber and Wiener (2018) add one more important component to this list: a specific time and space dedicated to reflecting on the differences in value frames between themselves and stakeholders.

Importantly, innovating with and for stakeholders in the social issue context represents an ongoing social interaction process (Rühli *et al.*, 2015) that requires top management commitment, large-scale data, and human resource practices. Such focus is needed to achieve a competitive advantage and improve an organization’s social and environmental performance (El-Kassar and Singh, 2019). While top management plays an essential role in allocating resources, creating a sustainability philosophy (Herrera, 2016), build capabilities, and help the organization gain a competitive advantage (El-Kassar and Singh, 2019). As such, the intensive social interactions between employees improve sustainable innovation performance (Delmas and Pekovic, 2016).

Having stakeholders onboard means increasing innovative capabilities for sustainable innovation based on specific organizational capabilities, such as engagement management capabilities, implementing co-creation actions, and learning from stakeholder engagement activities (Watson *et al.*, 2017). Therefore, stimulating stakeholder dialogue and its transformation into knowledge is relevant to integrate sustainability issues into the innovation process. After all, stakeholder involvement means for an organization to find answers to critical questions such as “who, how, and when to work with” (Juntunen *et al.*, 2018), considering stakeholder capabilities. According to Garriga (2014, 493 p.), they can be defined "as the stakeholders' effective opportunities to undertake actions and activities with the firm that they want to choose to engage in the value creation process."

1.10 OUTPUTS

A growing public awareness of various forms of social and environmental issues is moving customers to increasingly foster businesses to act responsibly (Candi *et al.,* 2018) and organizations - by adopting innovations that respond to social needs (Osburg and Schmidpeter 2013) and support social legitimacy and endorsement (Quist *et al.,* 2011; Watson *et al.*, 2017). Simultaneously, an internal organizational pushing factor for sustainable innovation is understanding the business's negative impact on the environment (O'Rourke and Strand, 2017). Even more, Dibrell *et al.* (2014) confirmed that environmental management influences organizational innovativeness strongly.

Previously, we mentioned that sustainable innovations are the outcome of the "sustainability sweet spot" (Savitz and Weber, 2007), in which stakeholders' interests represent one of two determinants of the spot. Shared activities between business organizations and stakeholders are vital for the entire process, primarily because stakeholders are the organizational knowledge source (Wagner, 2007). Within this context, *stakeholder involvement* regards the organizational activities aimed at stakeholder identification, consultation, communication and dialogue exchange, and mutually beneficial collaboration (O'Riordan and Fairbrass, 2014). Stakeholder involvement appears as a critical outcome of corporate social responsibility (Sánchez and Benito-Hernández, 2013) and open innovation (Altenburger, 2018; Juntunen *et al.*, 2018). Drawing on Candi *et al.* (2018) and Ketata *et al.* (2014), two primary sources of external threats drive organizations to include social content in their innovations. These are demand-driven threats and pressure-driven threats.

The organization's commitment to sustainable innovation may be a source of competitive advantage (El-Kassar and Singh, 2019). Altenburger (2018) summarizes several academic works that underline the benefits of stakeholders' involvement in sustainable innovation. According to Altenburger (2018), such benefits may include, for example, direct access to information linked to social and environmental issues, the renewal of organizational knowledge in changing environments, and the origin of innovations. We call particular attention to the issue of shared vision, stakeholder integration, and organizational learning (Sarpong and Maclean, 2012; Albertini, 2018).

González-Moreno *et al.* (2019) state that organizational cooperation with diverse stakeholders is one of the fastest and cheapest ways to access necessary resources and knowledge to innovate sustainably. Based on this perspective, sustainable programs are adopted when "organizations believe that such practices would lead to financial gain, operational improvement, and enhancement of their competitive advantage, positively related to corporate competitive advantage and environmental performance" (El-Kassar and Singh, 2019, p. 484). From this perspective, organizations want to play a leading role in the sustainability debate and react to external pressure, considering sustainability as a core element of their strategy. Therefore, professional stakeholder management with adequate resources is indispensable. The challenge is to implement a standard stakeholder management model and work with the unique cultural, organizational, and historical context, and develop a unique managerial approach (Altenburger, 2018).

Kusi-Sarpong *et al.* (2018) state that stakeholder involvement is an essential process for promoting sustainable innovation in organizations, fostering diverse and positive changes for the organization by developing R&I organizational cost-saving, improving reputation. However, such an engagement represents a long-term systemic perspective that stresses combining knowledge actors, technologies, and links in specific contexts (Breukers *et al.*, 2014).

Social interactions significantly expand access to new knowledge, help knowledge transfer among employees, develop innovative ideas (Delmas and Pekovic, 2016), and support customer orientation processes (Wong and Gao, 2014). In this regard, Albertini (2018) argues that cooperation with stakeholders helps organizations to develop a more proactive environmental approach (since they collaborate with a wide variety of social, environmental, and economic stakeholders in finding solutions to the environmental problem) and at the same time to reach organizational financial goals. However, the social and economic sides are correlated with one of the most critical challenges of such cooperation: stakeholder interest heterogeneity, which may be mutually conflicting (Flammer *et al.*, 2019). Such tensions stimulate sustainable innovation and contribute to foster radical changes at the organizational and societal levels. These studies underscore that stakeholder involvement addresses the management task of balancing social and economic interests to achieve sustainable relationships and equitable reciprocation for the mutual benefits of both society and business (O'Riordan and Fairbrass, 2014). This balance requires combining and integrating all stakeholders' resources and capabilities. A critical aspect that emerges in this context is that this dynamic process will lead to innovative products and services through mutual value creation (Rühli *et al.*, 2015).

Researchers make efforts to explain how to achieve success in combining innovation and sustainability. Even if the process is very challenging, they agree that close cooperation between an organization and its stakeholders is essential (Watson *et al.*, 2017; González -Moreno *et al.*, 2019). Innovation activities are characterized by long gestation periods, significant resource commitments, and a high failure rate. The sustainability framework clearly states that social and environmental performance requires a long-term horizon (Flammer *et al.*, 2019). Additionally, organizational innovation capacity is based on belief systems. Managers exploit beliefs to define, communicate, and reinforce the organizations' core values, purpose, and direction, introducing new priorities or values (Albertini, 2018). Gaining knowledge regards the local context and inputs from stakeholders are necessary for the effectiveness of involvement practices. This also minimizes (though not eliminates) challenges such as conflicting interests, creation of shared vision, social and cultural characteristics, diverse social needs and values, lack of trust, unclear knowledge transformation, and higher uncertainty. It is also worth adding that the issue of stakeholder involvement may also reflect managers' opportunistic search to improve their reputation and follow private benefits (González -Moreno *et al.*, 2019).

While innovations are primarily concerned with the competitiveness and for-profit economic growth perspective (Candi *et al.*, 2018), sustainable innovations consider societal challenges and are positively related to customer acceptance. The last one has a complex nature and requires a multi-stakeholder focus, multiple player interactions, and more intense R&D cooperation (Juntunen *et al.*, 2018), especially in the development, validation, and acceptance of innovation (Sarpong and Maclean, 2012). Therefore, it is essential to consider that *sustainable development (or sustainable development goals) provides a framework for organizational opportunities to meet human values and needs through the innovation process,* or the so-called sustainability Sweet Spot. Meanwhile, an organization that wants to cope with sustainability issues should be ambidextrous, which means "to be efficient in its management of today's business while being adaptable for coping with the changing demand of tomorrow" (Nielsen *et al.*, 2019, p. 142).

1.11 DISCUSSION AND CONCLUSION

Innovation and sustainability are recognized as crucial drivers of industrial and socio-economic development (Hall and Vredenburg, 2003; EC, 2019). Arguably, sustainability and innovation may correlate intensely and challenge organizations and society to implement new managerial practices. These practices can be implemented successfully if they are framed by cooperative and competitive links between an organization and stakeholders – network interactions

(Brennan and Dooley, 2005; Quist *et al.*, 2011; Janssen and Moors, 2013; Herrera, 2016) and materialized within a policy setting (Albrecht, 2013).

In this study, we contribute to the current understanding of stakeholder involvement strategies associated with a context of sustainable innovation. This paper responds to the call for a better understanding of the sustainable innovation framework and its components. Specifically, we offer a unique overview that overcomes the "snapshot in time" of scholars working in multiple directions (Kusi-Sarpong *et al.*, 2018).

1.11.1 Implications for business practices

While sustainability is based on the triple (or quadruple) bottom line, our literature analysis shows a clear focus on environmental issues mainly. We argue that sustainable innovation fosters positive changes framed by the Sustainable Development Goals and interactions between the actors supporting these Goals. This would help to understand better the role of society in the context of sustainability.

Additionally, our framework considers the diversity of links and dynamics among numerous actors/processes and their impact on overall organizational performance, competitive advantage, and territorial well-being. Building on this literature, we believe that adequate tools are: workshops or co-creation events (Albrecht, 2013; Breukers *et al.*, 2014; Elzen and Bos, 2019); participatory back-casting experiments (Quist *et al.*, 2011), financial incentives, for example, to suppliers who signaled more substantial customers commitment to a product, or the establishment of research funding aimed at improving healthcare, collaborative approaches in risks mitigation and others (Klassen and Vereecke, 2012).

1.11.2 Research Agenda

Stemming from the conceptual framework proposed in this study, we identify some essential lines for future studies. First, investigating stakeholders' involvement practices for sustainable innovation by considering local facilitators and promoters of Sustainable Development Goals. For example, as non-governmental organizations, their mediation/facilitation role in sustainability innovation processes, contributing to a better understanding of uncertainties, as an innovation system development can be limited by lack of consensus (Alkemade and Suurs, 2012).

Second, focusing on the link between driver and organizational resource-management of sustainable innovation, we invite scholars to explore how company governance affects the choice to implement sustainable innovation. According to Hambrick and Mason (1984), organizations are the “mirrors” of their decision-makers. We believe that decision-maker’s value, heuristics, and biases will affect the choice to push sustainable innovation and resource allocation, management, and reconfiguration within the firm. Then, one might suppose a key role of governance in shaping a company’s aptitude to formulate and implement a sustainable innovation strategy.

Third, focusing on the inter-organizational resource-management of sustainable innovation, we call for studies on the mechanisms that lead to leverage the full potential of stakeholders’ knowledge. This investigation may enrich the analysis of stakeholders’ involvement in sustainable innovation processes. In this regard, we believe that qualitative studies are suitable in explaining in-depth the processes that facilitate cooperation practices, the main organizational and socio-cultural barriers, and proposed solutions for such cooperation.

Fourth, we call for additional studies on the inter-organizational resource-management of sustainable innovation. This will help to understand whether and how shared values, methods for creation of ‘common’ language, and working style between multi-faceted actors affect the cumulative process of recognizing the challenge and searching for potential and acceptable solutions for all (Evans *et al.*, 2007; Olsen *et al.*, 2017; Reypens *et al.*, 2016). Also, we suggest a deeper reflection on sustainable innovation as an outcome formed or settled by a democratic process. This process may be based on a voluntary or monetary positioning of a stakeholder in this novel process (the intrinsic value of choice or the temporality and dynamism of expectations and preferences of stakeholders (Garriga, 2014), power and influence in the relationships between an organization and stakeholders.

Finally, we stress the importance of the pressure of external factors on collaboration practices, as they represent unpredictable or partly predictable elements, which impact organizational decisions, based on which an organization may construct its network for innovations and sustainability. Thus, the other two chapters of the thesis concentrate on the impact of the policy change and exogenous shock on inter-organizational networks in a specific field, such as the European research and innovation (R&I) area. Analysis of the dynamics within these networks under the mentioned factors will support developing research knowledge to promote innovations for sustainability in the cooperation of heterogenous actors.

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CHAPTER 2. THE POLICY IMPACT ON THE EU R&I INTER-ORGANIZATIONAL NETWORK DYNAMICS

Keywords: Inter-organizational networks, Framework program, Policy, Network analysis

2.1 INTRODUCTION

Starting from 1960, scholars have widely contributed to recognizing external sources of scientific, technical, and other market information as vital input for successful innovation processes within inter-organizational networks (Freeman, 1991; Chesbrough and Prencipe, 2008). For decades, the European research and innovation system is fostered by the EU Framework Programmes, aiming to create a more competitive and inclusive European Research Area (ERA). Moreover, the economic network theory confirms that firms engaged in various external cooperation and use internal and external resources in their activities show higher innovative performance than firms in which only internal resources are used (Oerlemans *et al.*, 1998; Gulati *et al.*, 2011). Management scholars underline that the network form of organization has significantly changed how organizations innovate (Dhanaraj and Parkhe, 2006). The last decade's research literature continues this line. It raises the importance of sustainability and planetary welfare, adding that cooperation between heterogeneous stakeholders in R&I is a prerequisite for sustainable innovation and sustainable development (Juntunen *et al.*, 2018; Dyck and Silvestre, 2018). Nowadays, it is widely accepted that innovations are framed by interactive processes of knowledge generation and exchange between diverse groups of actors involved in innovation systems and cooperation networks (Tödtling *et al.*, 2009). An inter-organizational network as a structure, according to Powell *et al.* (1996), supports a firm's competitive position in fast-changing environments. By being a part of a network, an organization can get easier and faster access to tacit and explicit knowledge (Kogut, 1988; Chesbrough and Prencipe, 2008; Mariotti and Delbridge, 2012) and stimulate innovative performance components based on the heterogeneity of R&D capacities (Rothaermel and Hess, 2007). In the past decade, significant attention in academic literature has been given to analyzing inter-organizational networks and their impact on knowledge and innovation creation (Powell *et al.*, 1996; Gulati, 2007; Manring, 2007; Gulati *et al.*, 2011). New research insights help expand an understanding of the quintuple helix model of innovation (Carayannis *et al.*, 2012) and diverse actors' roles in such a complex system.

At the European level, the latest EU policy and R&I instruments, such as framework programs, fostered organizations to reflect on innovation and sustainability in closer cooperation with the overall organizational environment, changing the inter-organizational system, potentially making R&I more open, inclusive, and innovative. In these conditions, the EU represents a complex public-sector organizational system (Murdoch, 2015), supported by inter-organizational networks. These networks are strongly promoted by the EU regions and support not so active in the past R&I actors such as SMEs, NGOs, and CSO, forming a more robust background for a quintuple innovation helix framework for innovation and sustainability. Thus, the dynamics of such partnerships are becoming crucial research questions. Monitoring and evaluating these networks is necessary to devise a policy to foster this specific organizational form of performance (Van Der Valk and Gijsbers, 2010).

This chapter presents research focused on analyzing complex inter-organizational networks for innovation within the EU R&I framework programs. Keeping the focus on variations in the network formation processes (Doz *et al.*, 2000), we collect and analyze data on the two latest framework programs under the R&I policy transition. Several studies were carried out to understand how these specific networks formed and evolved (Breschi and Cusmano, 2004; Anrold, 2005; Arnold *et al.*, 2012). We focus on the inter-organizational *mesoscopic level* dynamics of these networks and contribute to research studies with the innovative approach on the identification of their types of patterns: *persistent stability, expansion of clusters and merging effect*, and of evolution process: *rich-club, knowledge spread and knowledge aggregation*, notable passing from Framework Programme 7 (FP7) to Horizon 2020 (H2020). The results that emerge from such analysis support the argument that policy incentives to simplify the application/management process and to include a more extensive heterogeneity of actors applied in H2020 changed some patterns of the R&I networks but did not modify the system significantly.

We structure the rest of the chapter as follows. First, we present a literature review on networks' structure to develop a framework for network understanding in organizational studies. Next, we propose a summary of the EU R&I pathway and policy transition on these networks' dynamics in order to position the empirical application of the research question of this study within the context of inter-organizational network studies. Methodology and results are discussed, after all, underlying the main types of patterns and evolution within networks. The chapter is finalized with the discussion and limitations of the study.

2.2 THEORETICAL BACKGROUND

In extant research, the innovation process is seen as a complex process due to its high risks, significant and late returns on investment, and overall uncertainties (Alkemade and Suurs, 2012). Van Der Valk and Gijsbers (2010) argue that such tensions can be minimized with organizational participation in a knowledge-intensive collaboration network. Such an impact is possible as the network provides broader access to suppliers, customers, competitors, other stakeholders, and new markets across sectors and countries (Yaqub *et al.,* 2020). Fagerberg (2018, p. 1568) outlines that modern innovation is seen “as a social phenomenon, in which many different assets are combined, and a variety of actors, both inside and – not the least – outside the innovative firm, take part and influence the outcome.” This is why being a part of the network is beneficial. Networks support risk-sharing and recombination of responsibilities, strengthening organizational innovation activities based on knowledge exchange, value creation (Dhanaraj and Parkhe, 2006; Ahuja *et al.*, 2012; Wu *et al.,* 2019) gain of complementary resources (Yaqub *et al.,* 2020; Dhanaraj and Parkhe, 2006), the potential for control and, even, influence (Madhavan *et al.,* 1998). Meantime, knowledge circulation can be examined as a phenomenon at the emergent network level (Qiao *et al.,* 2019). Consequently, in strategic performance, inter-organizational networks play a role of the strategic resources, which under a specific executive action can impact the structure of networks and push an organization to reach a particular context for future action (Madhavan *et al.,* 1998). Consequently, the network’s evolution outputs result from both environmental context and strategic action (Koka *et al.,* 2006).

2.2.1 Link formation in dynamic social networks

Organizational scholars agree that a network is a collaborative perspective or a system of social interaction with its specific functions. Breukers *et al. (*2014) argue that networks’ primary function is to moderate and spur the knowledge exchange between all the actors involved. In this context, networks are defined as a set of actors connected by a group of relationships (social and business) for a creation of strategic inter-organizational opportunities (Protogerou *et al*., 2010). The links can change under exogenous and endogenous factors (Gulati *et al.,* 2011; Ahuja *et al.*, 2012). Within the inter-organizational network, an institutional ecosystem has more potential for boosting innovation creation as it has a more excellent resource pool than individual members of a network (Manring, 2007). This underlines the complex nature of the network.

Brown (1991) stresses that inter-organizational networks can be evaluated from three different points of view: (i) as an organizational form in the private sector; (ii) as a central object for public decision making and community governance in the public sector; (iii) as a mechanism for solving problems in intersectoral collaboration in Public-Private Partnerships (PPPs).

However, inter-organizational relations can be driven by the need for resources, expression of power, and values.

Being a specific form of an organizational structure (Powell *et al.*, 1996), a network has three main elements: (i) *actors*, who are linked by specific relationships, and (ii) *ties*, consequently (Fig. 2.1), and (iii) *patterns* that result from these ties, which represent the third essential element for the architecture of all networks (Ahuja *et al.*, 2012).

It is widely recognized that network studies are rooted in mathematical graph theory and are used actively in computer science, biology, physics, social sciences, and other research areas. The two previously mentioned components – *actors and ties* (Fig. 2.1) – can be called differently depending on the study area or discipline in which a network structure is interpreted (Albrecht, 2013).

The actor is a common name for nodes in social studies. They can be called by the name of the point, node, vertex, agent, and element in other areas. One of network actors' main constants is implementing *transformation and transaction activities* and own or control organizational (physical, financial, and human) resources (Oerlemans *et al.*, 1998). According to the authors, *transformation activities* can be described as one actor's action and are characterized by the fact that resources are improved by combining them with other resources. Meanwhile, *transaction activities* connect the transformation activities of the diverse actors, which increases innovation potential. In the meantime, ties in other disciplines can be called a link, line, edge, path, site, bonds, other.

According to Protogerou *et al*. (2010), *ties* represent policy-driven cooperative relationships that allow actors to gain specific or extra resources, strengthening core capabilities and assets for innovative activities. Scholars stress that a link appearance in the network can be based on several factors: (i) social factors, for example, social relations between actors; (ii) economic activity, for example, common economic activities within or outside of the sector (Gulati, 2007); (iii) or political and environmental motivators, such as SDGs and EU Green Deal strategy. Doz *et al.* (2000) provide a partial taxonomy of the mentioned factors and nominate them as new policy regulations, rapid market changes (for example, increased competition), joint market opportunities and interests, similar industry origin or organizational characteristics, past R&D alliance experience, other. Mariotti and Delbridge (2012) classify ties into four types and provide their characteristic (Table 2.1).

Table 2.1 Four Types of Network Ties (Source: Mariotti and Delbridge, 2012, p. 515)

Ties:	Strong	Weak	Potential	Latent
Social relations	Particularistic	Universalistic	Currently universalistic	Particularistic but currently inactive
Orientation and regulation of relationships	Mutual reciprocity, trust, norms	Self-interest, contracts	Mutual interest, currently contractual	Differed reciprocity (may be reactivated)
Frequency of interaction	High	Varies	Low	Declined, low to none
Length of relationship	Long term	Varies	Short term	Long term

Based on the analysis of the previous studies, Ahuja *et al.* (2012, p. 443) stress other four typologies of the ties in the business world: “hierarchical ties reflect authority, and affective ties reflect an emotional or kinship bond; market ties reflect competitive or transactional relationships, and referential ties represent certification relationships.” Additionally, Qiao *et al.* (2019) stress three types of mechanisms to select partners: “objective selection mechanisms, feedback-based selection mechanisms, and random selection mechanisms”, adding that “from the macro perspective, the emergent patterns of knowledge diffusion within organizations” still are not framed by any rule.

Network theory proposes a rich spectrum for scholars on how actors perform within the network. However, all networks are represented by different systems, which can be described by diverse interactions or structure of dependencies (Kwapień and Drożdż, 2012). To address specific issues on network dynamics, it is vital to categorize forces that act within such a complex system, as the network’s structure, the strength of the link, and nature influence the actors’ innovation capabilities significantly (Van Der Valk and Gijsbers, 2010).

In the research literature, three kinds of network evolution are mentioned: *micro, meso, and macro dynamics.* The first one explains the formation process of the network structure (for example, link establishment). Meanwhile, the last one – represents key factors of the whole network evolution process (for example, the number of links, their dynamics) (Cherifi *et al.*, 2019). Mesoscopic level provides a picture of connections between micro and macro levels. Information on how networks change helps develop the knowledge base regarding their outcomes and supports actors’ strategic orientation for the network’s actions (Ahuja *et al.*, 2012). In this chapter, we concentrate on mesoscopic level dynamics only. Meanwhile, microdynamics are discussed in Chapter 3 of this thesis.

Nowadays, networks support an integrated approach of the organizational transformation linked to changes in the corporate strategies aiming to respond to the needs of the highly uncertain market environment, the political arena, and, finally, stakeholders’ values. This complexity and heterogeneity are hidden components of the network’s evolution processes and outcomes, contributing to networks functioning on specific coordination and governance processes. Overall, the network structure depends on a sequence of two actors' chronological events, also called an *establishment of links* (Cherifi *et al.,* 2019). The social networks' common characteristic is their erratic actions due to actors' behavior that spur changes in the overall system by adding new or canceling stable actors and relationships and impacting the overall performance (Albrecht, 2013). This provides a rich academic and managerial debate on factors that link the actors, such as power, trust, reputation, conflicts of interest, leadership, and other stakeholders' cooperation ties, or external factors, as a policy change.

Social networks can be characterized by communities contracted by actors, their links, density, and network properties as an organizational form. The main properties are nominated below:

(i) Betweenness centrality demonstrates the number of times a node plays as a link along the shortest path between two nodes. It is often associated with power and influence (Dhanaraj and Parkhe, 2006), reputation, and early adoption of innovation (Madhavan *et al.*, 1998).

(ii) Degree represents a number of links attached to the actor (Newman, 2010) and demonstrates the system's actors dominant or peripherical positions.

(iii) Geodetic distance (reach-club or small-world effect) is "a distance between to vertices in a network to be the minimum number of edges one would have to traverse to get from one vertex to the other" (Easley and Kleinberg, 2010);

(iv) Any series of vertices in which an edge in the network connects every consecutive pair of vertices in the sequence is called a path (Newman, 2010).

Moreover, it is essential to say that Polidoro *et al.* (2011) argue that the instability of ties can be raised due to positional embeddedness (network centrality). Meantime, the stability of ties can be guaranteed by structural embeddedness (shared partners). Authors state that to keep order in inter-organizational relationships common partners are essential for a social mechanism. According to Kim and Park (2009), a small-world network presents the most efficient and fair structure for R&D collaboration network. Meantime, Qiao *et al.* (2019), based on a literature review, underline typical network models: regular networks, random networks (Erdős and Renyi, 1959), scale-free networks (Barabasi and Albert, 1999), and small-world networks (Watts and Strogatz, 1998), which affect the extent of knowledge circulation based on the existence of these specific structures.

Analysis of networks is based on so-called studies of ego-centred or personal networks. According to Newman (2010), this is a network concentrated around one particular actor (Fig.

2.2). Centrality within a network is a crucial strategic advantage (Madhavan *et al.,* 1998). Meanwhile, community detection or clustering refers to "division of the vertices of a network into groups, clusters, or communities according to the pattern of edges in the network" (Newman, 2010, p. 354).

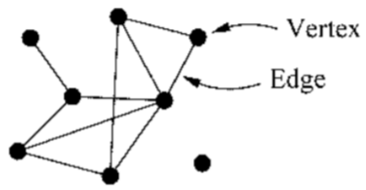

Fig. 2.1 Network with eight actors and ten links (Source: Newman, 2010)

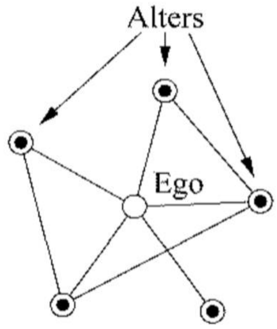

Fig. 2.2 Ego-centred network of ego and five contacts (alters) (Source: Newman, 2010)

The evolution of networks depends on the system's diverse mechanism; there, a system is created by two types of ties. The *strong ties* represent links corresponding to very close/good known actors, meantime the *weak ties* – the weaker links, corresponding to familiarities.

One of the essential principles in the network is triadic closure (in other words – a triangle in a network), representing the fact that two nodes create closeness with the third node (Fig. 2.3). This is a natural effect in a system. It creates a wide range of opportunities for the actors; for example, a relationship between B and C is potentially strong due to a common A node, an element of *trust and incentive* (Easley and Kleinberg, 2010). Formation of the triangles in the system recall building blocks of communities at the mesoscopic level of the system, which we want to study in this chapter.

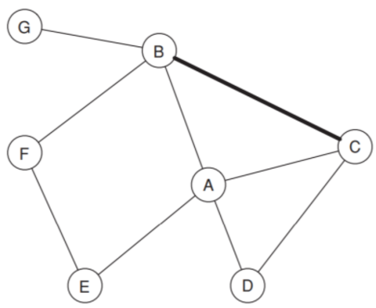

Fig. 2.3 The triadic closer of the B and C due to a common neighbor A (Source: Easley and Kleinberg, 2010)

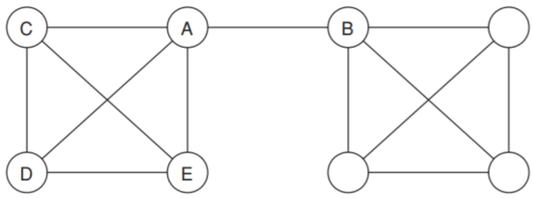

Fig. 2.4 A bridge representation by A and B (Source: Easley and Kleinberg, 2010)

Structures of the networks can have diverse forms, not only triangles, and these forms can be linked to each other by a *bridge*, a link that connects two actors (Fig. 2.4). Being a route between two networks provides access to both networks' resources; removing this link will separate networks from each other and function as separate systems. If two sets of nodes do not interact closely, they can be "linked" by a structural hole (Fig. 2.5) (Easley and Kleinberg, 2010). Meantime, if the node shows a central position in the system, which guarantees diverse actors' connection, this position can be called powerful (Fig. 2.6).

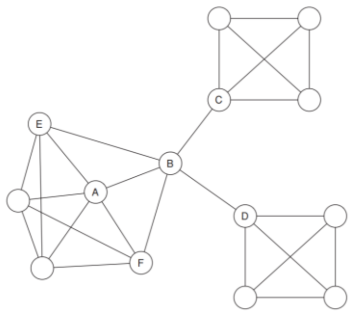

Fig. 2.5 Structural hole (Source: Easley and Kleinberg, 2010)

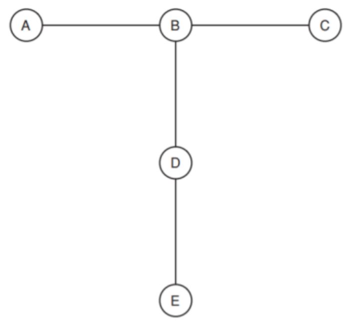

Fig. 2.6 Representation of the powerful position in a social network (with five actors and with node B occupying an intuitively powerful position)

Interpreting actors' innovation potential, Schilling and Phelps (2005) provided empirical evidence on organizational innovation capacities within a network, stating that two structural characteristics are vital. *Clustering* is understood as a measure of the proportion of the networks' partner that is directly connected; it increases "the information transmission capacity of the network" (Schilling and Phelps, 2005, p. 1114). It is possible due to the similarity and complementarity mechanisms, which are happening in the overall network. Dense connectivity stimulates the exchange of resources, acceptance of common standards, risk-sharing, and development of shared understanding, transparency, finally, trust between the actors. All these foster a higher potential for recombination possibilities (Schilling and Phelps, 2005).

Naturally, dynamics in the network are the outcome of the internal and external environments. Homophily is one of the most "basic notions governing the structure of the social network" and means that the nodes' have stronger wiliness to be linked with the similar nodes due to "similarities and characteristics of the nodes and the activities that the nodes engage in," but this does not mean that networks do not face an evolution (Easley and Kleinberg, 2010). Opposite, due to social influence and selection (also the notion of power), they are linked to represent changing structures: be more open or closed (focal closer, membership closer), in such context, a social structure affects the experiences and behaviors of its actors, for example, nodes can demonstrate a *dependence*, an *exclusion, satiation* – "having diminishing rewards for increased amounts of something," and *betweenness* – is an example of a centrality measure that supports to look for "central" points in a network (Easley and Kleinberg, 2010).

Previously literature proposed an overview of networks' impact on organizational behavior and performance results (Gulati *et al.*, 2011). However, Dhanaraj and Parkhe (2006) state that a network should be stable. In the opposite case, it does not support value creation or value extraction. However, it should present a high adaptation and agility, minimizing the risk that this network will lose an innovation potential. According to Madhavan *et al.* (1998), changes within the inter-organizational networks derive in response to specific events, which in strategic management can be called *structure-reinforcing* or *structure-loosening* events, called by Barley (1986) "occasions for structuring." In other words, "the structure is reinforced if the existing distribution of network power is strengthened, benefitting the network "rich"[18] actors at the expense of the network "poor" actors. The structure will be lost if a network power is redistributed, benefitting the network "poor" at the expense of the "rich" (Madhavan *et al.*, 1998, p. 444) (Table 2.2).

Table 2.2 Characteristics of events affecting network structure according to Madhavan *et al.* (1998)

Characteristics of events	**Structure-reinforcing event**	**Structure-loosening event**
Effect on the bases of competition	Enhances and strengthens existing bases of competition	Radically changes the bases of competition
Who benefits?	Dominant players with high centrality in the current network	Peripheral players with low centrality in the current network
Who initiates?	Dominant players in the current network	Peripheral players in the current network

Koka *et al.* (2006), studying network dynamics, observe the direct effects of a network change in terms of the two evolutionary primitives, so-called *tie creation* and *tie cancellation*. The authors present a matrix representing four different environmental scenarios and their impact on a specific change pattern (Fig. 2.7). According to the authors, understanding the network dynamics provides information on an organization's network's role in achieving strategic goals via an analysis of the compatibility between desired wanted strategic objectives and its current network position.

[18] According to Madhavan *et al.* (1998, p. 444) rich actors are whose who have network power – central position within it, meamwhile, poor actors are less powerful firms within this network. The poor actors are less connected to many partners than the central firms.

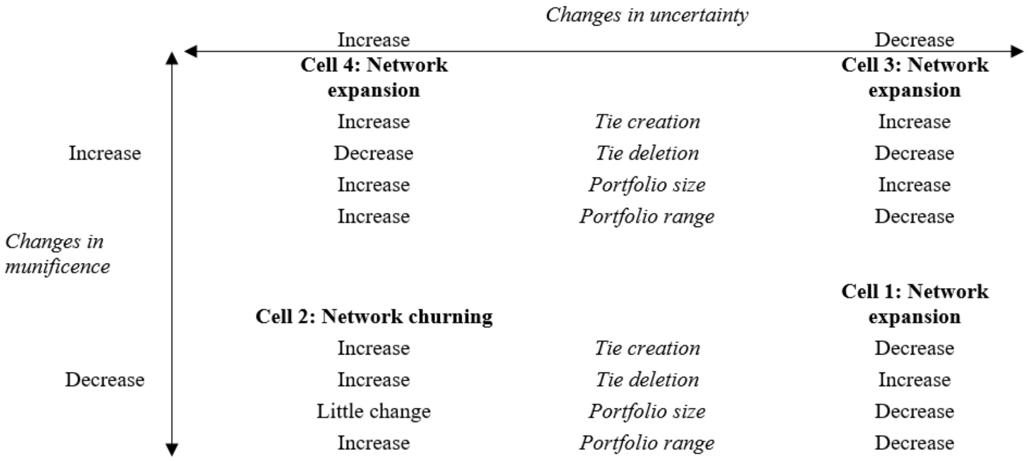

Fig. 2.7 Environmental Effects on Patterns of Network Change (Koka *et al.,* 2006, p. 724)

Doz *et al. (*2000) add that a network can function efficiently on relational and embedded ties, but this can be limiting for the final output. The critical issue regarding the networks' understanding is linked to understanding the mechanisms that foster changes in tie creation (Gulati *et al.*, 2011). Policy transition undoubtedly is an external factor for the modification of organizational behavior. As such, in this work, we introduce a policy change as a transition event, which "provide occasions for network restructuring" (Madhavan *et al.*, 1998, p. 443) or also called a "micro foundation" – factor, which impacts tie's existence (Ahuja *et al.,* 2012).

Finally, according to Biermann (2007), networks are created to achieve better policy output through synergies, like norms, ideas, and knowledge, which are shared continuously utilizing contact and communication. Identifying a policy change as a driver of network change, we extend prior related research on network evolution by adding this specific source of concrete inputs to change drivers and change patterns. On the other hand, the study contributes to comprehending the mechanisms through which R&I policies actually affect inter-organizational links and performance.

2.2.2 Policy formation for the EU R&I networks

Policy-making at the international, regional, and national levels directly correlates with the whole research area (Freeman, 1991). Graf and Broekel (2019) underline that innovation policy provides monetary support for collaborations and influences a network structure. As a result, it alters the knowledge flows and mechanism of dependency relations. Innovation policy refers to a variety of policy instruments and incentives (policies for training and skills, cluster policy, policies to support collaboration, innovation networks policies, and others) that have been implemented to R&I, and in the past were titled as research policy, industrial policy, science policy, or technology policy (Edler and Fagerberg, 2017).

The European Commission promotes Research and Innovation as a critical component of thematic policies to contribute to the EU as a leading continent for science, ideas, and sustainability (EC, 2016). To foster such a direction, an instrument for collaborative R&I activities – Framework Programme(s) (FPs) – was introduced in 1984 by the European Commission (Scherngell and Barber, 2011). For decades, this program experienced various transitions towards coherent policy. Being a technology-oriented program, a significant change in policy thinking was introduced in the Commission's White Paper on Growth, competitiveness, and employment (1993), followed by the 'Green Paper on Innovation' (1995). This shift reflected on more societal orientation, pasting from the technological step, linked to the FP5. Thus, according to Frenken *et al.* (2007) and Reillon (2017), at the end of the 1990s, FP7 became part of a more comprehensive innovation policy. Policymakers have a need to adapt their instrumentation to transform economies and deal with social problems through innovation (Edler and Fagerberg, 2017).

As a result, European initiatives such as the Lisbon agenda (2000), which aimed to build a common market in research and enhance European research to become globally competitive, formed the overarching environment for FPs. In terms of European added value, the most significant innovation of FP7 was the expansion of the concept to include continental-level competition for individual researchers, allowing the European Research Council to be established in 2007. It also advanced the use of big instruments for significant public-private R&D partnerships, such as Joint Technology Initiatives, Joint Programming, and "Article 185" (previously Article 169) arrangements, by assisting stakeholder groups in defining and implementing strategic research agendas (Arnold et al., 2005). While formally Framework program is a composite of many sub-programs addressing societal challenges. The Commission stresses that FP aims to link excellent researchers in their fields, engaging the more research-intensive companies within their respective branches. New participants, on the other hand, appear to be learning the importance of networked R&D and are becoming more interested in open innovation initiatives, even if they are not as involved with the FP. A solid core of established players and networks exists, with the composition gradually shifting over time.

As mentioned previously, these programs are based on shared project activities between diverse private and public actors, which create an inter-organizational network. A growing number of participants and competition in this area confirm Rothaemel's & Hess's (2006, p. 2) words, that "R&D capability has become more critical to innovative performance as many industries have become more science-driven." Moreover, being the policymaking instrument, these programmes face the role of the promoter of the policy directions, for example, sustainable innovations. In these conditions, organizations are willing to distribute work processes across organizational boundaries, based on inter-organizational project networks, creating specific network orchestration for interactive learning, minimizing uncertainty and complexity of innovation processes (Taylor and Levit, 2007; Scherngell and Barber, 2011). Even more, R&I inter-organizational networks are seen as a pillar to reduce the impact of the economic and social crises of the last decades. The Commission stresses that Programme and Partner countries combine their efforts to explore new forms of innovation collaboration for inclusive, innovative, and reflective societies (EC, 2019). These new forms are supported by solid partnerships based on new models of ecosystems and national innovation systems. They rely on partnerships with similar or/and different market players to manage knowledge resources and innovate. These dynamics are happening due to discrete complementarities in innovation policy. The public sector plays an important role and helps identify problems arising from science application (Schot and Steinmueller, 2018), and the mentioned policy tools are based on understanding experience with actions, study on current challenges, and perception of future actions. Thus, innovation policy aims to influence innovation activity to boost economic growth and, with it, productivity and job creation (Dosso *et al.,* 2018). According to Mohnen and Röller (2005), policies aimed at removing barriers to innovation can have a variety of outcomes, depending on their goals. One approach is to encourage incumbents to innovate (i.e., the intensity of innovation is conditional on being an innovator), while another is to encourage entrance (i.e. increase the probability of becoming an innovator). As such, to understand a policy impact on networks, there is a need to analyze policy changes, network groups, neighborhoods, organizations, social circles, and all system communities – how the knowledge actors interact, what are their roles and which social control mechanism govern the process (Linton C. Freeman, 2004)?

This policy also includes what is known as "mission-oriented" goals, which are aimed at addressing more specific societal issues (e.g., social exclusion, environmental and energy issues, health and welfare, and others) (Dosso *et al.,* 2018). The long-term goal of transforming the economy to sustainability has recently provided policymakers with an opportunity to provide a more precise direction for innovation, relying on many actors' active participation (Fagerberg, 2018). Nowadays, this program reflects more actively policy-driven issues, and for example, it initiates a stronger focus on sustainability in innovation development. The first time sustainable economic development and growth were mentioned during the FP5 (1998–2002). Kastrinos and Weber (2020) calculated that the adjective 'sustainable' is mentioned 47 times in the program. It was meant to address critical economic and social "systems." Sustainability was linked to sustainable health, sustainable agriculture, sustainable cities, and others. This pattern is repeated in FP6 and FP7, where the adjective "sustainable" is presented 37 and 44 times, respectively. In Horizon 2020 – 117 times. The study of Kastrinos and Weber (2020) underlines some key issues regarding sustainability. The authors highlight that up to now, sustainability issues in EU R&I policy have been looked through the prism on how the technology works in society, and a new reflexive approach – transition should be introduced. Authors make a citation of the Voß and Kemp (2006, p. 4), they state that this approach "calls into question, envisions alternatives, reinvents, shapes, and probes the foundations of governance itself, i.e., the concepts, practices, formal and informal institutions by which societal development is governed."

Policymakers are finding it difficult to make the best policy decisions for innovations due to the sophistication and speed of recent innovation and socioeconomic developments, especially in the era of the globalized economy when dealing with unpredictable and intangible items like organizational research and innovation (Dosso *et al.*, 2018). Notwithstanding this, it is of interest to analyze how the EU R&I policy implementation incentives support innovation network changes in practice.

Table 2.3 A comparison of FP7 and Horizon 2020[19]

Description	FP7	H2020
Focus	Research	Research and Innovation
Budget	55 billion €	~ 79 billion €
Components	Cooperation, Capacities, People, Ideas, Euratom, JRC	Excellent Science, Industrial Leadership, Societal challenges, Spreading Excellence, Science for Society, EIT, JRC, Euratom
Funding rate (up to) for research	75%	100%
Funding rate (up to) for Demonstration/ Innovation projects	50%	70% 100% for non-profit organizations
Time-to-grant	12 months on average after the submission of the proposal	Reduced to 8 months
Ex-ante financial viability check	All beneficiaries exceeding 500,000 EUR EU contribution	Coordinators only

The current framework program, H2020, was impacted by different policy incentives aiming at more robust multidisciplinary research and transnational cooperation and fostering European innovation partnerships' strength. Considering the long history of the FPs, evaluation results and experts' proposals, specific policy directions, diverse incentives occur in the new Horizon 2020 program. According to Graf and Broekel (2020), these incentives address cluster policies, foster embeddedness of organizations into knowledge networks, and system-level analyses

[19] Source: A comparison of FP7 and Horizon 2020, http://cerneu.web.cern.ch/horizon2020/fp7-comparison

must understand the benefits of application and timing of their implementation. As a result, the most essential and inclusive changes are presented with Horizon 2020, passing from the FP7 to Horizon 2020 (Table 2.3). These changes theoretically brought new inputs and visions into the networks' dynamics, for example: (i) rethinking a funding rate opened a possibility for new knowledge flows from the partners that are not particularly financially stable, (ii) reduction of the time to grant agreement so as to support a faster implementation on the proposed innovation, (iii) sustainability, open innovation, and responsible research and innovation are promoted as a cross-cutting pillar for R&I.

To stress, in our opinion, a policy change correlates directly with time. As so, key findings of Ahuja *et al.* (2012) can be applied to the policy change concept's impact on the network's dynamics. The authors argue that time plays a notable role in the relationship between organizational performance and network structures. The key idea is that the evolution of a network is driven by a process where the actors are fostered by the micro–foundations (such as agency, opportunity or exogenous factors) to form, maintain, or delete ties. This motivation forces actors to seek specific partners or/and tie patterns, which stimulates changes within the inter-organization network.

As such, the shift of dynamic of relations in inter-organizational networks is the core of this research. We selected the EU R&I framework as the research setting to empirically analyze which dynamics appear in the networks.

2.2.3 Prior research on the R&I networks

A wide range of authors empirically confirmed the vital importance of external sources and knowledge on firms' innovation. Still, at the same time, the role of a new organizational structure – (formal and informal) networks of innovators – was scientifically questioned, aiming to clarify their specific contribution to the mentioned process (Freeman, 1991). Easley and Kleinberg (2010) underline that diffusion of innovations is strongly linked to information capital (on a new behavior, practices, technologies, and other), person–to/person influence, and such characteristics as "*complexity* for people to understand and implement; its *observability*, so that people can become aware that others are using it; its *trialability*, so that people can mitigate its risks by adopting it gradually and incrementally; and, perhaps most crucially, its overall *compatibility* with the social system that it is entering" (p. 565).

R&I programs play a crucial role in the EU R&I policy agenda as a policy instrument towards an integrated ERA (Arnold, 2012). They are represented by actors and institutions around specific goals and are implemented in innovation systems. Mapping the EU scientific objectives in 2000, a system of scientific research programs – ERA started its active operation in medical, environmental, industrial, and socioeconomic research, aiming at creating the EU single market for research, innovation, and technology[20]. Taking into consideration the fragmentation and overlapping of the EU R&I actions, four main directions were prioritized:

(i) foster research and innovation;

(ii) strengthen partnerships among higher education institutions, business, and other R&I actors;

(iii) support and promote the mobility of researchers and the flow of knowledge;

(iv) and advance gender equality and diversity in R&I.

According to Breukers *et al.* (2014), such R&I systems have seven functions: knowledge development, knowledge diffusion, resource mobilization, entrepreneurial activities, the guidance of the search, market formation, lobbies, support from advocacy coalitions with a final output of a socio-technical innovation, which from 2015 were pushed to target Sustainable Development Goals. In the early 90s, Liyanage (1995) stated that R&D clusters support public policymakers in the indention of "complementarities between generation, acquisition, and diffusion of knowledge across a range of innovations rather than a single innovation." Such collaboration helps to link, map, and develop those areas of technology development "that firms are willing to support in conjunction with public research institutions" based on networking, straightforward institutional arrangement, transfer of tacit knowledge and competencies for improved competitiveness and better advantage in industries (Liyanage, 1995). Being a part of a network, an organization may take the role in so-called, by Dhanaraj and Parkhe (2006), network orchestration. The authors describe this process as the set of "purposeful actions undertaken by the hub firm as it seeks to create value and extract value from the network" (Dhanaraj and Parkhe, 2006, p. 659), fostering innovativeness within this process. Schot and Steinmueller (2018) argue that innovation may be considered as an outcome of an interactive cooperation model, which has several characteristics: the context of the application, which acts as a base for knowledge production; transdisciplinary, which supports the development of a new common framework for research; heterogeneity and organizational diversity, reflecting the increasing diversity of actors involved in knowledge production, and a more comprehensive range of experts involved in the research process leading to a better presentation of social concerns. Research continues into how innovation evolves depending on specific knowledge sources and links (Tödtling *et al.*, 2009). After reviewing the relevant literature, a group of authors (Tödtling *et al.*, 2009) found that advanced and radical innovations result from new scientific knowledge (coming from higher education institutions and research

[20] Source: The European Research Area, https://ec.europa.eu/info/research-and-innovation/strategy/era_it

organizations) to reflect on a local and regional level. Meantime incremental innovations go beyond the region and result from interaction with knowledge actors from business, and this makes frames of the innovation ecosystem broader.

Within the framework programs, innovation has moved from labs to an ecosystem without previously existing organizational boundaries. Innovation networks become the driving force of progress and interactions of informal and formal groups of knowledge actors based on trust and confidence (Freeman, 1991), shared resources (Gulati, 2007), shared vision, and shared values. Such networks affect cooperation practices since new players and/or users, transactions reinforce existing activities. They also foster growth in value creation and in a number of users. Starting from the FP7 and continuing in H2020, it is visible that society (in its broad understanding) has an increasingly prominent role in the innovation creation process. Seebode *et al.* (2012) stress that it is notable how innovations can arise from the development of unusual partnerships across sectors. These partnerships support structural division in open/social innovation, promoting a solid trend on R&I outsourcing and alliances and democratization of innovation process (Gassmann *et al.*, 2010), fostering operative partnerships. They are followed by:

(i) Intensive business ecosystem changes – the partnership becomes a tool for problem-solving, filling gaps, diversifying risk, and sharing both market and technological uncertainties of innovation (Trailer *et al.*, 2011).

(ii) Sustainable development issues. The concept of "sustainability" is a major and growing driver of company transformation. The goal of living and working in a world of up to 9 billion people with rising expectations, providing energy, food, and resource security, dealing with climate change, ecosystem degradation, a widening economic divide, and a host of other interdependent issues are among the implications for innovation. These need a “massive change in products, services, processes, marketing approaches, and the underlying business models” which frame the challenges (Seebode *et al.*, 2012, p. 195).

(iii) Issues of resource management. Mansfield (1986) showed that innovation requires less time and resources if external actors participate in the co-creation process. The co-creation is a core of open innovation. This notion is defined by several writers as a set of approaches for establishing an active, creative, and social collaboration process between producers and users during the development of new products (Piller and Ihl, 2010; EU, 2016).

Manning (2017) stresses that research, by definition, should produce new knowledge. Due to increased R&I collaborations and networks in the knowledge creation process and increased complexity of innovation processes, formalized R&I collaborative activities are used as a proxy for knowledge flows (Scherngell and Barber, 2011). In this part, we present some of the latest research findings regarding the EU R&I networks, which support our reflection on R&I network dynamics and compare our contribution to the research discussion with previous ones.

Töpfer *et al.* (2017) analyzed the German R&I cluster policy, which aimed to foster innovation activities for Germany's good international competitiveness in a broad set of high–tech technologies. The results show that the network dynamics were driven by the respective technological and industrial environments rather than policy. This research showed that personal links are more robust than applied innovation policy.

Lyneis *et al.* (2001) underline that due to the heterogeneity of actors and type of decisions made on projects (strategic, tactical, or /and operational), the research and development projects represent a complex system (complex projects or highly non–linear feedback systems). They are vital for organizational due to the access to knowledge diversity, funding, and innovation potential. Manning (2017) states that core teams in EU-funded structures are mainly composed of core funded regions to satisfy funding criteria and operate as intermediaries. The author writes that in academic research, partners are typically linked with academic and research institutions due to several motives: funding criteria, the ability of research bodies to incentivize research, to allocate human resources for such actions, and act as project coordinators (Manning, 2017). This is also confirmed by the social network analysis carried out by the Directorate-General for Research and Innovation in 2016: "Previous monitoring and evaluation activities related to the FPs have mainly investigated participation patterns of the "classical" organization types defined in the framework programs: universities, private research organizations, companies, public bodies, and other organizations." These works continue to show that European R&I activities are dominated by formal knowledge actors (Martinuzzi *et al.*, 2016). Three categories of R&D alliances have been identified in particular: (i) within–cluster alliances (the partners belong to the same cluster); (ii) semi-distant alliances (the partners form a so-called "shortcut" between two different clusters); (iii) foreign alliances (at least one of the partners is an isolated node, i.e., a newcomer firm) (Tomasello *et al.*, 2014, p. 1).

The results of the research of Almendral *et al.* (2007) presents that FP5 are scale-free networks with the accelerated growth of new partnerships (especially among small-size participants). These networks possess the small-world property, are robust to structural changes, and collaboration among similar size participants appears more effortless (Almendral *et al.,* 2007). In other words, this means the closeness of the R&I programs. However, being a form of a public-private partnership, such a collaboration supports a need to find a solution effectively and rapidly for a challenge and/or to fill knowledge gaps (Traitler *et al.,* 2011). However, the previous research states that SME participation is less successful than big companies and produces more negligible impacts (Arnold *et al.,* 2005).

Additionally, the social network analysis carried out by VU Vienna's team (DG RTD, 2017) states that in the FP6 and FP7 civil society (CSO) had created a limited impact on network performance and research outputs. The logic proposed is that researchers have mainly shaped FPs networks, focusing on scientific excellence. The business sector focuses on profits and competitiveness; meanwhile, CSOs follow a diverse logic, focusing on societal impacts (Martinuzzi *et al.*, 2016).

Moreover, R&I cooperation occurs most often between organizations that are not too far from each other in the technological space (Scherngell and Barber, 2011). Precisely, the previous studies in the analysis of the FP4, FP5, and FP6 collaborative networks in the area of Information Society Technologies showed that the actors are found to be highly connected, and the central role is given to universities and research centers, as so strengthening their positioning and strategic position in the topic through the years. These networks have small-world qualities and could be deemed somewhat efficient in terms of knowledge creation and diffusion (Protogerou *et al.,* 2010). As it was stated by Madhavan *et al.* (1998), "the structure of an industry network plays an important role both in firm performance and in industry evolution" (p. 440). The authors underline that the structure provides an input for the context for competitive ambiance. An organization's position within the network impacts its access to the network links, timely provided resources, isolation, or centrality. Moreover, the structure stimulates the dynamics within the created complex system, as organizations aim to use "advantage of opportunities to improve their positions in the network" (p. 440).

The previous examination of innovation networks in EU-funded projects showed that such inter-organizational partnerships align with one or several industrial sectors. Still, the openness in resource flows and outcomes is expanded widely (Jarvenpaa and Wernick, 2011). The diversity of technologies characterizes inter-organizational innovation networks, services, and processes that companies working by themselves would be challenged to find (Almirall and Casadesus-Masanell, 2010). These partnerships have complex and multidisciplinary inter-organizational relations, value creation for their participants, and qualitative change (Jarvenpaa and Wernick, 2011). Some scholars, however, wonder whether the growing usage of project networks inside and across industries fosters or stifles innovation (Taylor and Levitt, 2007).

The research carried out by Arnold *et al.* (2005) demonstrates that many organizations in FPs (4-6) are short-lived, but there is a core of stable participants within the evolving networks. In the past, these programs have contributed to creating highly dense networks whose structure and dynamics are likely to affect the new policy's response. This is happing because new programs are linked to a network extension and do not create wholly new R&D networks. Additionally, it is worth mentioning that these programs are a source of operating revenue for some of the actors – for example, to knowledge infrastructure actors. They attach much higher importance to FP participation than industrial participants. According to Bruce *et al.* (2004), the FP5 was the first attempt to establish interdisciplinary groups of researchers to contribute to the need to solve complex societal problems and establish more effective policymaking. Participating in this policy instrument brings many benefits for the participants, making this program very competitive. Some benefits are well presented by Arnold *et al.* (2005) (Table 2.4).

Table 2.4 Benefits of participating in FPs according to Arnold et al. (2005, p. 21)

<table>
<tr><td rowspan="4">Benefits</td><td>FP3-4 Impact</td><td>FP4 Impact Growth</td><td>FP4 Impact Ireland</td><td>FP5 Impact Norway</td></tr>
<tr><td>Knowledge and technological goals
Networking
Organizational and management goals</td><td>Development of new tools and techniques
Enhanced skills of RTD staff
Increase access to the source of expertise
Enhanced knowledge base</td><td>Impact on scientific and technological standing
Capability building goals</td><td>The building of competencies and networks
Scientific results of participants were successful
New R&D projects in the future</td></tr>
<tr><td>FP4-6 Impact UK</td><td>FP4 Impact Austria</td><td colspan="2">FP4 Impact Denmark</td></tr>
<tr><td>The improved knowledge base of participants in general and linked to specific fields
Improved relationships and networks
Enhanced reputation</td><td>Scientific reputation
Competitive position
Employment</td><td colspan="2">Development of new methods
Scientific publications
Implementation of new technologies
Development of new products and prototypes</td></tr>
</table>

These programs spur a development of a system of coordinated links between researchers, technology, industry, markets, and customers. In recent years, the analysis of R&I networks has become very vibrant and interdisciplinary research. The EC (2015) publication stresses that it supported learning how to cooperate between HEIs and companies worldwide within three decades of the program functioning. It was changing boundaries and organizational practices, making the environment more open and engaging with a specific contribution of the social sciences and humanities, which were not considered at the beginning of the program.

However, the dynamics of partnerships are evolving and questioned by researchers periodically.

2.2.4 Definition of the research question

We interpret the EU R&I policy incentives applied to H2020 passing from the FP7 as a specific event – "occasion for structuring" (Barley,1986), which spur dynamics within the R&I inter-organizational network structures. Newly adapted incentives (Table 2.3) in the Horizon 2020 mechanism stress the differences between the two programs and motivate to research how such changes impact composition and processes within innovation systems. Especially because previous analysis of the FPs shows that these inter-organizational R&I networks do not tend to change dynamics. They tend to reproduce each other for a long time. Therefore, in this chapter, we are questioning *in what way do innovation policy incentives influence the EU R&I inter-organizational network dynamics?*

2.2.5 The Case Study

The current chapter focuses on analyzing a specific innovation ecosystem, such as the EU Framework Programmes for Research and Innovation, specifically focusing on the two latest FPs: FP7 and Horizon 2020. We concentrate on these innovation networks, both because:

(i) they provide access to the data linked to innovation actors, which enrich understanding of inter-organizational performance in a real-world complex system, and

(ii) create a common background for understanding the policy impact and processes through which the EU performs research and innovation activities.

Moreover, some specific characteristics of these programs support the search for an answer to our research question, and they are:

(i) FP7 and H2020 are the most significant publicly funded programs in Europe.

(ii) These FPs are characterized by an extensive international collaboration network with a heterogeneous profile of stakeholders involved in the R&I competition.

(iii) The programs represent social issues, public values and should foster active change in the EU R&I area, creating social benefits.

(iv) FPs act as policy instruments used to reinforce and strengthen EU competitiveness on global markets while limiting or sustaining organizational behavior in the market.

These research collaborations are seen as an effective means of getting input on new practices, and we know that sustainability is formulated in public policies and supported by a policy mix (Lindberg *et al.*, 2018).

2.3 METHODOLOGY

2.3.1 Data collection and method

Both selected programs are the tool for EU R&I funding, which are planned for seven years and is accompanied by a package of policies and rules for the region's social, technological, and economic impact. A list of specific changes was applied for Horizon 2020, aiming to spur innovation potential in the region. It reflects on societal needs based on the best know-how. It aims at more robust, multidisciplinary research, transnational cooperation, the appearance of new links between different formal and informal knowledge actors. Different policy incentives impacted the mentioned program, such as increased budget, more flexible funding schemes, support of new entries, and others (Table 2.4), influencing internal and external changes in inter-organizational networks.

This chapter's data is essentially collected using all FP7 and H2020 projects in the EU Open Data Portal: https://data.europa.eu. Our dataset contains: (i) the list of FP7 projects – 22,228 started between 2007 and 2014, and (ii) the list H2020 of projects – 22,153 started between 2014 and 2019. We downloaded the data in September 2019. Social network analysis was employed to understand the structural properties and dynamics of both networks. The created dataset analysis is implemented through several steps:

1. Identification of the unique organizations in FP7 and H2020 projects. The datasets were cleaned, institutions without PIC (Participant Identification Code) numbers were eliminated from the dataset to avoid mistakes in networks' composition.
2. As the FPs represent complex systems and have a bipartite nature, with one set of elements being Institutions and the second one being Projects. Such a system can be described through a bipartite network (also called, *affiliation network* ((Breschi and Cusmano, 2004; Easley and Kleinberg, 2010) in which a link is set between an institution and a project if that institution participated in that project. Newman (2010) describes the bipartite network (two-mode network in sociology literature) "as the membership of vertices in groups represented by hyperedges in a hypergraph equally and often more conveniently".

   This representation naturally considers the system's bipartite nature since no link can occur between two projects or two institutions. The bipartite network has been projected onto the set of institutions, providing a weighted network of institutions. A link is set between two institutions if they participated in at least one project together. The weight of the link corresponds to the overall number of projects in which both institutions were involved. Such a network has been filtered by applying Statistically Validated Networks (SVN) (Tumminello *et al.*, 2011) to test the statistical significance of link weights (the so-called co-occurrence) against a null hypothesis of random co-occurrence. Statistically validated networks for both programs were developed.

3. Community detection has been performed on both networks through modularity optimization[21].
4. The resulting communities for the two programs have been compared by constructing a confusion matrix[22]. Such a matrix could be helpful in identify persistent patterns of institutions' aggregation across the programs, as well as clustering deterioration (that is, one community in the FP7 that "explodes" into several clusters in the H2020), and the revere, that is, community formation (Table 2.8).

2.3.2 The Statistically Validated Networks

The evidence for the research is collected through a social network analysis (SNA). The SNA was introduced to organizational studies as a support tool for an interpretation and understanding of the inter-organizational relationships (Gulati *et al.*, 2011) and dynamics (Sozen *et al.*, 2009), as a social environment is a pattern for configuration of relationships (Wasserman and Faust, 1994). SNA may even support an understanding of an innovation policy development and its evaluation (Breschi and Cusmano, 2004; Van Der Valk and Gijsbers, 2010).

This method is selected due to its advantages. In networks, it is used to research and model information flows, understand social situations, explain interactions and social roles, analyze social exchange processes, study organizations' structure and dynamics, and cooperate between them. Applying SNA in innovation network analysis provides a possibility to identify differences in actors' network status and identify closely interacting groups of actors, to underline the structural properties, which describe actors' behavior or classify actors according to their status (Wasserman and Faust, 1994). This method is used widely; for example, it is mentionable that other studies of the FPs using network analysis provide in-depth information on:

(i) a single FP programme and its actors (Stuckmann *et al.*, 2007);
(ii) evidence of geographical factors in FPs (Scherngell & Barber, 2011; Balland, Boschma & Ravet, 2019),

[21] *Modularity* - is a measure of the structure of a graph, quantifing the excess of density of connections within the communities of a given partition of nodes with respect to a null hypothesis of random classification.The modularity optimization allows to detect communities in the networks based on their modular structure. Source: Newman, M. E., Girvan, M. (2004). Finding and evaluating community structure in networks. *Physical review E*, 69(2), 026113.
[22] The entries of a *confusion matrix* associated with two partitions of the same set of elements report the cordinalities of the intersections between group pairs from different partitions (Newman, 2010). For instance, element c_{ij}=12 of a confusion matrix indicates that the number of elements that belong to the intersection between group *i* in one partition and group *j* in the other partition is 12. Looking at a partition as the outcome of a classifier, the confusion matrix summarizes the classification performance of a classifier with respect to some test data. Source: Ting, K. M., Sammut, C., & Webb, G. I. (2017). Confusion matrix. *Encyclopedia of Machine Learning and Data Mining*, 260.

(iii) or take such a program as an example of applying and understanding network characteristics in network theory (Almendral *et al.*, 2007; Balland *et al.*, 2019).

Several studies on the impact of the national clusters and EU innovation policy on collaboration networks' structure were developed (for example, Töpfer *et al.* (2017)). With the help of the SNA, we suppose to evaluate the innovation policy impact on the R&I inter-organizational network dynamics.

In this work, we concentrate on complex and heterogeneous affiliation networks. Affiliation network is a specific two-mode (Fig. 2.8), bimodal (Balland and Rigby, 2017), type of social networks, which is constructed by a set of actors ($N = \{n_1, n_2, \dots, n_m\}$) and events $M = \{m_1, m_2, \dots, m_n\}$) and can be demonstrated by a *bipartite graph*. This is the graph in which two subsets can represent nodes, where ties between pairs of nodes have dependencies with diverse subsets (Wasserman and Faust, 1994).

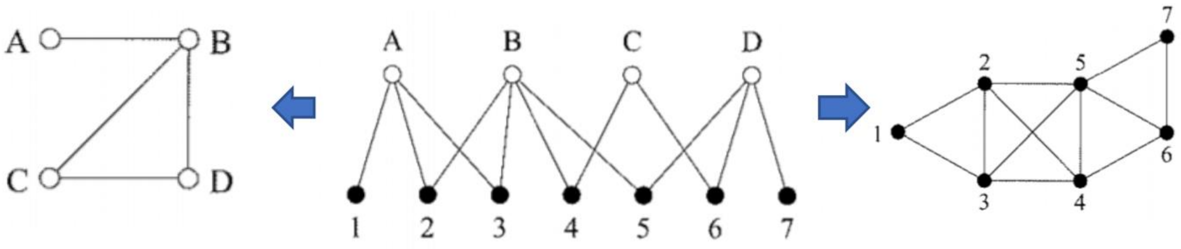

Fig. 2.8 The two one-mode projections of a bipartite network (Source: Newman, 2010)

To interpret the information such as a network, we proceed with the Statistically Validated Networks (SVM) introduced by Tumminello *et al.* (2011). This method helps statistically validate a link between the actors under the null hypothesis of random connectivity.

2.3.3 Descriptive statistics of the networks

Recently developed the Monitoring Flash report[23] prepared by the Directorate-General for Research and Innovation demonstrated that some countries based on the number of participations of entities from individual States between FP7 and Horizon 2020 showed a high increase in participation compared to FP7: such countries as Luxembourg, Cyprus, and Croatia, and a substantial decrease in participation from FP7 to Horizon 2020: Hungary, the United Kingdom, Germany, and others demonstrate stability within the networks: the Netherlands, France, Greece, and Malta (Fig. 2.9).

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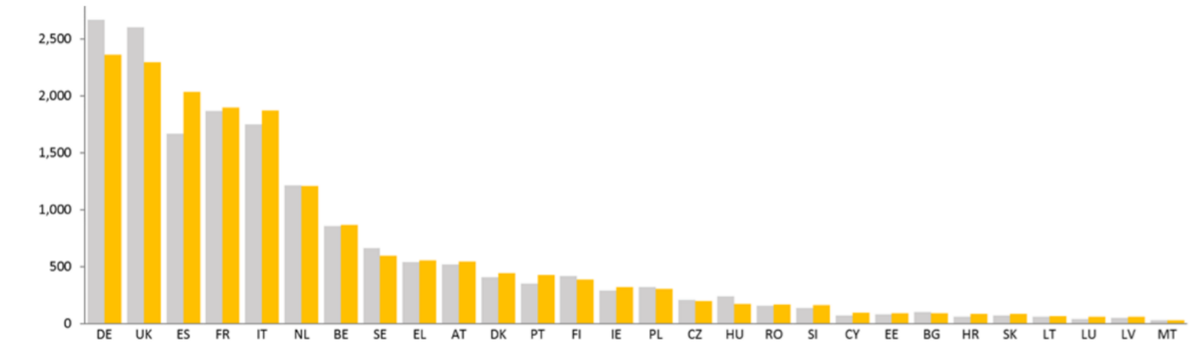
[23] Source: https://ec.europa.eu/research/evaluations/pdf/archive/h2020_monitoring_reports/h2020_monitoring_flash_092018.pdf



	DE	UK	ES	FR	IT	NL	BE	SE	EL	AT	DK	PT	FI	IE	PL	CZ	HU	RO	SI	CY	EE	BG	HR	SK	LT	LU	LV	MT
FP7	2,668	2,603	1,669	1,867	1,748	1,213	857	659	541	519	409	349	417	287	319	207	237	156	134	67	80	102	59	71	61	37	48	29
Horizon2020	2,363	2,297	2,034	1,896	1,871	1,208	867	596	554	547	443	428	387	320	305	200	169	169	163	95	92	91	86	82	65	60	57	28
Difference %	-11%	-12%	22%	2%	7%	0%	1%	-10%	2%	5%	8%	23%	-7%	12%	-4%	-4%	-28%	8%	21%	42%	15%	-11%	45%	15%	7%	64%	17%	-2%

Fig. 2.9 Number of participations to Horizon 2020 and FP7 per year per Member State of beneficiaries[24]

Our dataset shows that overall, 147 countries took part in FP7 and 111 in Horizon 2020. The decrease is linked partly to non-EU participants. For example, these countries did not pass from FP7 to H2020: Syria – 6 actors involved in FP7, in H2020 – 0; Sudan – 5 actors involved in FP7, in H2020 – 0; Honduras – 4 actors involved in FP7, in H2020 – 0, and others. However, it is essential to underline that some non-EU countries, which were not in the FP7, appeared in H2020. For example, Paraguay, the United States Minor Outlying Islands, Mongolia, Iraq, and others. Even facing a decrease in the total number of countries in H2020, the number of participants in H2020 increased by 4% compared with the previous program. These changes can be linked to the budget increase for H2020 and new actors' entry to the R&I network. Notably, PRC, OTH, and PUB take the leading positions in the new framework program (Fig. 2.10), supporting the statement that the role of the public in R&I actions is strengthened within this new framework program, changing the existent dynamics of the FP7 slowly.

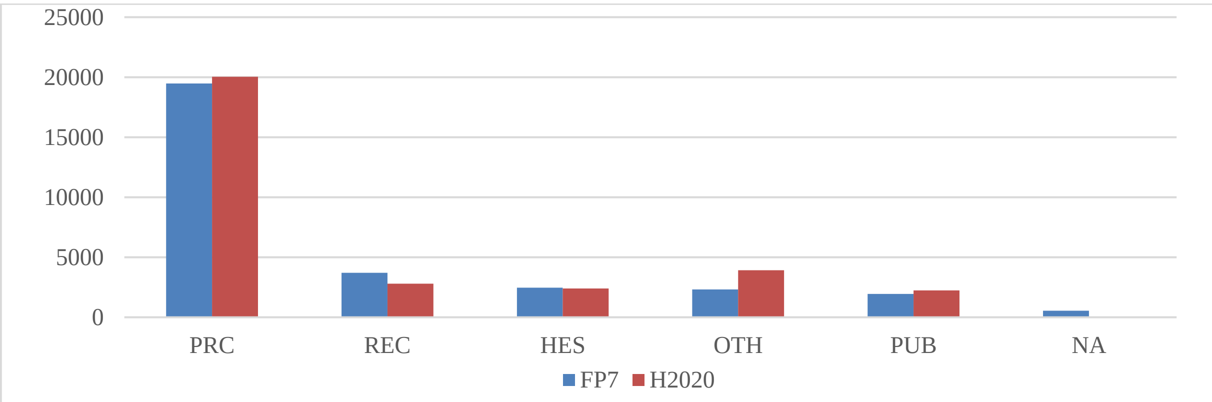


Fig. 2.10 Number of Participants per Program and Type

It appears that that such changes demonstrate the openness of the innovation ecosystem for public authorities, SMEs, CSOs, fostering a bottom-up approach and local knowledge

[24] Source: From HORIZON 2020 to HORIZON EUROPE, Monitoring flash

integration into applied and basic research. They are making the role of the public-private partnerships within the EU R&I more stable. These changes may be associated with Calls, which fostered reflection on glocal content within the region. The content represents (i) new societal challenges and diverse policy agendas to implement, such as Europe 2020, Smart specialization strategies for innovation, Innovation Union, or (ii) new pillars of the program: Responsible Research and Innovation and Widening participation.

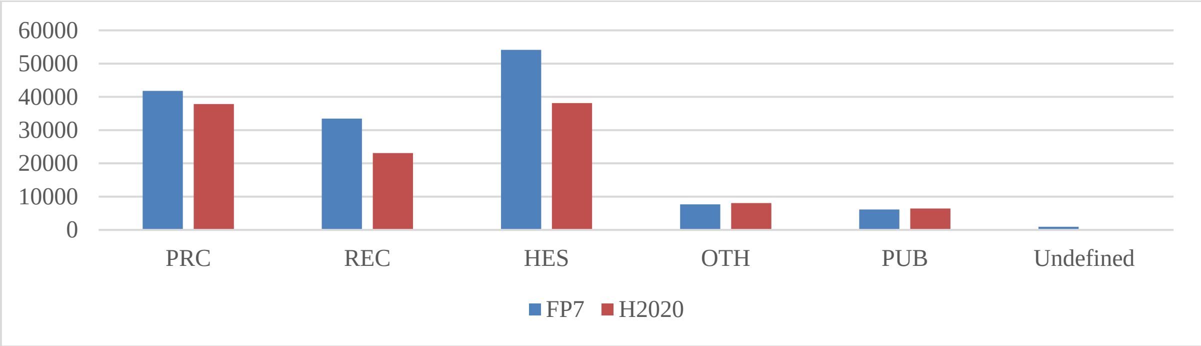


Fig. 2.11 Number of Projects per Participants/Type

Additionally, we can notice that almost similar dynamics exist in evaluating the projects per partner type (Fig. 2.11). The decrease passing from FP7 to H2020 is visible in number, representing PRC, REC, and HES. Meantime, the average number of projects per OTH and PUB is growing slightly, trying to balance their role and contribution in FPs.

The results propose that the actors' overall map is changing; sporadically, links between formal and informal knowledge actors are becoming more visible. Being a program of the strong and classical actors in the past, today it represents openness for diversity and association of novelties based on glocal approach and push of co-created innovation, as PUB and OTH type of actors, in general, represents local actors.

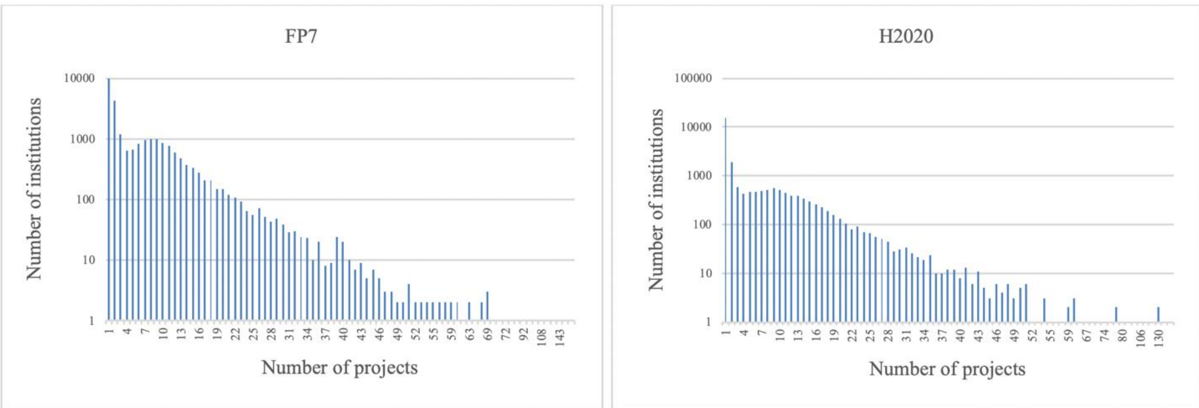


Fig. 2.12 Number of projects per partner in both programs

Fig. 2.12 presents a number of projects per partner in both programs. The difference is not essential. However, it demonstrates that in Horizon 2020, knowledge actors tend to work closer, creating more substantial innovation clusters.

2.3.4 Networks of institutions: mesoscopic analysis

We provide some descriptive statistics of the FP7 and H2020 collaboration networks to deepen our understanding of these real-world complex–system dynamics: clustering coefficient, betweenness centrality, and degree. These collaboration networks are obtained by linking together institutions that participated at least in one project together. Furthermore, we have extracted Statistically Validated Networks (SVN) from these networks to reveal preferential patterns of collaborations in the system, and we provide descriptive statistics for these (filtered) networks also.

Clustering coefficient

A network can be evaluated by analyzing the clustering coefficient (C), as it is a property of a node that provides information about the neighborhood of the mentioned node. If the C = 1, the node's neighborhood is fully connected; when C = 0, the neighborhood's connections are rare. Fig. 2.13 presents the coefficient for FP7 and H2020, SVN FP7, and SVN H2020.

The higher picks (0 and 1 values) are presented on the top graph's right side. It demonstrates that in H2020, preferential attachment between actors has risen comparing with the FP7. Calculated media for the clustering coefficient in FP7 is equal to 0,813; in H2020 – 0,799; in FP7 SVN – 0,434; and in H2020 SVN – 0,491.

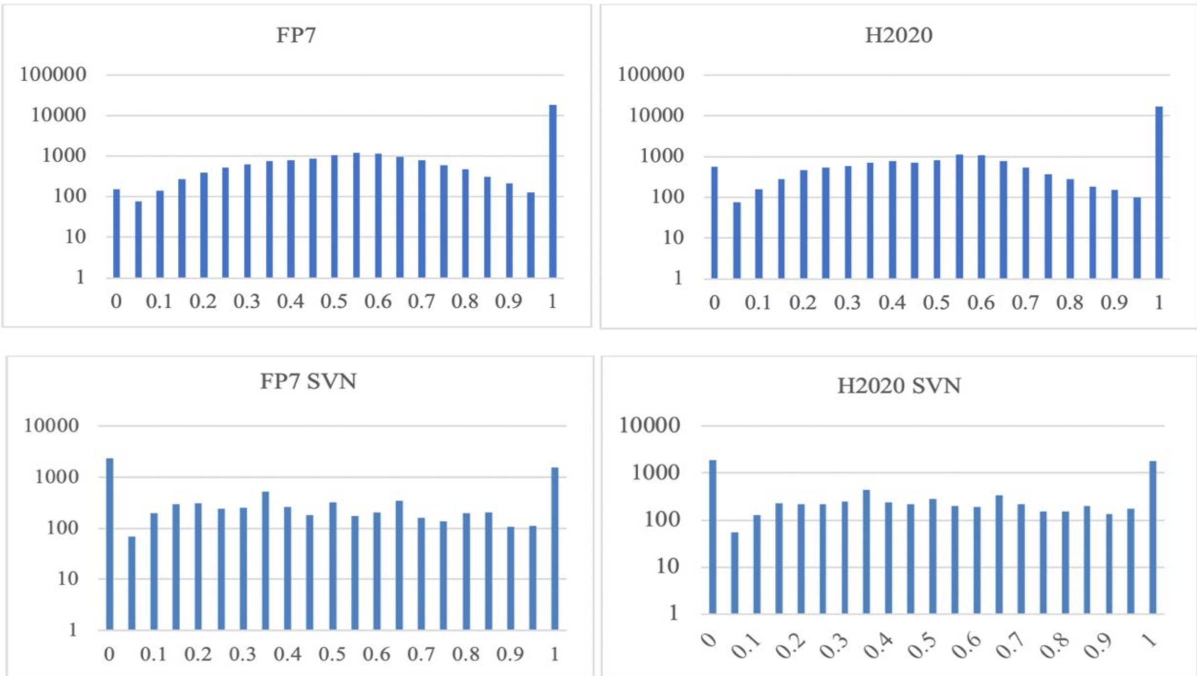


Fig. 2.13 Clustering coefficients of the networks

It helps to notice that in the SVNs, preferential connectivity patterns between the actors are more significant in H2020 SVN. In this case, the network demonstrates the characteristics to be denser and create stronger ties (based on triangles or richer form of the network), which correspond to stronger cooperation with the good-known neighbors and the most influential position within the complex system (Table 2.5). Calculated percentages of ratio also confirm this.

Table 2.5 The clustering coefficient of the networks

	FP7	H2020	FP7 SVN	H2020 SVN
Total number, pax	30237	27529	8191	7752
CC = 1, pax %	61,50	62,23	19,27	22,21
1 < C < 0, pax %	38,00	35,76	52,35	52,98
CC = 0, pax %	0,50	2,01	28,38	24,81

Using data from Table 2.5, we calculate percentages of ratios for SVNs and state that in H2020 SVN, the value is equal to 0,895 (22,21 / 24,81). In FP7 SVN – 0,677 (19.27 / 28,38). We notice that preferential attachment is higher in H2020 SVN. This network demonstrates a tendency to increase the core clusters' role in the R&I system, creating more solid and conservative structures. Such a tendency frames the system's innovation capacities within "classical" actors and limits new knowledge flows from the actors of the networks' newcomers.

The results' interpretation proposes that in H2020, the network environment's diversity is slightly more prosperous than in FP7. We can notice that this network has clusters that are stronger connected than in the previous program. However, at the same time, the percentage of actors with hardly any connections in the neighborhood is higher. Knowing this, we can state that more robust clusters (more aggregated/or more actors involved in the project) implement H2020. However, it is notable that the new program is supported by new actors, with their sporadical role in a partnership and the network.

Betweenness centrality

The high value of the *betweenness centrality* helps to understand which network actors play a key role in it or stay on both clusters' periphery or acts as leaves. Table 2.6 demonstrates that in FP7 and H2020 networks, almost 28% of actors demonstrate low participation in the FPs. This means that they do not enter the pool of active actors of the framework programs. However, it can represent an essential link between diverse knowledge clusters. This number is almost double in SVNs. Evaluating these numbers, we can agree that this innovation ecosystem has similar behavioral characteristics within both programs. The SVN data provides information on two extreme behaviors similar to the networks' actors: a strong existence of the preferential patterns and "accidental" or supportive participation of "weak" actors with their limited role in the innovation process.

Table 2.6 Betweenness values of the networks

FP7, actors	30237	H2020, actors	27529	FP7 SVN, actors	8191	H2020 SVN, actors	7752
Betweenness = 0	8192	Betweenness = 0	7753	Betweenness = 0	3371	Betweenness = 0	3217
Betweenness = 0, %	27	Betweenness = 0, %	28	Betweenness = 0, %	41	Betweenness = 0, %	41

The graphs (Fig. 2.14) demonstrate no extreme changes in both programs; however, the SVN networks represent the actors' more robust behavior within the systems. To validate this, we calculate a degree distribution.

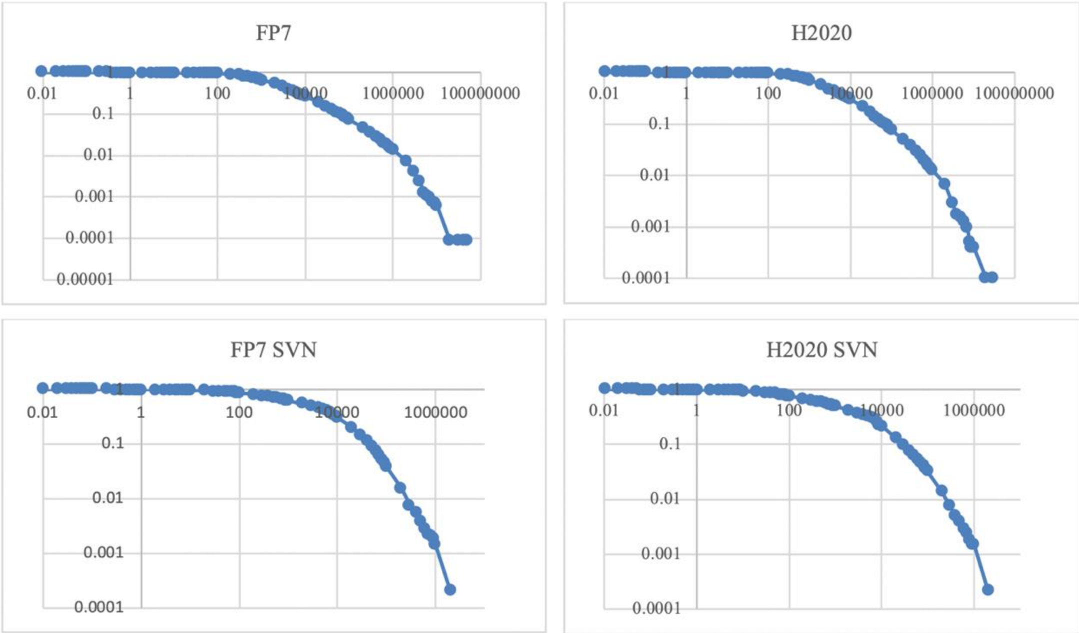


Fig. 2.14 Betweenness values of the networks

Degree distribution

Degree distribution helps identify large–degree actors, which can be referred to as knowledge hubs within the system, as a degree of an actor is a number of neighbors. High-degree actors keep the network connection and support the spread of information within it. Consequently, small degree actors foster the appearance of new knowledge within the system.

The distribution of our data presented in Fig. 2.15 can be explained by log-normal distribution and power-law behavior. As we can notice, the log-normal distribution is more associated with the FP7 and H2020, underling a higher probability of the random link creation between the system's actors, more complex system, and extreme behaviors. In the meantime, a power law presents a functional relationship between the actors and controls the system's future behavior. More connected behavior, preferential attachments, is demonstrated by the H2020. Such results propose a conclusion that a triadic closer mechanism is more similar to the H2020 SVN.

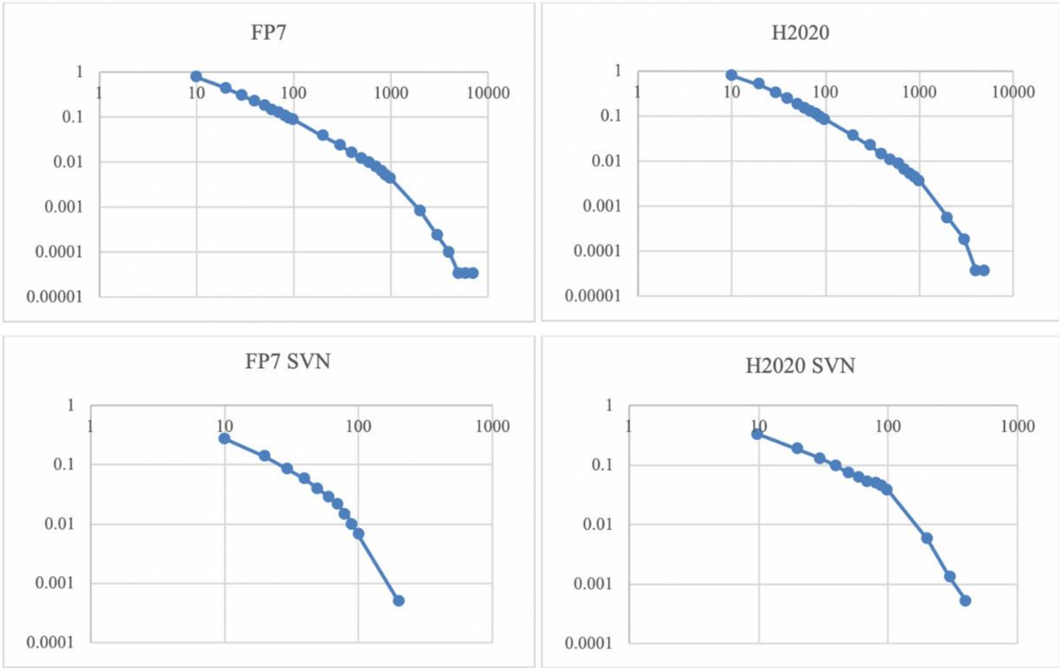


Fig. 2.15 Degree distribution of the networks

To summarise, we could notice that the connectivity between actors was high in the not filters networks already. This proposed a statement of the very clustered structure of the R&I system. Building blocks are essential for the system. Further, we filter out the system's heterogeneity and focus on preferential patterns – links representing persistent cooperation of knowledge actors (more than in one project); we notice that in H2020 SVN, the clustering coefficient becomes higher than is observed in FP7 SVN. Remarkably, the new program is more conservative for new types of cooperation. However, this is compensated by the new institutions coming to the R&I network, which casually and sporadically enter into the complex system. As so, within the R&I system, the so-called "middle class" organizations are reduced. Top R&I organizations create stronger links for cooperation with similar actors and open entry options for new actors for their sporadical actions. These actions are linked to specific (probably) local knowledge, contributing to the innovation creation and response to the Programme's Call, making the proposal more competitive.

2.3.5 Assortativity coefficient

In general, network scholars state that actors tend to be linked with other actors with similar degree values in social networks. This means that nodes are linked to attach to other nodes that have similar characteristics to them somehow. The assortativity coefficient (r) describes a preference for a network's actors to link to actors that are similar in some way. The value of the coefficient generally lies between −1 and 1. Positive values imply relationships between actors with comparable degrees of involvement, whilst negative values show ties between distinct actors. If the *coefficient* = 1, the network has a perfect assortative mixing pattern; when r = 0, the network is non-assortative, while at $r = -1$, the network is entirely disassortative. In most cases, social networks represent strong assortativity since they tend to divide into groups based on similarities (Newman, 2010). According to Ahuja *et al.* (2012), homophily processes foster assortativity; meanwhile, disassortativity is influenced by complementarity needs.

In our case, to understand the dynamics of the system, and if assortative mixing depends or not on the preferential patterns of collaboration, we calculate the assortativity coefficient for every call of both FP7 and H2020 original and statistically validated networks of collaborations. Figures 2.16-2.19 demonstrate that similarities between actors are notable in both programs and that there is no significant difference between whole networks' and SVNs' indicators. This result indicates that, typically, assortative mixing in both programs is mostly influenced by the preferential patterns of collaboration among institutions.

Fig. 2.16-2.17 presents that in five groups, the coefficient is higher than zero, and the highest coefficient of assortativity is presented in the Specific Programme – Capacities: Science in society (SIS). The SIS aimed to bridge the gap between science professionals and informal science actors through science education and culture. The second highest value is linked to the Specific Programme – Capacities: Regions of knowledge and support for regional research-driven clusters (REGIONS), dedicated to the EU regions empowerment in strengthening their capacity for research and technological contributions to their sustainable economic development. We observe the smallest positive assortativity within specific programs – Cooperation: socioeconomic sciences and Humanities (SSH). It was created to provide R&I solutions in the political, economic, social, and humanities in order to develop a better understanding of and respond to policy issues that are important to Europe, such as employment and competitiveness in a knowledge society, democracy, citizen participation in governance, and others.

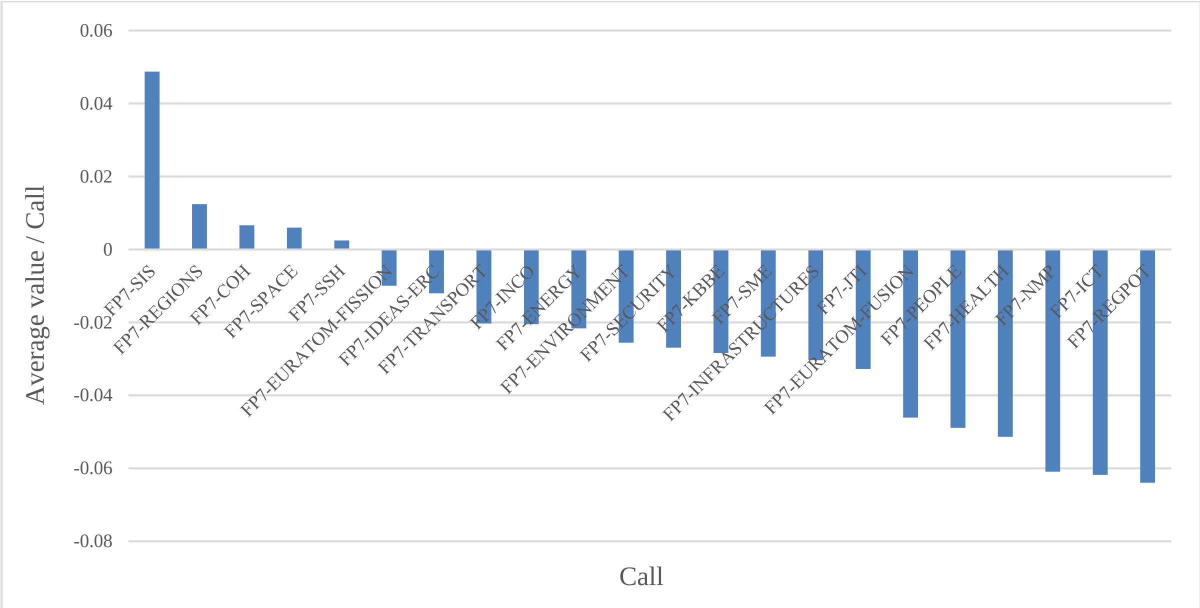


Fig. 2.16 Assortativity coefficient in FP7

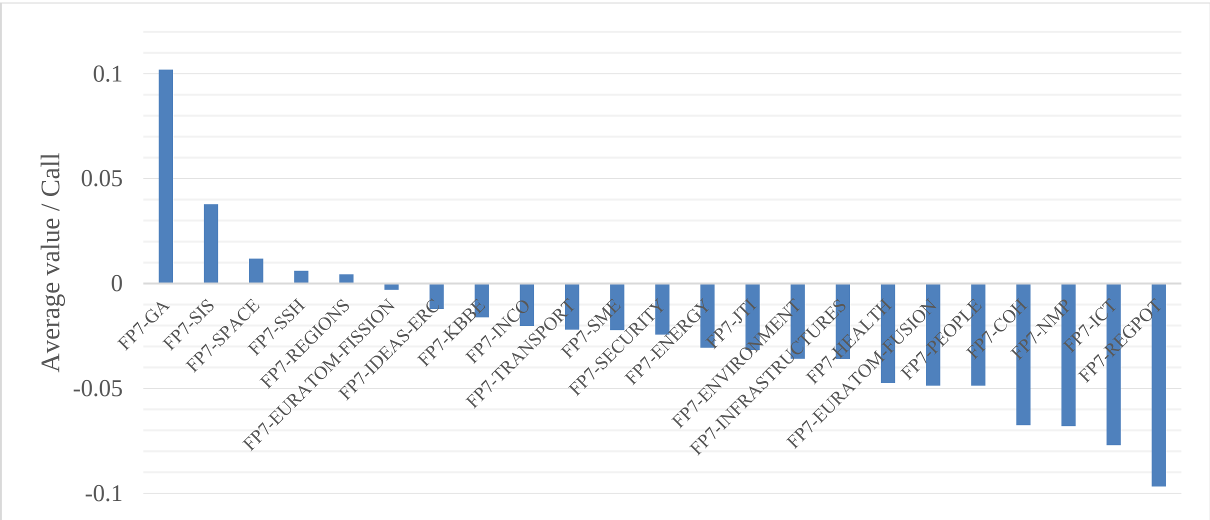


Fig. 2.17 Assortativity coefficient in FP7_SVN

Extreme values of the negative coefficient are presented within the Specific Programme - Capacities: Research potential of Convergence Regions (REGPOT), a tool for exploiting Europe's research potential in the less advanced regions of the European RTD.

In the H2020 program, we can see that in fifteen groups present coefficient's positive value. The highest assortativity coefficient (Fig. 2.18-2.19) is notable within the clusters of the organizations participating in the calls under the sub–group EU.5 (EU.5. e, EU.5. d, EU.5.h, EU.5. g, EU.5.c, other.) – Science with and for Society, which supported the continuity of the FP7 SIS.

A negative coefficient is linked to the sub-groups H2020-EU.2.1 (Leadership in enabling and industrial technologies – Information and Communication Technologies), H2020–

EU.1.2. (Calls for sensing functionalities for smart battery cell chemistries and Future Emerging Technologies program). Meantime, H2020–EU.3.5 (Societal challenges – Climate action, Environment, Resource Efficiency, and Raw Materials) and H2020-EU.3.3 (Societal challenges – Health, Food, Energy, Inclusive, innovative and reflective societies, Inclusive, innovative and reflective societies) demonstrate value close to the 0.

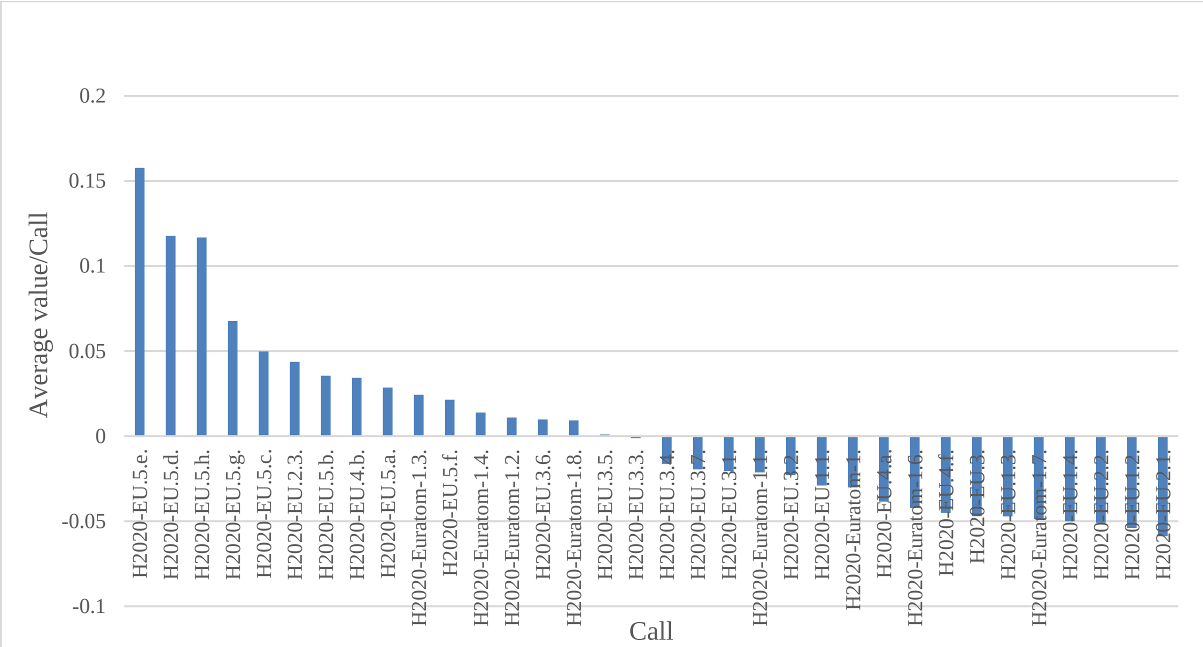


Fig. 2.18 Assortativity coefficient in H2020

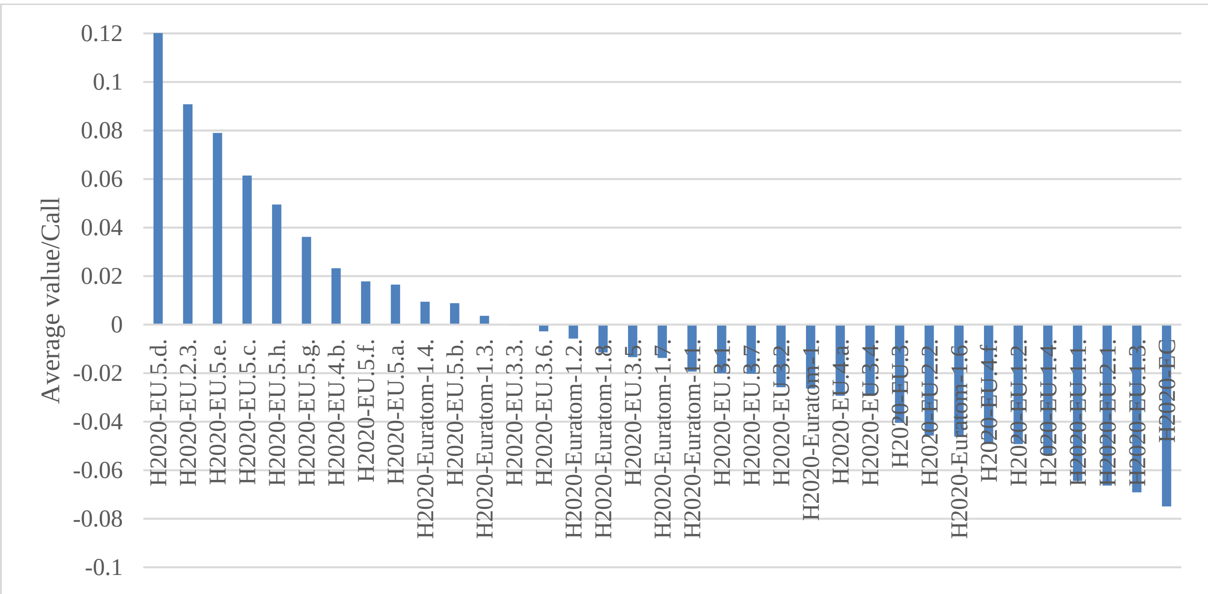


Fig. 2.19 Assortativity coefficient in H2020

Interpretation of these results proposes that the actors working on topics linked to societal issues present stronger connections within both R&I networks than in other topics, such as industrial. The nature of the R&I results – outcomes can influence such cooperation. In social calls, the R&I output is linked strongly to new tacit knowledge development and their systematization. Meantime, in industrial calls – innovation action takes a more extended period, requires the application of explicit knowledge on the specific technological and commercialization solutions, competitiveness in the market, others. Moreover, it is well known that technological innovation takes more time to reach the market. This is why technology is concerned with path dependence (Edler and Fagerberg, 2017).

Additionally, industrial actors can be characterized by a more robust competitiveness index, so they are less open to actions with similar profile actors. Furthermore, a consortium requires specific skills, and the projects coordinators have to avoid duplication of profiles if the Call does not require this. However, such duplication can happen in social calls.

To abridge, the positive assortativity coefficient of the H2020 is visible in fifteen groups, which is three times higher than in FP7. To stress, the axis of the graphs provides valuable information as well. In the case of H2020, the values are almost three times higher than in the previous program. This demonstrates the R&I system with more extreme behavior, which can be translated into the actor's behavior: (i) 'classical' actors with solid power in the R&I, (ii) "casual" actors linked to the groups of excellence.

In conclusion, we argue that the H2020 SVN is strongly influenced by homophily. Solid and conservative knowledge clusters characterize this network's structure. However, the results also demonstrate that the system exploits the links based on the clusters' complementary needs, which may involve specific knowledge necessary to respond to the call that cannot be found within the consolidated clusters. This can motivate the formation of the center-periphery ties that we observe in the actual collaboration network. As such, the clusters can make use of the network externality in a more absorptive way.

To finalize this overview, we report the scatter plots of assortativity between original and statistically validated networks (Fig. 2.20 and Fig 2.21).

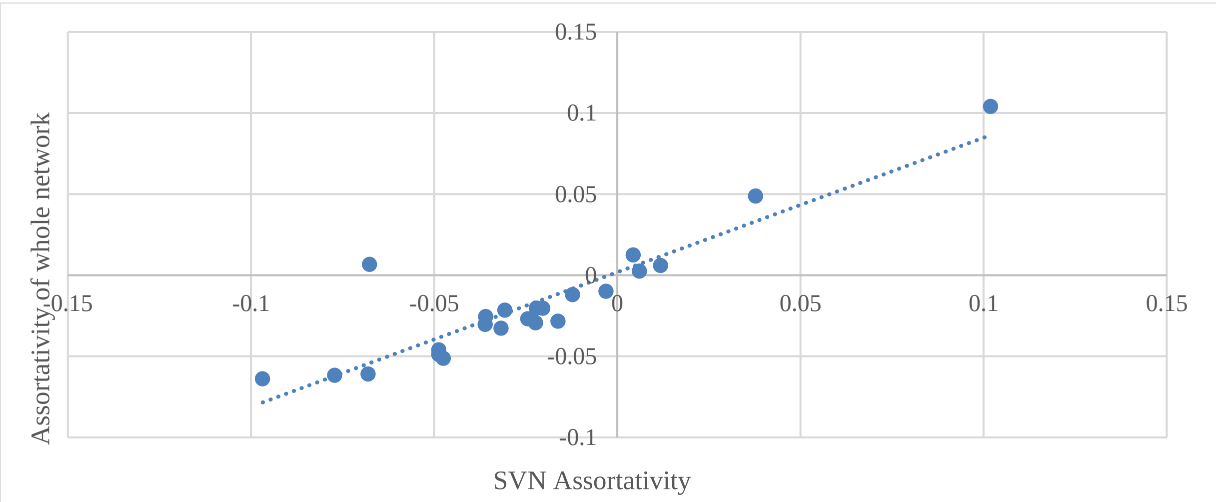


Fig. 2.20 Scatter plot of assortativity of FP7 networks (whole/SVN)

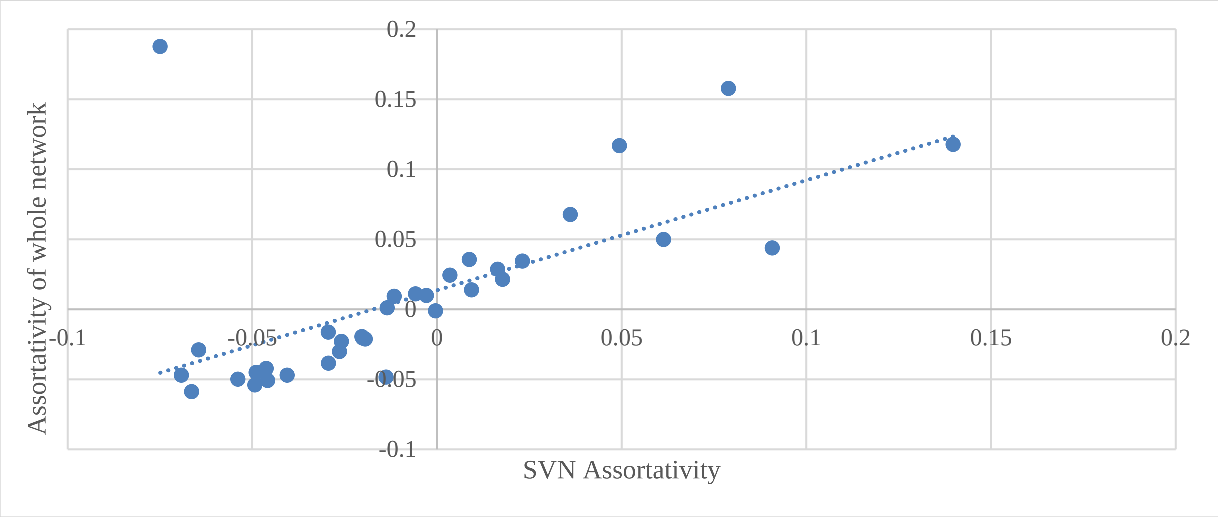


Fig. 2.21 Scatter plot of assortativity of H2020 networks (whole/SVN)

These diagrams help to observe and visualize how assortative mixing varies from the whole network to the statistically validated network. The figures indicate that assortative mixing is mostly associated with preferential patterns of collaboration in both programs, due the strong positive linear relationship observed in the figures. However, if we look at calls one by one, we notice that the ERA-NET – funding instrument (both for FP7 and H2020, launched in 2002 under FP6) represents an exception to that conclusion. In FP7, this funding tool was linked to a coordination action focused on mapping and reducing gaps in (national and regional) public research programs[25]. In H2020, it continues its existence as a public-public partnership' (PPP) support tool for "preparation, establishing networking structures, design and implementation, and coordination of joint activities"[26] of PPPs. The nature of the call, which is meant to favor the interaction among leading institutions to create or consolidate fruitful partnerships, may explain why the resulting original subnetwork is assortative (it indicates the collaboration among leading organizations), whereas the corresponding SVN is disassortative (the call fosters the formation of partnerships among leading organizations that did not collaborate, or did it marginally, in the past). In general, the presented results for the assortative mixing indicate a tendency for organizations to work in so-called rich-clubs, a tendency that has increased in the H2020 program. This cooperation is not accessible to all the community's actors, as actors tend to cooperate within the specialized partners in even more closed circles. Thus, it underlines a stronger concentration of the closeness of research activities within the static and well-rooted organizations within the EU R&I system.

[25] Source: The ERA-NET Scheme, https://www.eranet-rus.eu/en/121.php
[26] Source: ERA-Net Cofund scheme, https://ec.europa.eu/programmes/horizon2020/en/h2020-section/era-net

2.3.6 Community detection and characterization

The R&I framework programs are perfect examples of how local, national and regional innovation systems can overlap due to the institutional participation in their resource combination and connections occurring across organizations. Knowing that a logical relationship exists between network evolution and innovative behaviors (Wu *et al.,* 2019), this part presents an analysis of the formal networks for R&I that can be identified at the EU level.

As mentioned previously, a confusion matrix between the sets of communities observed in the FP7 and H2020 networks can be studied to identify persistent patterns of institutions' behavior across the framework programs and specify the dynamic process of network evolution. The confusion matrix (Table 2.7) has a table form in which rows represent FP7 communities and columns H2020 communities. In total, there are 40 FP7 communities and 18 H2020 communities. Such numbers are different because they only considered communities with at least 15 institutions/actors during the confusion matrix creation. These communities present a more extensive view of the system. The analysis of some colored elements of the confusion matrix will be performed further only, as they represent the most compelling cases of the networks' evolution.

The confusion matrix outcome shows that three phenomena of the FP networks represent the overall system's dynamics. We argue that three main behavioral characteristics can represent the dynamics of the R&I networks.

1. persistent stability or knowledge concentration / rich-club effect (also called "oligarchic core" by Breschi and Cusmano, 2004), between two programs clusters (marked by dark blue colour in the confusion matrix: FP7C1_H2020c1, FP7C1_H2020c2, FP7C1_H2020c7, FP7C2_H2020c4, FP7C3_H2020c3, FP7C4_H2020c5, FP7C5_H2020c6);
2. expansion of clusters – knowledge spread in another program (horizontal lines marked by light blue color in the confusion matrix: FP7C1, FP7C3, FP7C6);
3. merging effect – knowledge aggregation (vertical lines marked by green color in the confusion matrix: H2020c8, H2020c9, H2020c11).

Table 2.7 Confusion Matrix

Clusters (FP7/H2020)	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	c16	c17	c18	TOT
C1	**407**	**144**	24	12	7	9	**108**	46	24	3	10	72	0	4	0	2	4	5	**881**
C2	21	13	39	**156**	17	9	4	12	22	5	4	2	0	1	0	0	0	0	**305**
C3	21	14	**146**	5	5	4	2	11	4	54	0	0	2	0	0	0	1	0	**269**
C4	23	7	38	36	**117**	6	2	16	5	4	4	0	1	0	0	0	0	0	**259**
C5	14	12	8	7	10	**169**	2	5	2	1	8	2	0	0	2	0	0	0	**242**
C6	34	22	31	18	42	7	11	13	42	0	1	2	0	0	0	0	2	0	**225**
C7	19	7	8	5	1	0	6	53	27	0	3	0	0	0	0	0	0	0	**129**
C8	16	8	1	1	4	0	0	1	1	0	0	0	0	0	0	0	0	0	**32**
C9	7	12	14	1	5	1	1	9	2	1	3	0	0	0	0	0	0	0	**56**
C10	11	1	0	0	2	1	0	0	0	1	0	0	0	0	0	1	0	0	**17**
C11	16	6	4	1	0	0	0	0	8	2	1	0	1	5	0	0	0	0	**44**
C12	1	0	22	1	0	0	3	3	0	2	0	0	2	0	0	0	0	0	**34**
C13	2	5	19	1	1	0	1	2	4	1	0	1	1	0	0	0	2	0	**40**
C14	8	1	1	1	0	0	21	1	0	0	0	0	0	0	0	0	0	0	**33**
C15	10	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**12**
C16	5	3	8	4	2	1	0	1	1	1	1	0	0	0	0	0	0	0	**27**
C17	17	3	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	**24**
C18	0	2	10	1	1	3	1	1	1	0	0	0	1	0	0	0	0	0	**21**
C19	5	3	4	0	0	2	1	0	2	3	0	0	0	0	0	0	2	0	**22**
C20	3	2	5	0	0	0	1	2	0	0	0	0	5	0	0	0	0	0	**18**
C21	6	2	1	0	1	1	1	4	0	0	0	0	0	0	0	0	0	0	**16**
C22	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
C23	1	7	2	0	2	0	1	0	3	0	2	0	0	0	0	0	0	0	**18**
C24	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**4**
C25	4	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**7**
C26	3	2	2	0	0	2	1	1	1	0	0	1	0	0	0	0	0	0	**13**
C27	5	3	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**10**
C28	0	1	0	0	3	1	1	0	0	0	0	0	0	0	0	0	0	0	**6**
C29	3	6	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	**12**
C30	1	1	4	2	0	0	2	0	0	1	0	0	0	0	0	1	0	0	**12**
C31	4	0	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	**8**
C32	3	4	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**9**
C33	4	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	**7**
C34	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**3**
C35	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**4**
C36	3	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**8**
C37	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**
C38	3	0	1	2	0	0	1	0	1	0	0	0	0	0	0	0	0	0	**8**
C39	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**
C40	1	0	2	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	**6**
TOT	**690**	**304**	**401**	**257**	**220**	**219**	**177**	**184**	**152**	**80**	**40**	**80**	**14**	**12**	**2**	**4**	**11**	**5**	**2852**

2.3.6.1. Knowledge concentration: communities persistent across the programs

The first behavioral phenomena linked to the networks' dynamics passing from FP7 to H2020 can be called persistent stability or knowledge concentration between two program clusters. This characteristic is associated with the *rich-club or small-world effect*. It corresponds to phenomena when high–centrality hubs are interconnected to each other more densely than expected, forming tightly interconnected communities (Colizza *et al.*, 2006). This effect demonstrates that the R&I network is based on solid innovation hubs, also well connected. Endogenous or exogenous factors can shape the network slightly, but, in general, it is resilient to any kind of change. As we notice, policy incentives (Table 2.3) applied in the H2020 program did not stimulate essential changes within these clusters.

This effect is demonstrated in the confusion matrix within the cells marked by dark blue color. In all the cases, the communities represent almost 50% of the single H2020 or FP7 community. We agree that such a concentration of the mentioned actors represents homophily or high assortative mixing of the system (Newman, 2010). This fact stresses the existence of power-law and rich-club phenomena. Below we provide a summary of these communities (Table 2.8). As we see, the FP7C5_H2020c6 presents the highest value of actors passing from one program to another, and we select it as an example for further analysis.

Table 2.8 Percentage of the community actors per total number of the actors in the program

	FP7C1_ H2020c1	FP7C1_ H2020c2	FP7C1_ H2020c7	FP7C2_ H2020c4	FP7C3_ H2020c3	FP7C4_ H2020c5	**FP7C5_H2020c6**
Total, FP7	46	16	12	51	54	45	**70**
Total, H2020	59	47	61	61	36	53	**77**

The analysis of the composition of the countries within the chosen community provides such a composition. The countries that take the leading positions in this community are the United Kingdom; Belgium and Spain; Germany; Italy and Ireland; France; Romania, Hungary, and Sweden; Greece, the Netherland, Bulgaria, and Slovakia (Fig. 2.22). Notably, this cluster is represented by a balanced appearance of the EU "classical innovation leaders" countries, such as the United Kingdom, Germany, Italy, and France. Moreover, it has a persistent geographical character (ES and IT, BE and FR), limiting the innovation ecosystem to specific knowledge of actors from the same regions (territories). Geographical character is one of the most common characteristics or similarities for link creation (together in line with a language, shared history, and other).

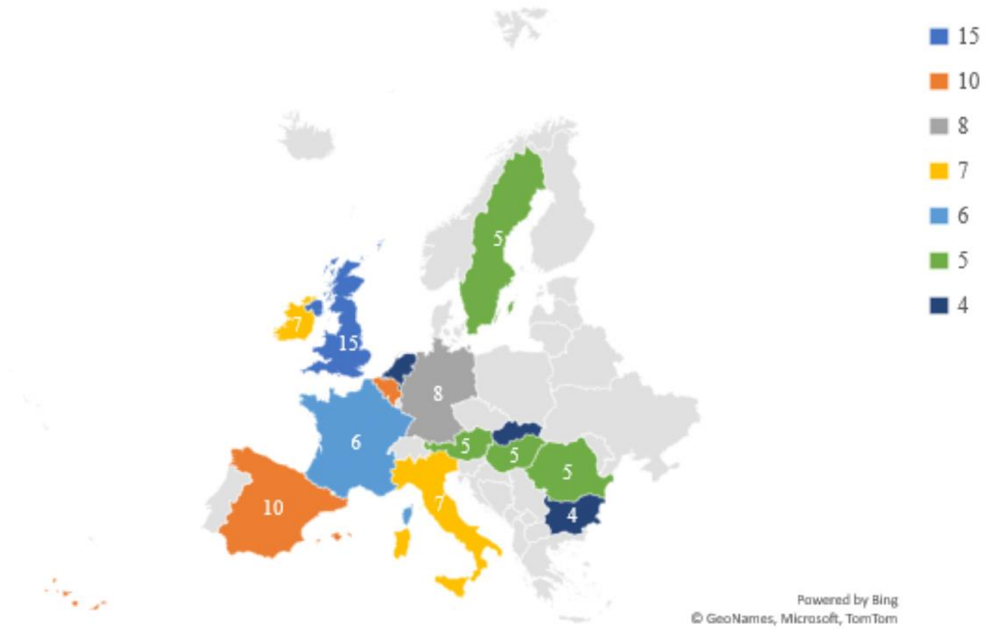


Fig. 2.22 Top 15 countries in the FP7C5_H2020c6 community

In the meantime, the dominant position in the community is taken by the actors who nominate themselves as public institutions, pushing one of the most classical and typical for the R&I networks, type of the actors – HES to the last position (Fig. 2.23). This is an interesting case, as HES was one of the most active actors in these programs.

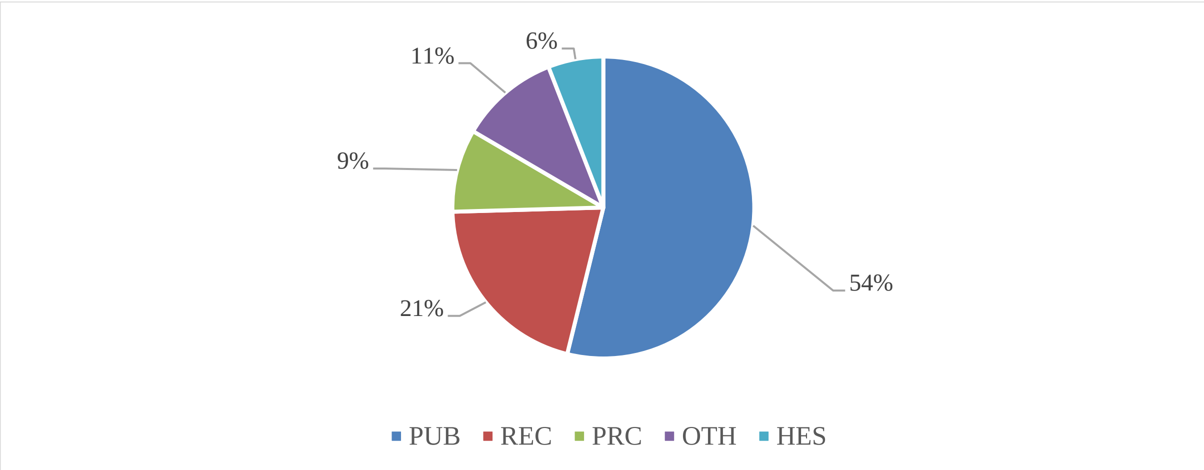


Fig. 2.23 Type of actors in the FP7C5_H2020c6 community

Such data demonstrates that this specific cluster empowers the participation of the strong public actors in R&I knowledge production linked to Marie Skłodowska-Curie Actions and such topics as: in FP7: Specific Programme – Capacities: International co-operation; Food, Agriculture and Fisheries, ICT, and in H2020: Societal challenges – Europe In A Changing World: Inclusive, Innovative And Reflective Societies; Health, demographic change, and well-being; food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bio-economy. As we can notice, both topics are similar, which confirms the rich–club finding in the system. Policy incentives applied within the new framework program did not change the dynamics notably. The system is still well connected.

2.3.6.2. Knowledge expansion: community fragmentation from one program to the next one

The second phenomenon we call a knowledge spread of the FP7 in the H2020 program. This process underlines the network's tendency to react to the changes happening within the system more drastically. Previously based on the FP7 in a specific cluster, under a new call in H2020, these actors are linked to separate and enter new collaborative dynamics. Such actors' role can be double: they provide cross-cutting services that support the R&I process (for example, dissemination and communication service) or are specialised in a field that was re-called by the new H2020 Calls R&I issue.

The extreme cases of this phenomenon are represented by the confusion matrix's horizontal lines marked by the light blue color. In this case, actors from FP7C1 contributed to 15 communities in H2020, FP7C3 – to 12 communities in H2020, and from FP7C6 to 12 communities in H2020. In total, 18 H2020 communities are included in the confusion matrix, so the presented numbers demonstrate that the previous program spurs newly developed H2020 communities. As we see in the below-presented Fig. 2.24, all three communities have significant differences. In the case of the FP7c1 private for-profit companies and research organisations are leading in this cluster. Their participation is linked to the in ICT, Transport, Nanosciences, Materials, Nanotechnologies, and Production Technologies (including SME instruments) calls. The second cluster (FP7C3) is represented almost by the equal number of the PRC, HES, and REC. These actors balance their participation within the programs linked to Calls, which invite developing scientific competencies and researchers' mobility and health calls. This demonstrates the capacities of the communities to mobilize their know-how regarding the actors and balance participation of actors in the network as a follow-up action for a response to the mentioned calls.

Meanwhile, positions are changing in the FP7c6, where HEI is dominating, the REC supports their work, and partly – PRC knowledge actors. These are the actors who contribute most to the knowledge development within the ICT calls. The specific character of these communities is hidden in the list of the countries involved in it. Comparing with the third community, the second one has a visible need in cooperation with non-EU countries: the United States of America (5 pax), New Zeland (1 pax), Georgia (1 pax), and Hong Kong (1 pax), creating a stable link for cooperation within specific calls and actors passing from the FP7. Also, one Lithuanian and Island partner are passing from one program to another. Meanwhile, the first community has a strong link that exists with Russia (23 pax). Leading positions (Top5) in these three communities are represented by innovation leaders: FP7C1 – Germany, Italy, France, Spain, and the United Kingdom; FP7C3 – Germany, the United Kingdom, Italy, France, and Spain; FP7C6 – Germany, the United Kingdom, France, Greece, and Spain.

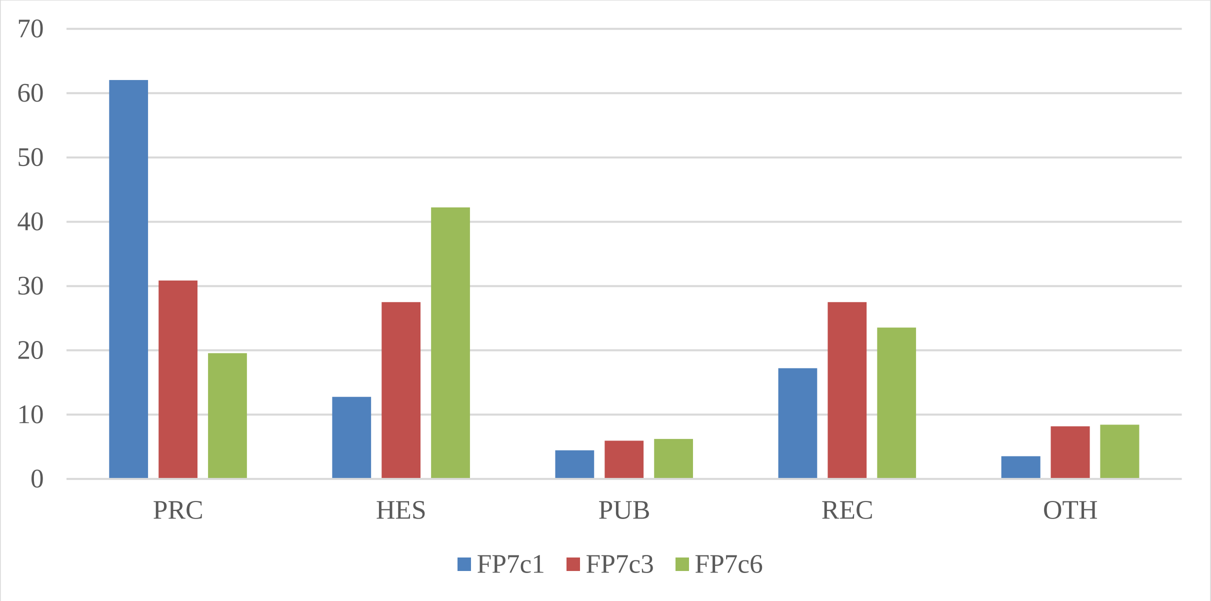


Fig. 2.24 Actors /type in three FP7 communities (%)

We can underline that such an expansion is strongly concentrated on regional clusters and fulfilled by the contribution of moderate innovators and associated countries, which act as the leaves in the networks that spur the R&I system by specific regional knowledge.

2.3.6.3. Knowledge aggregation: community formation

The third and the last phenomena is called – knowledge aggregation. This characteristic underlines the network's tendency to emerge, knowledge actors, that were split in FP7 become reunited in the new H2020 calls. In other words, this is the opposite effect of the knowledge expansion presented in 2.3.6.2.

Extreme cases that represent such behavior are visible in three H2020 communities presented in the confusion matrix. They are H2020c8, H2020c9, and H2020c11 (marked by light green color in the confusion matrix). Twenty FP communities from the total number of 40 contributed to the H2020c8, 18 – to the H2020c9, and 13 – to the H2020c11.

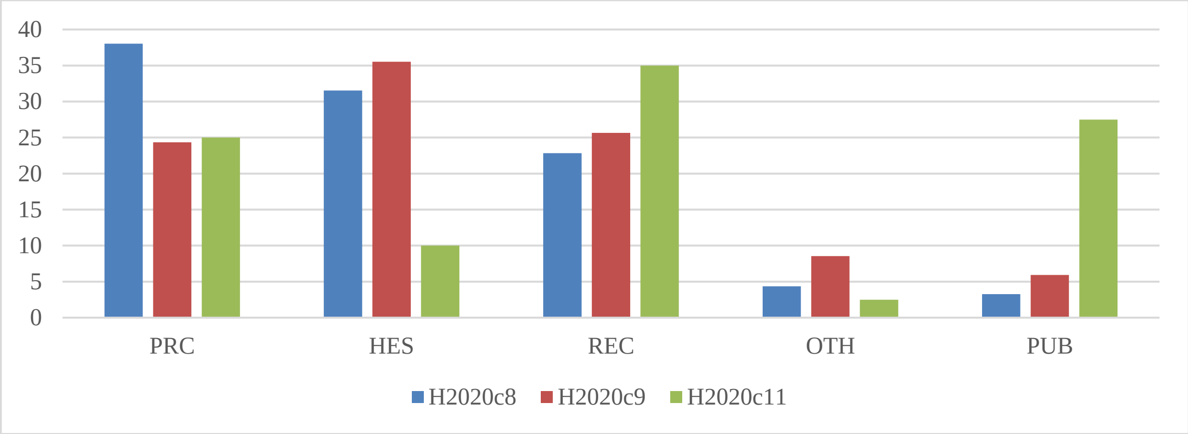


Fig. 2.19 Actors /type in three H2020 communities (%)

Three different communities have a diverse logic of link creation within the group. In the case of the H2020c8, leading positions are taken by private, higher education, and research organizations. In the second case, the leader is HES; equal participation is guaranteed between PRC and REC. In this case, another type of organization (CSOs, SMEs, others) also provides a significant contribution, adding different innovation potential into the system. The third case is represented by the REC and PUB's domination, with a minimal contribution of the HES and OTH. Knowledge aggregation in these cases is associated with the calls, which are linked to the calls as Marie Skłodowska-Curie Actions, leadership in enabling and industrial technologies, research infrastructures, low-carbon energy, and others.

Knowledge aggregation example demonstrates considerable diversity within the countries in the mentioned clusters but with significant domination of the classical innovation actors. The top 10 countries in the communities are: (i) H2020c8: The United Kingdom, Germany, Finland, Spain, France, Sweden, Slovakia, Romania, Switzerland, and Austria; (ii) H2020c9: Germany, Spain, France, the United Kingdom, Italy, the Netherland, Romania, Portugal, and the Czech Republic, and (iii) H2020c11: France, Belgium, the United Kingdom, Italy, the Netherland, Greece, Austria, Lithuania, Germany, and Poland. In the case of the third group, no links with the non-EU countries are visible. In the first case, meantime links exist with Japan, South Korea, Israel, Ukraine, and Uruguay; in the second case, with the countries: Turkey, Jordan, Uruguay, and Taiwan.

2.4 CONCLUSIONS AND DISCUSSIONS

To introduce innovations and reach leading positions in R&I, countries and regions apply a series of policies and strategies to foster collaborative linkages between knowledge actors. This is partly because science, technology, and innovation have become more collaborative (at a local level) due to global competitiveness (Chen *et al.*, 2019). Scholars questioned the contribution of such inter-organizational networks to innovations and analyzed this complex system within diverse frameworks (national, regional, international), applying different research prisms: geographical composition, knowledge flows between actors, structures, and patterns of the networks and others. Accordingly, these studies attracted the attention of practitioners and policymakers functioning is such a complex R&I network. The present study seeks to fill the fragmented gap that appeared in assessing the policy impact on the complex R&I networks. In particular, the aspects the research has focused on conducting analysis on highly competitive and heterogeneous inter-organizational networks established within the two latest EU Framework Programmes: FP7 and Horizon 2020, this work contributes to deepening scholars and policymakers understanding of R&I network's dynamics stimulated by newly introduced innovation policy incentives within H2020.

We apply network analysis as a research instrument to identify and measure the fundamental structural properties of collaboration networks. At the mesoscopic level, resulting communities for both FP7 and H2020 networks have been compared, looking for changes in collaboration patterns. The work provides an in-depth analysis of the framework–program networks' characteristic changes at the mesoscopic level by tracking the shifts that appeared in this complex system passing from the FP7 to H2020. This work claims that the Horizon 2020 network intends to be more clustered and supported by new actors' sporadic participation in this complex system under a policy change. Meantime, three different characteristics of inter-organizational connections define network dynamics within the EU R&I ecosystem.

Consequently, the chapter expands research knowledge regarding the policy impact on the EU R&I inter-organizational networks; for instance, their stronger concentration, persistence, and the rich-club phenomenon; and establishing links and knowledge exchange within this complex system and the EU innovative performance globally.

2.4.1 Research findings

As stated publicly, implementing Framewor k programs, the European Commission targets knowledge excellence hubs' creation and sustainability at the regional level. In other words, it promotes cluster policy, which supports interaction in R&D among co-located organizations (Graf and Broekel, 2020). Such hubs' stability supports the creation and extraction of value (Dhanaraj and Parkhe, 2006) for R&I. However, presented homophily in the network does not mean that they do not change (Easley and Kleinberg, 2010). Exogenous and endogenous factors can stimulate slightly or shape the structure of the networks drastically. Accordingly, the organizational agency should demonstrate a solid ability to recognize such changing factors and the resulting patterns in the collaboration network. This approach will support selecting organizational behavior strategies (Koka *et al.*, 2006) and collaboration with the partners, who can improve strategic organizational flexibility regarding activities, resources, and technologies (Bierly and Coombs, 2004).

In this work, we interpret the EU R&I innovation policy incentives as an exogenous factor and occasion for network (re-)structuring, which fosters the appearance of new logic for links' creation among the R&I actors of the inter-organizational network, also, underlying common behavioral patterns within the system. The comparisons of network partitions at the mesoscopic level stress the appearance of the minor changes in the composition of the network's actors and architecture passing from FP7 to H2020. Notably, the new R&I system (H2020 network) becomes more diverse due to the new entries (mostly OTH and PUB types of actors), making their role more essential in this network than in the FP7 ones. We hypothesize that such diversity in the actors' composition is linked to the context of the program's calls linked to glocal issues, and this acts as a research hypothesis for further works of the scholars. Previously in this work, it was stated that sustainability is mentioned periodically in the new calls. In line with the extant research literature, we know that implementing sustainability requires shared actions with local formal (for example, municipality) and informal (for example, CSO) actors, reflection on glocal challenges, and co-creation of innovations for the existing context. Our results suggest that such actors' knowledge is more visible in the new EU R&I network, and the network demonstrates a transitional behavior (Kastrinos and Weber, 2020). However, we also argue that such participation is sporadic. The overall network of collaborations within the H2020 program demonstrates the structural embeddedness of actors, which are more concentrated (based on triangles and broader structures, such as communities) compared with the FP7.

Furthermore, prominent actors (hubs) in the network display a tendency to collaborate more among them than with others within the new program. This evidence supports the conclusion that an implicit outcome of the new policy is knowledge concentrated in a few clusters of organizations that reflect "excellence" at the EU level. The analyzed data indicate that the EU R&I system represents a "locked-in" innovation system, with solid domination of the rooted EU countries and organizations, but with an enriching list of the non–EU stable actors' H2020.

New actors enter the collaboration system within the H2020 program, but their contribution is sporadic, likely just occasionally due to diverse factors**.** Our findings partly support the research carried out by Arnold *et al.* (2005) for the FP4-6, who demonstrate that many actors in these networks are short-lived, but there is a core of stable participants within the evolving networks. In particular, we demonstrate that such a tendency is reinforced in the H2020 program. Concerning the sporadic behavior of most of the actors involved in the last FP, we propose several discussion inputs.

Extant literature underlines that innovation requires new knowledge and a diversity of actors in the process. Our results show that in FPs, there is a tendency for “causal” interaction between new and classical R&I actors, as the program’s mission is the creation of excellence centers in Europe. Newly proposed R&I mechanisms within the H2020 program, on one side, stimulate newcomers but, on the other side, make the system more unbalanced. We find the behavioral tendencies of the actors in H2020 similar to those demonstrated by the Herfindahl indexes. It seems that excellence partners will be supported and will have more chances to fund their R&I proposals, rooting the rich-club phenomena in this social complex system **(**Colizza *et al.*, 2006)**.** The newly launched Horizon Europe program provides a reliable funding mechanism to stimulate SMEs and start-ups in R&I. The newly established European Innovation Council provides a ten bln EUR budget for the innovations proposed by mentioned actors. We see this idea as just partly acceptable. Even being a powerful instrument for the new R&I actors, it creates a gap in funding schemes. Indeed, “classical actors” will keep being more and more supported by R&I funding (in Horizon Europe) due to the rich-club phenomenon, newcomers will be supported by the unique instrument (EIC), but what will happen with the “medium” R&I organizations? We see their actions as unbalanced in the EU R&I, as they will not be evaluated “equally” compared with the excellence partners and newcomers. They will try to link with the “classical” actors and contribute to R&I but will likely have insufficient access to the R&I funds compared with the two previously mentioned groups. In other words, it appears that the funding of new actors will come at the cost of under-funding medium partners to realize their ideas. The research conducted in this study suggests that such an imbalanced mechanism, which is formalized within the new R&I program, will bring “medium” R&I organizations to be progressively marginalized in the EU funding scheme for R&I.

To finalize, to evaluate the impact of the innovation policy in Horizon Europe on the R&I network and compare it with the H2020, we need a minimum five-year period of time. In this period, dynamics can be evaluated systematically. However, anticipating, we can state that the diversity of mechanisms reflects the diverse R&I actors' needs.

The analysis of the evolution of communities of collaborating organizations across the two programs shows that three patterns of evolution characterize these networks under the policy change: *(i) persistent knowledge stability, (ii) knowledge spread, (iii) and knowledge aggregation.* The first behavioral pattern is linked to the actors' stability passing from FP7 to H2020, keeping the knowledge concentration between two program clusters, rooting the system's rich club, and reinforcing the prominent role of "classical" actors. The second one can be interpreted as a call for the FP7 knowledge spread in the H2020 program. This process underlines the network's tendency to react to the system's changes more drastically. Previously based in a specific cluster within the FP7 program, under a new call in H2020, these actors split up to participate in different clusters and enter new collaborative dynamics. The last one presents the network's tendency to merge diverse FP7 clusters of institutions into a single cluster in the H2020 calls. Basically, all three dynamics are fostered by the EU classical innovation actors (Germany, Spain, Italy, the United Kingdom, and France). At the same time, they are demonstrating a more robust link creation with non-EU countries. This underlines the fact there is no stability between the EU and non-EU actors' links, as they are developed based on the actual need described by the Call. In this case, cooperation is based on the past link that disappeared for a time and is reconstructed under a specific call for action. These transition activities amplify four types of links in business networks presented by Blau[27] in 1964 (Ahuja *et al.*, 2012): affective, referential, hierarchical, and market ties. Considering the R&I sectors, we claim that more static EU links are represented with the Marie Skłodowska-Curie Actions, Food, Agriculture, and ICT. H2020 calls in Transport, ICT, Transport, Nanosciences, Materials, Nanotechnologies, and Production Technologies (including SME instruments), and ICT demonstrated knowledge expansion and joining actions with some non-EU actors (for example, the USA, New Zealand). Three different communities have a diverse logic of link creation within the group. In the case of the H2020 community 8, leading positions are taken by private, higher education, and research organizations. In the second case, the leader is HES; equal participation is guaranteed between PRC and REC. In this case, another type of organization (CSOs, SMEs, others) also provides a significant contribution, adding different innovation potential into the system. The third case is represented by the REC and PUB's domination, with a minimal contribution of the HES and OTH. Knowledge aggregation in these cases is

[27] Blau, P. M. (1964). Exchange and Power in Social Life. John Wiley and Sons, New York.

associated with the calls, which are linked to the calls as Marie Skłodowska-Curie Actions, industrial technologies, research infrastructures, low-carbon energy, and others. In these communities, we noticed the stability of links with actors from Japan, South Korea, Israel, Ukraine, Turkey, and others.

We agree with the statement of Polidoro *et al.* (2011), who argue that joint partners in inter-organizational relationships are essential for a beneficial social mechanism. However, we underline that the FPs, in general, favor some specific types of actors. We doubt that such heterogeneous and reach (based on the number, type of actors, and funding) network can fully take advantage of the EU ecosystem based on the "favored" actors' knowledge. In this sense, the innovation policy incentives passing from one program to another sustain a reach-club phenomenon, empower self-reinforcing mechanisms, and structural inertia, both at the organizational and country level. So, two objectives of Europe: (i) creation of the R&I excellence centers and (ii) taking a leading position in worldwide R&I, should be emerged based on a policy framework that partly contains essential knowledge for the region and absorbs innovative thinking at the glocal level. Based on that, our work also provides policy application, which we discuss in the next section.

2.4.2 Policy application

Our research has substantial public policy implications because R&I networks are known to influence EU R&I evolution. The study of network dynamics is another useful tool for evaluating the possible impact of policy interventions on the EU's R&I potential.

As we know, the evaluation mechanism of the projects takes into consideration several factors, which are mainly: (i) Excellence; (ii) Impact; and (iii) Quality and efficiency of the implementation. Some of the evaluation criteria are linked directly to the competencies and resources of a partner of the consortium. The evaluators know the partnerships at the beginning of the evaluation process. This knowledge substantially impacts reinforcing the reach club effect at the EU level and partial lobbying. However, the research literature underlines that innovativeness can be hidden in entrepreneurial ideas. Our results demonstrate that classical program actors lead in the EU FPs, leaving newcomers at the network's periphery, acting as leaves. This supports the sustainability of excellence actors within the system but limits new knowledge flows. We propose to review the proposal's evaluation process to balance the weights of new actors and open broader possibilities for them, spurring new knowledge entries. We believe that adopting a coding of the partners during the project submission period and evaluating the innovation potential would stimulate new actors' growth and limit the lobbying within this statical system. Anonymity at the "impact" evaluation would guarantee the broader openness of the R&I program for new actors. New actors could establish new supporting relationships within the network, stimulate the business environment, and reshape the ecosystem, fostering and balancing the diversity in a complex system and moderating the rich-club phenomenon for R&I.

The EU strategic documents demonstrate that cluster building and expansion are now widely accepted as key pillars of local development policies. Naturally, the rich-club effect is an expected outcome of the R&I networks under the paradigm of "excellence" promoted by the EU. However, we argue that moderating the rich-club effect may benefit R&I, and the new innovation policy should address this issue. Indeed, the discussed dynamics demonstrate that after decades dedicated to creating regional specializations and fostering a rooting process of the knowledge hubs at the EU level, the EU innovation policy may introduce some novelties. Indeed, we are all experiencing the consequences of the fact that, in a crisis, the COVID-19 pandemics, the EU was the only big economy unable to develop its vaccine, which makes it apparent that innovation policy should be improved in Europe.

On the one hand, the objective to create "excellence" in R&I is to reach its target from the social perspective, i.e., increasing assortativity and reducing the funding to smaller (classical) innovators. On the other hand, the outcomes of concentrating funds and knowledge in the "excellent" (classical) actors do reflect such excellence. We need to look for ideas on keeping smaller R&I actors integrated into the system and benefit from them. The reader can state that partly, this is addressed by the European Structural and Investment Funds. However, researchers know how diverse and challenging these funds' governance is and the delays in using these funds at the local level due to a bureaucracy in managing the various schemes, which is "killing" knowledge actors' wiliness to use these funds. Instead, the adaptation of central policy ideas to local needs and supporting best practices are promising pillars, as China demonstrated during the last decade entering in top R&I countries.

2.4.3 Limitations

This research is subject to several limitations, although we have tried to make this analysis as comprehensive as possible. Firstly, although the CORDIS database is one of the complete sources of the projects and actors funded by the EU Framework Programmes, it should be stated that some data is missing for the development of the knowledge base. In particular, no information about unfunded projects and the corresponding partnerships was available. The European Commission protects this data based on the Personal Data Protection Law. In our opinion, this data is essential to finalize the development of more representative inter-organizational collaborative networks and make conclusions regarding their dynamics in the R&I ecosystem. This is why the analysis of our results should be treated by taking into consideration the mentioned limitation. It is essential to consider that these R&I networks are created based on the competition element. Only winning organizations are included in the network. This is a specific shortcoming that limits our analysis of the policy effect on innovation networks. Secondly, no qualitative research method was applied in this research. The future research should provide qualitative insights to enrich this study, for example, to implement in-depth interviews with the coordinators and participants of the projects to understand their motives for creating or entering the project consortium. It is essential to evaluate which limitations in FP7 and opportunities in H2020 the knowledge actors faced. Finally, our work concentrates on a particular R&I policy framework, and in the case of the other framework, future studies are needed to validate the outcomes of the present work.

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CHAPTER 3. COVID-19'S IMPACT ON EU R&I HEALTHCARE PUBLIC-PRIVATE PARTNERSHIPS

Keywords: Public-private partnerships; Healthcare sector; Coronavirus (COVID-19), Path dependence; Network analysis

3.1 INTRODUCTION

The global spread of the COVID-19 virus has caused widespread social and economic threats and challenged healthcare systems. While the World Health Organisation (WHO) recognizes this virus as the global problem of this century and invites for proactive, collaborative, and strategic public-private partnerships to overcome this virus outbreak, researchers call the COVID-19 a catalyst of change (Mention, Ferreira, and Torkkeli, 2020; Swaithes *at el.*, 2020). They propose to reflect on the partnership processes which are entering into the force under the urgency conditions. Meantime, the management literature confirms that crisis creates new opportunities for business and society (Mention, Ferreira, and Torkkeli, 2020) and contribute to:

- *Innovations and inventions* (Ucaktürk, Bekmezci, and Ucaktürk, 2011). Many innovations are made during the second world war: plasma, penicillin, pressurized cabins, computer, and others. This happened due to a sense of urgency to defend – be protected, which fostered collaboration between local actors and leading governmental support for crisis management (Hoyt, 2006).
- *Reflection on processes and their optimization.* Mather (1986) states that the Three Mile Island Accident's innovation process's output is improved communication management in general (underlying the importance of written communication in management). Ineffective management communication procedures caused the accident. The lines of communication, in essence, did not support the decision-making process. The author argues that, in particular, stakeholders' role was essential in this crisis management. Following the accident, nuclear power stations were not built without extensive public participation in the decision-making process.
- *Stimulate the learning process.* As we know, pandemics and big disasters rarely point out an essential feature of lessons learned due to such crises – as a rule, lessons are learned by one generation. Still, this knowledge is usually actively applied by the next. This is visible based on Chernobyl and Fukushima examples and modern concepts for

the management of severe accidents. Therefore, the transfer of accumulated knowledge about the lessons learned as a result of such crises to subsequent generations is an important task (Большов, 2016).

- *Create stronger links and reflection with stakeholders for R&I. F*or example, after the Three Mile Island Accident, decisions of a nuclear power plant siting and construction cannot be implemented without consultation with local stakeholders. This process is avoidable (International Atomic Energy Agency[28], 2006).

As we see, the innovation process triggered by significant events is determined by the implicit need to cope with an organizational readiness to accept the risk and to be open to new partnerships. Specifically, in general, the concept of natural disaster is associated with an event that has an extremely low probability of occurring – a sudden event – and determines severe consequences at a regional, continental, or worldwide level. One piece of information to consider is that catastrophes usually belong to categories of events (accidents, virus spread) that are pretty common. Therefore, trying to reduce the probability that such events occur is very hard if not unreasonable. Consequently, to minimize the risk associated with such extreme events, i.e., the product of probability and damage, the only effective approach is to develop mechanisms, procedures, drugs, controls, and others to mitigate the consequences of a catastrophic event. However, such an approach implicitly calls for ingenuity, social and management changes, and extremely demanding resources and effort. In other words, such an approach includes facing significant challenges and a willingness of countries, governmental and trans-national organizations, the "public" in one word, to invest significant resources. The joint presence of a major challenge with many facets and the aforementioned willingness to invest by the public represents the gap that, according to Russell and Faulkner (2004), entrepreneurs will find. From a quantitative point of view, such a vast gap occurs whenever the distribution of the damage (death toll, property damage) for a given category of events (accidents in the energy sector, crashes of financial markets, plague outbreaks) is a power law. Indeed, at the difference with other distributions, such as the Normal distribution, extreme events' probability is minimal but not negligible.

Furthermore, the need to cope with multi-facet interdependent challenges makes it effective and even spontaneous to increase the degree of coordination among the actors involved concerning everyday business. That explains, at least in part, the formation of private-private and private-public partnerships. According to Bierly and Coombs (2004), such

[28] International Atomic Energy Agency, https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1276_web.pdf

partnerships can help an organization preserve a superior competitive position in the market.

The European Commission estimates the economic impact of the COVID-19 could be more significant than the financial crisis in 2008. Meantime, the International Monetary Fund stresses the decline of the economy as the worst since the Great Depression of the 1930s. As we see, the spread of COVID-19 (Fig. 3.1) has severely impacted worldwide territories and the healthcare sector in particular. Such an immediate exogenous shock fostered stronger cooperation between public and private bodies at the EU level, aiming at finding a new operational framework for a sustainable future. Facing the COVID-19, many research funding organizations have opened specific calls to fund public-private partnerships (PPPs) for R&I that aim to address this outbreak. These calls include financing for research focused at actively combatting the SARS-CoV-2 virus and the COVID-19 disease it causes, as well as study into the pandemic's societal and economic effects. According to Casady and Baxter (2020), the PPPs have all potential to harmonize strategic objectives mobilizing both public and private resources to build resilience against global pandemics. Pauchant and Mitroff (1994) describe a crisis as an interruption that influences a general framework and undermines its fundamental presumptions, abstract self-appreciation, and existential center. In such conditions, the PPPs need to take fast strategic actions to mitigate undesirable developments and find solutions to arising problems (Burnett, 1998). In the healthcare sector, the PPPs can forecast the new dynamics of the outbreak, boost diversity in public health response, and support well-being (Casady and Baxter, 2020).

In other words, a crisis/shock becomes a trigger mechanism for accelerated growth, changed attitudes, and a new competitive edge (Barker and Angelopulo, 2005). The pandemic, continuing to be a concern for national and international public health, pushes rapid changes on the market and establishes PPPs at the regional and organizational level, aiming to minimize total infection cases, total mortalities, and the impact on public health services. This context applies changes in creating organizational ties: how an institution performs and the "choices of institutions that societies choose to govern themselves" (Bednar *et al.*, 2015). Therefore, these conditions may rapidly transform organizational capabilities to create necessary ties. This leads to the creation of new organizational paths to partners and key stakeholders and new product and service offerings.

Even more, the outbreak invites an organization to balance the innovation potential and the risk-sharing with "old" or totally "new" partners. This issue is more specific in the healthcare sector, as the sector is represented by a strong cluster of organizations functioning as a complex system. As so, it requires an understanding of dynamic interrelations among various elements ("heterogeneous agents at various levels, contact structures between agents, adaptation, nonlinear dynamics, and stochasticity") (Diez Roux, 2011, p. 1627). Furthermore, this system is in itself complex, requiring the creation of new paths to remain stable.

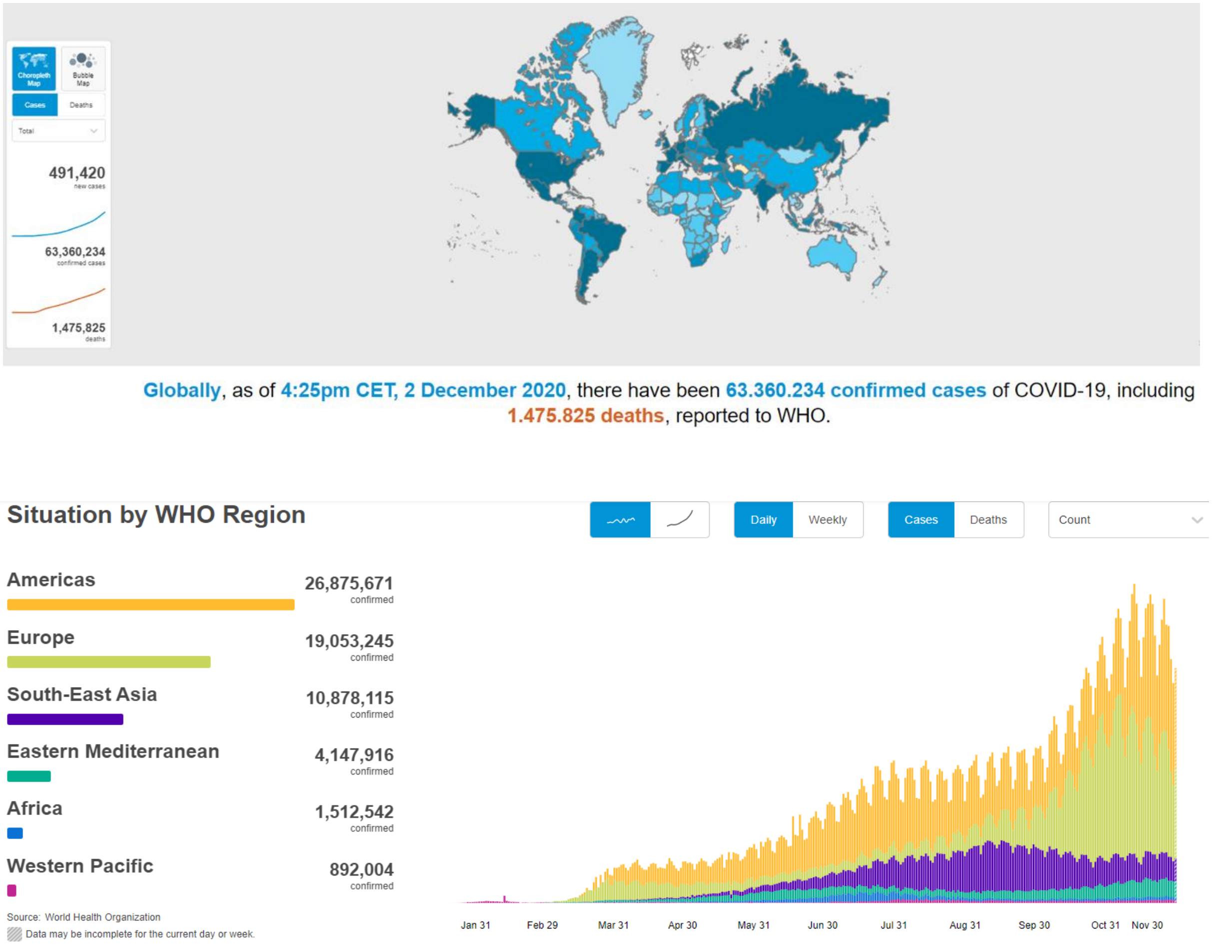

Fig. 3.1 COVID-19 statistics in the World[29]

Thus, this part of the thesis presents research on the evolution of partnerships in healthcare R&I networks under exogenous shock and examines:

(i) *Which evolution process(es) do these types of networks manifest?*

(ii) *Does the emergency policy influence such an evolution process?*

(iii) *Does urgency play a role in shaping such an evolution process?*

The current COVID-19 pandemic and the EU R&I framework program favor the test of these research questions. As so, this chapter is organized as follows. Section 3.2 presents an overview of the literature and the theoretical framework regarding the evaluation of the

[29] Source: World Health Organization, https://covid19.who.int/

collaboration networks and the role of the public-private partnerships in the healthcare sector. Section 3.3 explains the empirical methodology and description of the results and case studies. Section 3.4 concludes the chapter with the conclusions, and Section 3.7 finalized this work with the input regarding limitations and input for future research.

3.2 THEORETICAL BACKGROUND

Freeman in the early 90s stated that networks are essential for innovativeness, information acquisition, and processing, as they help to solve the biggest challenge of innovation "to process and covert information from diverse sources into useful knowledge about designing, making and selling new products and processes" (Freeman, 1991). Due to this, an ability to interpret network dynamics is crucial for successful organizational performance, as such a complex system, as a network, should be evaluated through the connectedness level between actors and level of behavior – actions and formation of links, which impact an outcome of this system (Easley and Kleinberg, 2010).

3.2.1 Evolution of Collaboration Networks

In organizational networks, the logic of link formation changes under the influence of endogenous and exogenous factors, which can be called stress or/and shock[30]. Such a factor becomes a measure of restoring force per unit area. Shock plays the role of a strain for a network, and as such, it contorts the entire complex system.

The academic literature provides a comprehensive list of studies regarding the transformation of collaboration networks. According to Pelacho *et al.* (2020), the work of Barabâsi *et al.* (2002) is recognized as one of the main contributions of the field. In the mentioned article, the collaboration networks play a role in a prototype of evolving networks, focusing on the network's dynamics and evolution. The most famous studies in this area are linked to the interpretation of scientific collaboration networks' structure, particularly to the links between scientists and scientific papers' production (Newman, 2001; Barabâsi *et al.*, 2002; Newman, 2004; Wager, 2005, others). This method is also applied in the development of a knowledge base regarding specific concepts; for example, Pelacho *et al.* (2020) research the citizen science expansion and evolution in terms of the properties of the graphs, which provide an in-depth view on links between co-authorship and the networks of collaboration. Other authors concentrate on analyzing the networks' evolution based on the patent analysis as an

[30] In this part of the thesis words shock and crisis are used as a synonym.

outcome of scientific collaborations (Balland and Rigby, 2017; Gao *et al.*, 2018; Angelou *et al.*, 2020). For example, Balland and Rigby (2017) constructed the city-tech knowledge network, using patent documents from the United States Patent and Trademark Office for the years 1975 to 2010. They find out that complex knowledge tends to be produced in relatively few places and, once assembled, this knowledge is not easy to move. This means that low complexity creates an experience that is easier to roll over space.

Meanwhile, we follow the way addressed by Tóth *et al.* (2018) and Balland *et al.* (2019), describing the evolution of R&D networks based on unique data of collaborative projects. Both authors research the R&D network dynamics to answer whether these networks represent innovation lock-in in the regions. Tóth *et al.* (2018), using the inventor-inventor collaborations on patents that the European Patent Office has registered in the 2006-2010 period, pointed out that triadic closure is a common form for new inter-region co-patenting collaborations. Meanwhile, the most influential factor for co-patenting maintenance is geographical proximity. All these conclusions show that the inter-regional cooperation network under the study is an intensive process of finding new partners, where it is possible to find a partner between your partner's network and reduce the uncertainty.

Furthermore, Balland and Ravet (2019) describe the evolution of the EU research network across countries based on R&I projects (the Framework program (FP) - FP6, FP7 and the first four years of implementation of Horizon 2020) and present the following outcomes. There is a spatial division across countries concerning the nature of their participation. However, a collaborative research network is characterized by stability during 2003-2017, which underlines its reproducing behavior. The results present that some countries (EU-15 countries: Austria, Spain, Denmark, Finland, Greece, the U.K., the Netherlands, Italy, Portugal, France, Germany, Belgium, Sweden, Ireland, and Luxemburg) appear to be more engaged in framework program parts that are considered to be more involved, while such countries as Romania, Croatia, Slovakia, Poland, Hungary, Latvia, Lithuania, Czech Republic, Estonia, Slovenia, Bulgaria, and Cyprus, participate in less complex parts of the program. Moreover, EU-15 countries are more active in the framework program and regularly play the hub's role in the R&I network.

All of the studies contribute to the research on understanding regards the evolution of collaboration networks. Additionally, both the authors' latest mentioned groups underline that the Jaccard distribution explains a power-law in a network. This index, which compares the structural distance between networks from one time to the next, is a powerful tool for studying network evolution. We will use this index to assess the similarity of the connections between the healthcare projects in FP7 and H2020 and between the H2020 and special COVID-19 R&I calls.

3.2.2 Exogenous shock and complex networks

The recent year and last decades showed that modern societies could not be fully protected from systemic crises. Such exogenous threats, as *financial crises* (financial crisis in 2008), *disasters* (Gorkha earthquake in 2015, the tsunami in Japan in 2011), *terrorism* (terrorist attacks in the USA of September 2001 or Egypt in 2019), *drug contamination* (Tylenol incident in 1982), *and in particular pandemics* (HIV in the 1980s, H1N1 in 2009 and COVID-19 in 2020) strongly affect the socio-economic development of countries and regions, and create, among others, a wide range of adverse economic and social consequences. All this is strengthening an understanding of exogenous shocks' core: unpredictability, complexity, and uncertainty. However, at the same time, such crises trigger innovation ecosystems and, overall, business.

Several studies highlighted that shocks' internal and external effects might determine radical transformation in social structure and inter-organizational networks (Corbo, Corrado, and Ferriani, 2016) and may determine path dependence in the underlying processes (Page, 2006). Indeed, to understand the functioning of many complex systems and how diverse organizations self-organize versus external factors, it requires distinguishing between endogenous and exogenous shocks (Sornette *et al.*, 2004). In the academic literature, the exogenous shock is also called a crisis, global change mechanisms (Widmaier *et al.*, 2007) or *force majeure* event (Casady and Baxter, 2020).

Widmaier, Blyth, and Seabrooke (2007), in work "Symposium on the Social: Construction of Wars and Crises as Openings for Change: Exogenous Shocks or Endogenous Constructions? The Meanings of Wars and Crises" state that an *exogenous shock* is a part of a mechanism, which creates shifts in economic structures and the distribution of capabilities, and questions the "roles of agency, uncertainty, and ideas in advancing change." "Exogenous peaks occur abruptly and are followed by a power-law relaxation, while endogenous sales peaks occur after a progressively accelerating power-law growth followed by an approximately symmetrical power-law relaxation which is slower than for exogenous peaks (Sornette *et al.*, 2004, p. 228701-1)." Even more, to understand "a real effect of the crises in terms of their material effects, the agents' intersubjective understandings must first give meaning to such material changes (Widmaier *et al.*, 2007, p. 748)".

Due to the exogenous shock's uncertainty, a configuration of organizational ties within a system is inevitable. Lagatec well describes the overall effect of a crisis on the complex system (1997). The author underlines that organizations are poorly prepared to manage a crisis; once a crisis is entering into force, it requires significant learning efforts from the agents. They usually rely on networks and expand cooperation without maintaining the stable relations they previously managed. This transformation happens very rapidly and encompasses many actors, at the same time shaping all the organizational system and requiring new management practices, “based on open exchanges of ideas and work done as teams on ambiguity, shocks or networks.” In particular, a shock may modify a system and impact the rules of affiliation and ties formation in a network (Powell *et al.,* 2005). Corbo, Corrado, and Ferriani (2016) citate Gulati and Gargiulo (1999) and Madhaven *et al.* (1998) and underline that external crises may foster networks to reproduction and opening to new paths for a transformation.

Moreover, Corbo, Corrado, and Ferriani (2016) state that an external shock engenders a blended logic of tie creation and stimulates the clustering tendency of a network. Also, Sornette *et al.* (2004) underline that a shock may lead to a similar power-law within a system (Sornette, Deschâtres, Gilbert and Ageon, 2004). In any case, it is critical to understand that crises offer opportunities for change by allowing social agents to explain events and encourage innovation, particularly at the policy level (Widmaier, Blyth, and Seabrooke, 2007). Liebowitz and Margolis (1995) underline that external shocks may force unknown parameters, shaping all path dependence logic between actors. Thus “some initial endowment alone could never tell us very much about the eventual path of real economies over time (p. 223)”. Finally, an exogenous chock creates acceleration processes in national and international collaboration regarding the uptake of innovation, product design, and new business models (Swaithes *et al.*, 2020).

To examine the impact of such a phenomenon on an inter-organizational network, we concentrate on healthcare PPPs and investigate the history dependencies within them and how an exogenous shock such as COVID-19 fosters an evolution of the complex R&I network.

3.2.3 Types of historical dependence in complex network evolution

Foss (2020), making a citation of Thompson (1967), stresses that organizational theory suggests that actors’ interdependencies may have triple interpretation: as pooled, sequential, and reciprocal, even more, organizations may decide on the intensity with which they manage this interdependency. A more depth understanding of this is developed by Page (2006). According to the author, three types of history dependences can provide a rich view of a complex system. In particular:

- “*a state dependence*, where the paths can be partitioned into a finite number of states which contain all relevant information*;*

- *a path dependence*, where the path of previous outcomes matters"*;*
- *and a phat dependency,* in which the sequence of events in the path is important but not the order in which they occur.

Furthermore, to add, Liebowitz and Margolis (1995, p. 207) underline that a path dependence can be present in three forms: i) "sensitivity to starting points exists but has no implied inefficiency first-degree path dependence"; ii) "second-degree path dependence, sensitive dependence on initial conditions lead to outcomes that are regrettable and costly to change"; and iii) "third-degree path dependence - sensitive dependence on initial conditions leads to an outcome that is inefficient—but in this case, the outcome is also remediable." While Vergne and Durand (2010) underline that path dependence is a mechanism that connects the past and the future and is a central construct in organizational research. However, authors are still questioning "why path dependence sometimes occurs and sometimes not, why it sometimes led to inefficient outcomes and sometimes not, how it differs from mere increasing returns, and how scholars can empirically support their claims on path dependence (Vergne and Durand, 2010, p. 736)." The authors also point out that previous research has tended to treat path dependency as both a process (i.e., history unfolding in a self-reinforcing manner) and an outcome (i.e., a persistent state of the world with specified attributes, known as "lock-in"). Still, in any case, history is a dominant factor since the order of events impacts values. However, according to us, *a borderline dependence* is also possible, where a system demonstrates equal presence, on some combinations, of earlier mentioned history dependencies.

Thus, identifying conditions that are sufficient for choices and outcomes in the past and to influence the present may support the enrichment of theoretical framework on inter-organizational network dynamics and propose a better understating of four outcomes caused by path dependence of a complex system: "increasing returns, self-reinforcement, positive feedbacks, and lock-in" (Table 3.1) (Page, 2006).

Table 3.1 Four outcomes caused by a path dependence proposed by Page (2006)

Impact	A meaning proposed by Page (2006)
Increasing returns	More a choice is made, or an action is taken, the greater its benefits.
Self-reinforcement	Making a choice or taking the action puts in place a set of forces or complementary institutions that encourage that choice to be sustained.
With positive feedbacks	An action or choice creates positive externalities when other people make that same choice.
Lock-in	A choice or action becomes better than any other one because a sufficient

Impact	A meaning proposed by Page (2006)
	number of people have already made that choice.

The path dependence literature in social studies is based on mathematical literature of nonlinear dynamic models, known as well as chaos or complexity models, for which a key finding is "sensitive dependence on initial conditions …and with an outcome a property of lock-in by historical events" (Liebowitz and Margolis, 1995, p. 206). Some specific research fields point out that, for example, "path dependence arises specifically because of powerful network effects and high switching costs" (Aghion *et al.*, 2019). According to them, the economic theory proposes that a pathway will be selected depending on the innovation process's initial conditions. Furthermore, the authors stress that systems, such as political, institutional, and behavioral, are already path-dependent. Still, Verge and Durand (2010) underline that path dependence provides information but does not predict causes on continuous persistence in organizational capabilities. Furthermore, recent research on network formation in R&D found that endogenous factors predominate over exogenous mechanisms in the formation of networks (Tomasello *et al.*, 2014).

To our knowledge, empirical research has not yet provided a depth practical contribution to all organizational history dependencies under exogenous shock. As some with our study, we provide such an enrichment. Additionally, the words of Foss (2020) support such an empirical contribution. The author states that "pandemic presents not only a unique test-bed for examining existing principles of organizational design[31] but might also stimulate new theory related to the temporal dimension of organization design and the influence of path-dependence."

3.2.4 Public-Private Partnerships: a framework to face crises

Novel Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) caused by the coronavirus (COVID-19) has emerged in 2019 as the most significant worldwide public health challenge. An outbreak, such as COVID-19, might be regarded as a natural catastrophe, according to the International Federation of Red Cross Red Crescent Societies' definition[32]. In such conditions, fast and sustainable solutions for the crisis's management are essential for the affected communities. Due to its extreme impact on society at a worldwide level, governments

[31] Organizational design, by Foss (2020) is described as an organization's optimal levels of differentiation and integration given relevant internal and external contingencies. Organizational design includes firms' internal division of labour (in terms of divisionalization, departmentalization, job descriptions, etc.) and how they allocate task responsibility to external as opposed to internal parties, as well how they keep their internal and external division of labour together by means of the allocation of authority, rewards, planning, routines, and information flows, as well as formal and informal contracts as well as ownership positions.

[32] Types of disasters: Definition of hazard. Source: https://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/

fostered closer cooperation initiatives with private and non–governmental organizations to moderate such an impact on the health, economic, and social dimensions. Multi-member partnerships indicate an awareness that some problems necessitate a large number of collaborators and sophisticated organizational structures to meet all of the challenges. Universities, industry, and governments are working together in rapid testing and rollout of innovations, with the best available evidence translated into practice within days (Mention *et al.*, 2020).

The PPPs propose a framework to face and overcome such a crisis with the potential of actors' heterogeneity and diversity of capabilities. These multi-member partnerships understand that some challenges necessitate a large number of partners and complex organizational structures to handle all of the issues. The PPPs are proposed to foster innovation and sustainable development, reflecting on global challenges and stakeholders' needs. In such conditions, the PPP becomes more crucial. Following different policy guidelines based on diverse policy incentives, such partnerships enhance and capitalize local competencies and resources to achieve a social impact and tackle regional challenges more effectively. They empower formal innovation actors, apply interdisciplinarity in R&I processes, support the development of new policy inputs, and strengthen a quintuple innovation helix framework.

Hodge and Greve (2007) describe the PPP as cooperative institutional arrangements between public and private sector actors. These forms of partnerships may include alliances, contractual and cooperative agreements, collaborative activities, and other collaboration forms for policy development. Thus, the PPPs have diverse dimensions important for this study: inter-organizational relationships, continuous cooperation, shared objectives, joint funding, risk sharing, contractual governance, and links to policy actions. Additionally, Brown (1991) stresses that sustainable social and economic development depends on effective local organizations, links between sectors, and national policy. It is framed by a concept of a public-private partnership, a form of an inter-organizational partnership that aims to provide a public value. For the healthcare sector, the WHO (2004) provides this specific description of the PPP: "an informal or formal arrangement between one or more public sector entities and one or more private sector entities created to achieve a public health objective or to produce a health-related product or service for the public good." A variety of the descriptions of the PPP concept presented proposes that these partnerships combine the strengths of private actors (innovation potential, technical skills, and knowledge) and the power of public actors (social responsibility, local knowledge, and skills) (Roehrich, Lewis & George, 2014). Summarizing, it can be stated that the potential of such PPP is seen in:

(i) a proposition of effective instruments to develop innovative solutions for a global challenge;

(ii) to re-think business processes with key stakeholders and to give voice to informal actors.

As such, the PPPs are a tool for multi-stakeholder governance, one of the United Nations SDGs' targets: SDG17 - Partnerships for the Goals. This goal aims to "strengthen the means of implementation and revitalize the global partnership for sustainable development[33]."

Such cooperation can take diverse forms in the healthcare sector (Fig. 3.2) and may benefit increasingly through the reduction of governmental spending, greater efficiency, shared risks, optimized decision-making mechanisms, and as a result, improved management of the healthcare system (Nikolic and Maikisch, 2006). Even more, working within the context of urgency, governments are ready to provide extra resources, create new governance structures and provide tools (intramural and extramural research projects) to develop a specific product, a vaccine, for example (Hoyt, 2006). Casady and Baxter (2020) and underline that, in such a specific setting as *force majeure*, more efficiently, the PPP may address:

(i) the financial aspects of the crisis;

(ii) apply flexibility in management and improve supply chains;

(iii) maintain more effective information exchange between actors.

During the outbreak, these organizational forms have a specific role. Katz *et al.* (2018) point out that capacity building through unique public-private partnerships can reduce infectious disease outbreaks' social and economic costs. In such cooperation, several characteristics predict the success of an outcome; these are trust (Mention *et al.,* 2020; Katz *et al.,* 2018; Bierly and Coombs, 2004), communication, and early relationship-building determines, knowledge integration based on established networks, protocols, and information-sharing infrastructure (Katz *et al.,* 2018). Additionally, Bstieler (2006) propose that trust is "modeled as an outcome of communication behavior, shared problem-solving, perceived fairness, the existence of conflicts during the development project, and partner egoism (p. 56)" and is a result of the relatively long duration of the relationship (EC, 2014). Katz *et al.* (2018) state that optimization of these PPP's effectiveness is possible if the responsibilities, expectations regarding roles, frequency of communication, and scope of information sharing would be established early on before the outbreak, so the partnerships formed during

[33] Source: SDG 17: https://www.globalgoals.org/17-partnerships-for-the-goals

emergencies should be preserved.

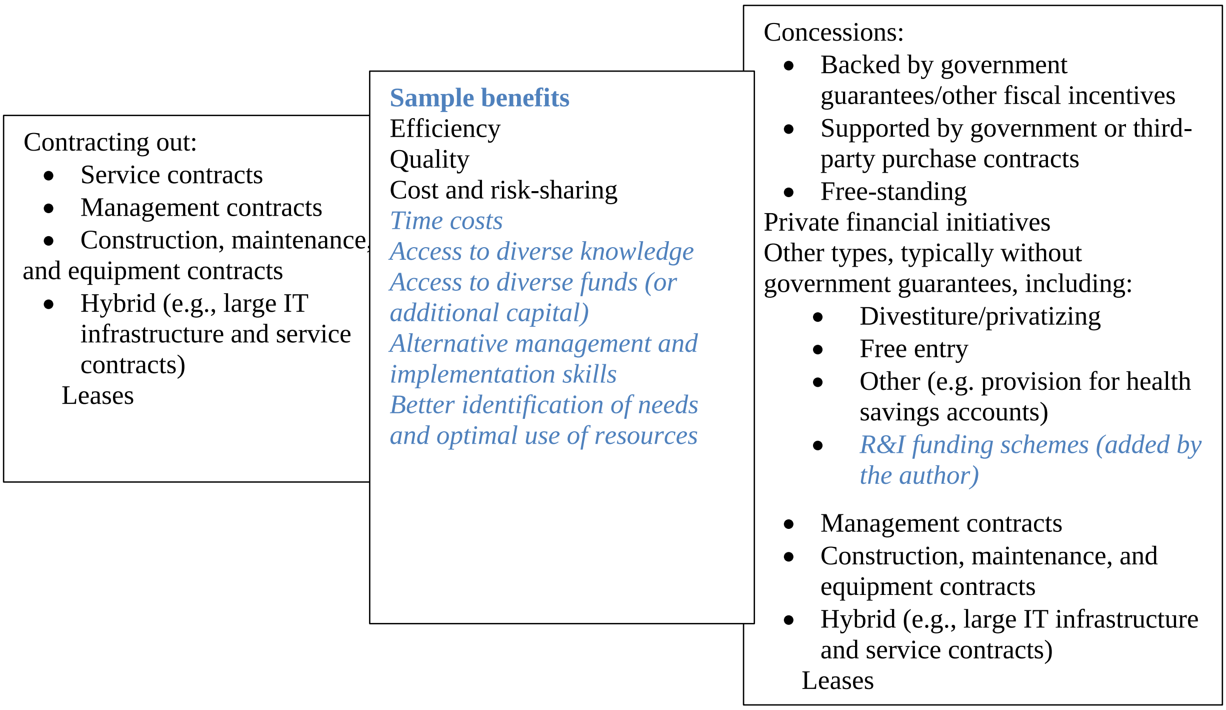

Fig. 3.2 Key types of public/private partnerships and collaboration in the health sector (Source: *Updated by the author* based on Nikolic and Maikisch, 2006)

As we can see, these PPPs are a particular form of inter-organizational partnership and propose many benefits. Still, no single formula exists for successful cooperation and roles division in them. Further research is needed to structure a comprehensive framework for this phenomenon, aiming to answer such questions, partly promoted by Hodge and Greve (2007): What can be learned from the history of these partnerships, what is new about their origins, structures, performance, and dynamics?

3.2.5 Lessons from the healthcare PPPs experience

The healthcare sector is characterized by the high social relevance and impact of the long-term provision of publicly beneficial services. Here, the pharmaceutical part is repressed by extraordinarily high R&D expenditures, the extended timeline for new product development, increased marketing costs, and very high profits (Bierly and Joseph, 2004). Even if the latest decades show more visible than ever, companies of this sector are leveraging strategic alliances to feed the internal resources base and minimize risks and costs. On another side, increasingly, and policymakers are exploring PPPs to improve this sector, testing new forms of cooperation, rules and providing diverse funds. According to allocated amounts, the European Court of Auditors (2018) presents that healthcare projects were in second place, preceded by projects in the transport sector and followed by projects in the education sector. Such a significant investment is represented by the heterogeneity of actors and specific cooperation dynamics. Nowadays, this sector faces increasing challenges linked to the pandemic; at the same time, technological and scientific advances offer new opportunities to solve these challenges.

For decades, the EU has been co-financing healthcare programmes and projects that improve and develop innovative and sustainable health systems. For example, within R&I programmes in 2014-2020, more than €449.4 million[34] were allocated to support health-related issues. Additionally, € 122 million were added to the Horizon 2020 programme, as the platform for healthcare innovation, aiming to contribute to the "Coronavirus Global Response initiative" launched on 4 May 2020[35].

Introduced in 90s, a public-private partnership typically represented a long-term agreement between one or more public and private entities, supported by shared interests and responsibilities. The general motive for PPP development was based on financial and risk shared issues. According to diverse authors, these partnerships in the healthcare sector represent a successful model of the public and private interests' balance between developing new solutions for health threats (Kostyanev *et al.*, 2016). Adopting the open innovation model by the healthcare industry has fostered novelties, and success of the PPP concept guaranteed minimization of high-risk endeavor and reached success later (De Vrueh, de Vlieger, and Crommelin, 2019).

Such success can be evaluated by listing the factors targeting justification, preparation, implementation, and monitoring processes of the PPPs (Nikolic and Maikisch, 2006). Now the call of such a cooperation is based on needs as new funding forms or budget, new or upgraded infrastructure, additional services/skills, acquisition of improved management skills to improve quality and cost-efficiency of healthcare delivery (PwC report, 2018[36]; EU, 2014).

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[34] Source: The third health programme 2014-2020. Funding health initiatives, https://ec.europa.eu/health/sites/health/files/programme/docs/factsheet_healthprogramme2014_2020_en.pdf

[35] Source: Coronavirus: Commission boosts urgently needed research and innovation with additional €122 million, https://ec.europa.eu/commission/presscorner/detail/en/ip_20_887

[36] Source: PPPs in healthcare: Models, lessons and trends for the future, https://www.pwc.com/gx/en/industries/healthcare/publications/trends-for-the-future.html

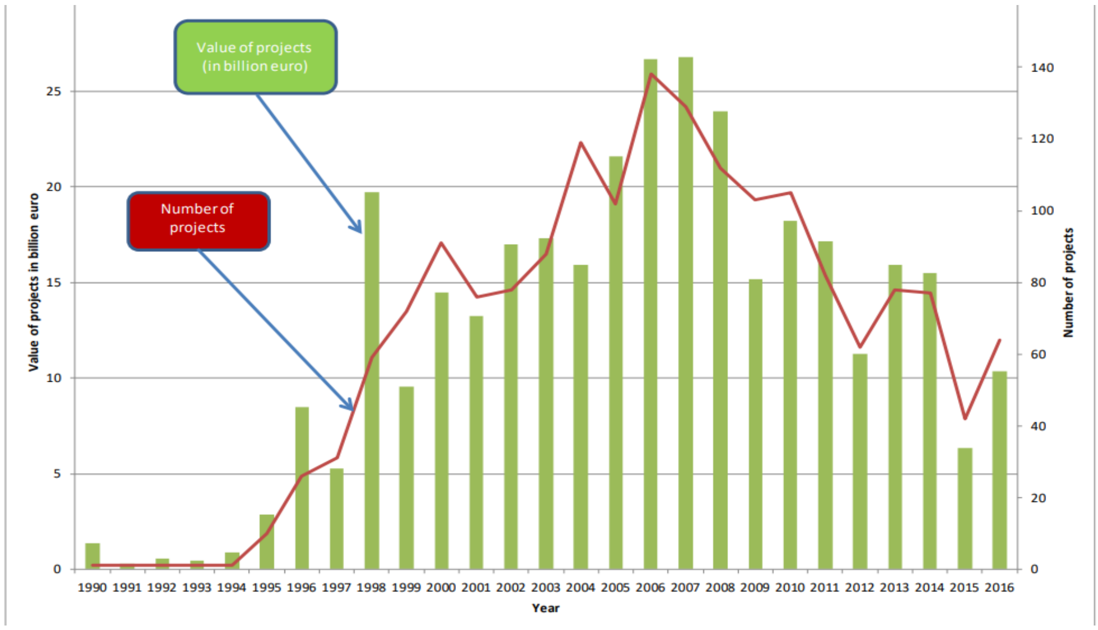

Fig. 3.3 EU PPP market from 1990 to 2016 (Source: the European Court of Auditors, 2018)

In our case, new management skills are based on the organizational competencies of crisis management. Montagu and Harding (2012) summarise that six significant issues are common to hospital PPPs. In our view, five of them can be applied to the healthcare sector in common:

(i) Not individuals, but the government, is the primary purchaser of outputs;

(ii) Market risks are shared;

(iii) As the performance outcome strongly depends on each individual, it is difficult to measure performance and the outcomes;

(iv) Epidemiologic and demographic conditions impact the mechanism of the PPP and its final output strongly.

(v) All of this is accompanied by fast changes in the organizational environment and technology (changing regulation, information, reimbursement systems, and technology).

This underlines the findings of the latest PwC report[37] on PPPs in healthcare: Models, lessons, and trends for the future. The report emphasizes that these PPPs can be distinguished from other forms of government-private contracts based on the long-term nature of the agreements between actors. The contract is based on mutually agreed-upon performance indicators, transfer of risk from the public to the public-private sector.

A special sub-group of the PPPs are so-called Product Development Partnerships

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[37] Source: PPPs in healthcare: Models, lessons and trends for the future
https://www.pwc.com/gx/en/industries/healthcare/publications/trends-for-the-future.html

(PDPs), which are represented well in the healthcare sector. They focus on developing products/services for specific communicable diseases impacting patients' health, where the leading players are represented by governmental funding programs, the pharmaceutical industry, SMEs, and academic knowledge actors (De Vrueh, de Vlieger, and Crommelin, 2019). These partnerships for infection prevention and control have initially been created to stimulate R&D for products that prevent and treat infections, primarily in developing countries (Ridley, 2004; Billington, 2016). In early 2004 Ridley underlined that such kind of cooperation to be positive should guarantee several characteristics: (i) to ensure that actor of the PPPs should not be super competitive or monopolist between themselves; (ii) they work for global health needs; appropriate mechanisms are in place to ensure the continued and sustainable products production when they are on the market; (iii) this cooperation should provide inputs for new policy development and implementation; moreover, conflict of interests are minimized. The latest research carried out by De Vrueh, de Vlieger, and Crommelin (2019) demonstrates the collaboration of diverse actors in the pre-competitive field based on project activities, where they share their strategic assets, promote the PPP concept as a trusted way of working. As so, "partners now seem comfortable to evolve the model with activities closer to their core business" (De Vrueh, de Vlieger, and Crommelin, 2019). PPPs, and PDPs in particular, should provide a suitable framework for implementing a model characterized by (i) flexibility (in designing a partnership and funding flexibility), (ii) adaptability to environmental changes - ensuring the evolvement alongside these changing environments to exploit emerging scientific or policy developments that could help the partnership accomplish its mission, and (iii) compatibility: no single actor can guarantee or solve the problem of pandemics. External businesses, programs, and governments involved in medical product development must be compatible with the PDP. Upon a successful outcome, the partnership may need to collaborate with an access PPP to facilitate product distribution at the national or facility level. Finally, a fourth property should characterize PDPs' model: sustainability – creating a sustainable resource base based on diverse donors' inputs and strong leadership and accountability within partnerships (Billington, 2016). According to Swaithes *et al*. (2020), this pandemic will create an ongoing impact on knowledge mobilization by developing and delivering services in the healthcare sector.

3.3 METHODOLOGY AND RESULTS

3.3.1 Data collection and description

While both policy and social actors implement different measures and develop incentive mechanisms to reduce SARS-CoV-2 impact on society, R&I instruments provide access to public and private funds to search for innovative medical solutions, such as developing a vaccine and effective medical therapies. This section describes the data and measures employed for our empirical analysis for the mentioned innovations.

To answer the research questions proposed in this chapter, the empirical context is based on analyzing specific research and innovation networks funded under the two latest EU R&I framework programs: FP7 and HORIZON 2020. In these FPs, the EU acts as a public actor, favoring and spurs cooperation between heterogeneous knowledge actors. We limited the sample to the EU R&I partnerships linked to healthcare sectors of the two mentioned programs (Table 3.2), as the complexity of the healthcare sector and COVID-19, in particular, fosters partnerships in the pharmaceutical industry. The data relating to these networks and their partners is downloaded from the CORDIS - Community Research and Development Information Service website in July 2020. This portal is an open access repository to communicate and disseminate information on the EU-funded research projects and their results.

Table 3.2 A brief description of the FP7 & Horizon 2020 (Health) programs

Programme, period	In brief
Framework programme 7 (FP7) 2007-2013	Specific Programme "Cooperation": Health (Including Innovative Medicines Initiative 1). The objective was to improve the Health of European citizens and increase and strengthen the competitiveness and innovative capacity of European health-related industries and businesses. Source: https://cordis.europa.eu/programme/id/FP7-HEALTH
Horizon 2020 2014-2020	Health, Demographic Change and Wellbeing programme. Responding to this challenge, research and innovation under Horizon 2020 is an investment in better health for all, and it also contributes to the sustainability of health and care systems. Source: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/health-demographic-change-and-wellbeing

The first part of the dataset represents FP7 healthcare and HORIZON 2020 healthcare projects, the second – specific COVID-19 calls of the H2020, one of which is Innovative Medicines Initiative (IMI2)[38]. In total, data of 2087 funded projects are involved in this study.

[38] The IMI2 represents the biggest public-private partnership in the life sciences in the world, which is funded jointly by the European Union (represented by the European Commission) and the European pharmaceutical industry (represented by EFPIA, the European Federation of Pharmaceutical Industries and Associations). Source: https://www.imi.europa.eu/ ,
The objective of the initiative is to boost pharmaceutical innovation in Europe and speed up the development of innovative medicines, vaccines and medical technologies, in particular in areas with high unmet needs. Interim evaluation of the IMI2 states that the programme functions, but needs improvement: The experts recommended that (1) stronger efforts be made to attract and integrate other industries besides pharmaceutical industries in the collaborative projects; (2) more efforts be deployed to attract more SMEs; (3) access to project outcomes be broadened and the sustainability of project results be improved, to increase impact; and others. Source: Faure, J. E., Dyląg, T., Norstedt, I., & Matthiessen, L. (2018). The European innovative medicines initiative: progress to date. *Pharmaceutical medicine*, 32(4), 243-249.

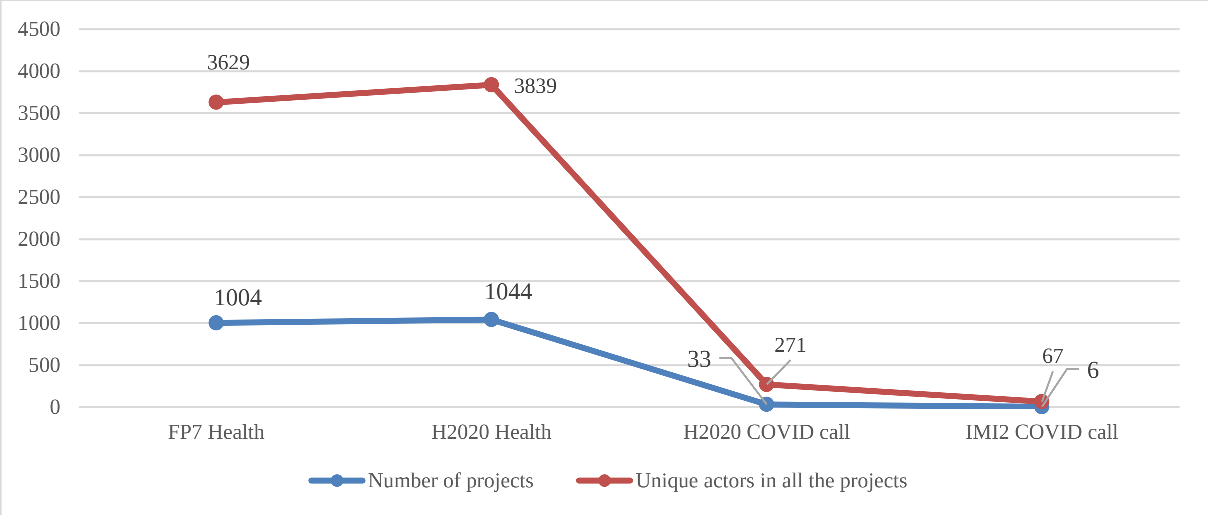


Fig. 3.4 Number of Healthcare projects and actors by program

The size of the partnership (network), funding period, and duration varied in terms of the Calls. The first group of Table 3.2 includes 1004 projects developed in the period: 2008–2021with an average duration of 47 months (min. 11 – max. 104) and 3629 unique organizations. The second group involves 1044 projects. The covered period is 2014 – 2026, with an average duration of 36 months (min. 1 – max. 101).

Table 3.3 A brief description of the COVID–19 Calls

COVID Call, the deadline for application	In brief
Horizon 2020 call: SC1-PHE-CORONAVIRUS-2020 / IBA-SC1-CORONAVIRUS-2020-3 *(March 2020)*	In January 2020, the Commission launched an emergency call, through which €48.2 million were awarded to research projects. The projects have started improving epidemiology and public health, including preparedness and response to outbreaks, diagnostic tests, new treatments, and new vaccines. Source: https://ec.europa.eu/info/research-and-innovation/research-area/health-research-and-innovation/coronavirus-research-and-innovation/preparedness-and-response_en
Special Innovative Medicines Initiative (IMI2) call *(May 2020)*	On 3 March 2020, the Innovative Medicines Initiative (IMI) supported through the European Commission's Horizon 2020 Framework Programme for Research and Innovation, launched a special fast-track call for the "Development of therapeutics and diagnostics combatting coronavirus infections" with an EU contribution €72 million. Source: https://ec.europa.eu/info/research-and-innovation/research-area/health-research-and-innovation/coronavirus-research-and-innovation/diagnostics_en

The first group of Table 3.3 includes 33 networks covered by the period: 2020 – 2025 with the average duration of 25 months (min. 11 – max. 59), and represents 271 unique organizations, the second group: 6, the period covers: 2020 – 2025 with the average duration of 32 months (min. 14 – max. 59).

From the short review above, key findings emerge: the average duration of a project in the COVD-19 calls is smaller than in the standard R&I calls. This suggests a statement regarding emergency correlation with the innovation development phase. Another promising finding is that the evaluation period of the project proposals varied as well: in the FP7, an assessment of the proposal lasted about five months, in H2020 Health – two stages call, more than three months (up to 8), and under emergency status, an evaluation process took about 40 days (in the specific single-stage CALL linked to COVID-19). This unprecedented approach to processing of applications is connected to the exogenous characteristics of the current coronavirus outbreak and the call of the EU for an emergent response to it: "It is crucial to rapidly gain a better understanding of the newly identified virus, especially in relation to potential clinical and public health measures that can be put to immediate use to improve patients' health and/or contain the spread of COVID-19[39]". Such a fact supports the words of Swaithes *et al.*, 2020 (p. 1804) "Healthcare systems rapidly and efficiently reconfigure services and pathways at pace and scale, in response to the urgent need to address the challenges posed by COVID-19".

3.3.2 Description of the research method and analytical approach

The network analysis, as a multidisciplinary research approach (Barabâsi 2002; Newman, 2001, and Tumminello *et al.*, 2011), was chosen to perform the analysis due to its efficiency in the representation of social structures and contextualization of the behavior of actors involved in the selected projects/communities. An in-depth analysis of them helps to understand if, under an emergency state, organizations are more likely to create a link based on past experiences, trust, reputation, specialization or other factors that significantly impact the establishment of links between two (or more) organizations. This work covers the empirical analysis of the two types of networks' evolution: (i) history dependencies between the actors of the FP7 healthcare and H2020 healthcare projects and (ii) history dependencies between the actors of the H2020 healthcare projects and specific EU R&I COVID calls (a sum of the Horizon 2020 COVID-19 and IMI2 projects).

According to their country of registration, we are starting work with all knowledge actors' analysis in three specific groups (FP7 healthcare, H2020 healthcare, and COVID-19). To measure country involvement in each program, we consider for any country c and program pr, the quantity $I_c = \sum_{i=1}^{N_{pr}} n_c(i)$, where N_{pr} is the overall number of projects considered in programme pr and $n_c(i)$ is the number of institutions from country c involved in project i.

[39] EU participant portal. Source: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/imi2-2020-21-01

Fig.3.4 reports the standardized values of I_c , that is, $i_c = \frac{I_c}{I} \cdot 100$, where $I = \sum_c I_c$, for the Top 9 countries. Indeed, the list of the top 9 countries (Fig. 3.5) is not changing across the programs, which can be interpreted as a mark of assortativity (Newman, 2001). This is a strong example of connections between actors with similar characteristics. After the 9th position, some changes become visible. For example, Denmark is 10th in both FP7 and H2020, and 11th in the COVID – 19 programmes, sharing this place with Portugal, the 21st in the ranking of FP7 program, and 16th in H2020. Ireland and Austria share the 10th position in COVID-19. Meanwhile, Ireland occupied the 13th position in FP7 and the 15th in H2020. It is also interesting to underline that one non-EU R&I leader, the USA, is present in TOP15 countries (14th – in FP7, 12th – H2020, and 13th COVID-19 program, together with Norway, Romania, and Cyprus). This country participates in FPs as a country with a jointly agreed co-funding mechanism, specific provisions for making national funding available for the country's participants.

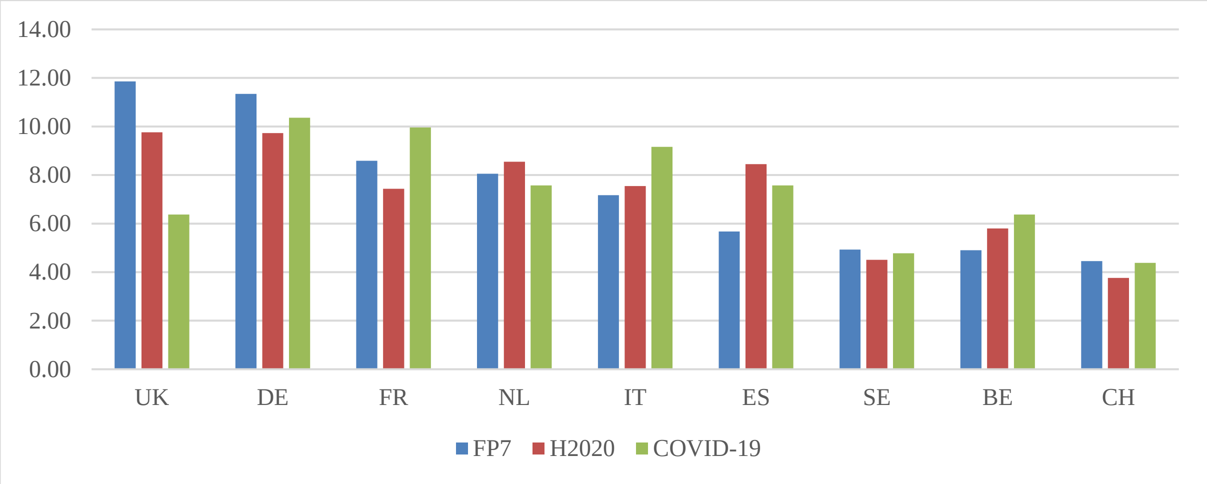


Fig. 3.5 Top countries in FPs based on their project participation (i_c)

The figure shows that the TOP 5 countries in terms of participation in the projects are the EU country[40] leaders in the mentioned sector, UK, DE, FR, NL, and IT. However, the dataset presents an openness of the H2020 to associated/third countries adding newcomers to the FPs list, for example, ME, SL, PY, SR, JM, CI, PA, MG, SZ, KG, TJ, and NC. The full list of countries involved in FP7 projects includes 124 countries, whereas 107 countries participated in H2020 projects. Meanwhile, for COVID-19 calls, the list of participants only consists of 35 countries. However, cooperation with non–EU R&I leaders is strengthened concerning previous programs. These countries are China, the United States of America, and Canada. Such an over-representation of non–EU countries marks the worldwide willingness to search for timely,

[40] Abbreviations of the countries, see Appendix 3.1

effective, and innovative solutions to the outbreak, the unprecedented mobilization of resources for everyday welfare purposes, and the scaling up of medical capacity for treatment and testing. This outbreak clarifies that worldwide cooperation is not a mirage. Instead, it is feasible even in the time elapse of a few months, under conditions of significant distress as experienced by the world population over the last year.

To finalize this part, it is helpful to include a brief note regarding the balance between EU expenditure and revenue compared to the countries' participation in the FPs. As it is well known, R&I is funded through the EU budget, which consists partly of Member States contributions based on complex rules and procedures. The statistics covering the period of 2017–2019 state that the highest expenditures in the latest program (H2020) are linked to all the previously mentioned Top 5 countries (DE, FR, UK, NL, and IT). They are all net contributors to the Union's budget, that is, the overall operating budgetary balance for these countries is negative. This means that a country contributes more to the overall EU budget than it receives from it. However, in the framework programs, the highest percentage of the EU R&I budget is divided between the so-called present in healthcare, strong innovators[41] (Germany, France, the Netherlands, the UK), and moderate innovator (Italy).

3.3.2.1. Statistical measures applied

Besides considering cooperation at a macroscopic level (countries), we shall focus our attention on microscopic patterns of collaboration and cooperation among single institutions in single projects. Along this line, we first provide an overview of R&I partnerships by looking at the system as a bipartite network of institutions and projects, in which a link is set between an institution and a project if the institution participated in the project (Asratian, Denley and Häggkvist, 1998; Tumminello *et al.*, 2011). This part of the study concentrates on evaluating institutional overlap between single projects, intending to study cooperation patterns and, in particular, the lock-in phenomenon. In total data of 2087 funded projects is involved in our dataset, which is represented by information about participants (Name, Participant Identification Code, Role in the project (coordinator/participant) Country, Funding) and projects (all participants, total funding, objective, call and topic, and programme). Identifying all unique partners in the mentioned projects, we construct a table with overlapping. The data linked to the projects and a common number of institutions passing from one program/project to another is presented (Appendix 3.2 and Appendix 3.3). Our interests are related to the

[41] Source: European Innovation Scoreboard, 2019

analysis of the projects with a minimum of 2 actors in common. The research does not cover projects with only one actor in common because they do not provide information about cooperation evolution. Instead, they indicate an actor's participation in multiple FPs. In total, 22,535 intersections appeared between FP7 healthcare and H2020 healthcare projects, and 596 between H2020 healthcare projects and COVID-19.

The first measure that we consider to study project overlapping is the *Jaccard index* (which will be formally presented later in this section). The index is calculated as the size of the overlapping institutions between two projects divided by the total number of unique participants in either project (size of the union). The FP7 healthcare and H2020 healthcare network present 22535 intersections, or 1453 unique projects. Meanwhile, the overlap of H2020 healthcare and COVID-19 is equal to 596 intersections with 305 unique projects.

Figure 3.5 shows four different quantities that can be used to describe the evolution of inter-organizational cooperation across two successive R&I programs, indicated with *P* (for previous) and *N* (for next). In particular, we introduce the following notation: n_P (n_N) indicates the number of partners in a project from the program *P* (*N*), while $n_{P\&N}$ quantifies the overlapping between projects, i.e., it indicates the number of institutions participating in both a specific project of program *P* and a specific project from program *N*. As mentioned above, an overlapping smaller than 2 is neglected in the analysis. Therefore, according to the introduced notation, in Fig.3.5, we report the distribution of the following four metrics:

(i) The top left panel ($n_{P\&N}/(n_P\ n_N)^{0.5}$) presents the overlapping standardized to the geometric mean of projects' sizes.

(ii) The bottom right panel ($n_{P\&N}/n_N$) demonstrates the overlapping standardized to previous program project size.

(iii) The top right panel ($n_{P\&N}/n_p$) shows the overlapping standardized to the next program project size.

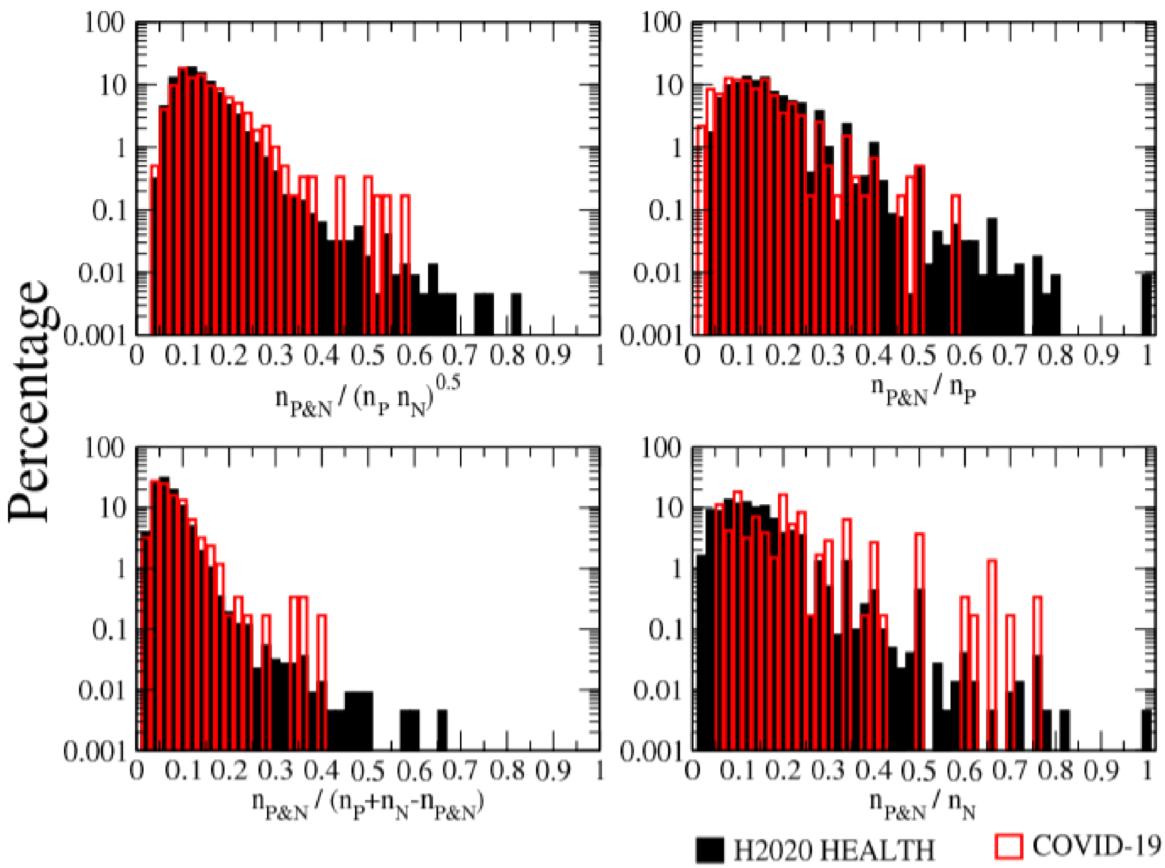
(iv) Bottom left panel – Jaccard coefficient[42] ($n_{P\&N}/(n_{P+}\ n_N\text{-}n_{P\&N})$) presents an overlapping. standardized to the size of the union of the projects from the previous and next program.

The left panels present two symmetric measures of project overlapping concerning the size of the two projects. The right one - non-symmetric measures. In both cases of symmetric and non-symmetric measures, the appearance of extreme lock-in in the FP7 and H2020 network

[42] *Jaccard coefficient* (Tóth et al., 2018; Balland and Ravet, 2019), like the other considered measure, helps to compare members for two diverse datasets and see which members are shared and which not. The value can be set in a range from 0 to 1 and represents the ratio between the size of the intersection of the two groups and the size of their union; a value equal to 1 indicates perfect overlapping, while 0 indicates none.

(black right tails presented in the histograms) is demonstrated.

To provide more quantitative insights about the distributions reported in Fig. 3.6, and, therefore, on the patterns of evolution of cooperation from FP7 to H2020 and from H2020 to COVID-19 programs, we report the first four moments of the considered distributions in Table 3.4. *The mean*, being a single value and a measure of central tendency, aids in the description of a data collection by identifying the central position within it. *Variance* helps to determine how far a set of data is spread out from its average value. *Skewness* is a measure of the asymmetry of the probability distribution of a real-valued random variable about its mean, and it aids in identifying the asymmetry of the data distribution.



Where: n_P stands for the number of previous actors, n_N – number for new actors, and $n_{P\&N}$ – number of overlapping between new and prior actors.

Fig. 3.6 Histograms of R&I actors' behavior in FP7 and H2020 programs

Kurtosis defines how heavy the tails of the distribution are. Knowing that the kurtosis of a Normal distribution is equal to 3, we can evaluate if, according to our distributions, extreme values are more likely to occur than they do according to a Normal distribution. All of the measures reported in Table 3.4 show a positive skewness, indicating a longer right tail in all the distributions. All of the distributions also show very high Kurtosis values, definitely larger than 3 – the value associated with a Normal distribution. Such a positive excess Kurtosis indicates the presence of fat tails, which, together with the positive skewness, points toward strong lock-in effects across programs, particularly in the verge between FP7 and H2020 programs. Indeed, the values presented in the table help us to develop a comparison of both groups. First of all, we note that the first two moments (mean and variance) are relatively similar in both groups. The only exception concerns the mean values in the last two measures. However, the different order of the mean value across the two groups for the last two measures reflects the fact that the average size of projects in the H2020 program is larger than the one in both FP7 and COVID-19 calls (Fig. 3.7), information that is carried by the denominator in the two measures.

Table 3.4 Statistical measures of the networks' evolution

	FP7 healthcare & H2020 healthcare				**H2020 healthcare & COVID-19**			
Metric	Mean	Variance	Skewness	Kurtosis	Mean	Variance	Skewness	Kurtosis
$n_{P\&N}/(n_P n_N)^{0.5}$	0.135280	0.002892	2.046939	13.698930	0.151046	0.005050	1.981733	9.771574
$n_{P\&N}/(n_P+ n_N-n_{P\&N})$	0.068566	0.001089	3.169694	30.424831	0.075883	0.001981	2.862202	16.752355
$(n_{P\&N}/n_P)$	0.160642	0.007013	1.720089	8.509679	0.138110	0.006697	1.607516	7.029742
$(n_{P\&N}/n_N)$	0.131136	0.005902	1.879639	10.217246	0.197581	0.016996	1.541544	5.837691

The two groups show similar values of the skewness for all the measures. However, the Kurtosis associated with the distribution of all the measures is larger for the first group (FP7 healthcare and H2020 healthcare). This is particularly striking for the Jaccard index (second row of Table 3.4), which shows a Kurtosis for the first group, which is about twice the one of the second. Such empirical evidence clearly indicates that the lock-in phenomenon. It means a large partnership persistence across programs occurs significantly more in the first group than in the second one. These results indicate that under exogenous conditions, the EU R&I network demonstrates the sector's mobilization of key actors. In other words, under the pressure of the pandemic, (new) partnerships tend to form by gathering together the top players in the needed sectors with lesser attention to the demonstrated fit among the partners than in the previous non-emergency programs. However, this tendency does not imply that the lock-in phenomenon disappears under emergency conditions. Indeed, an evaluation of the healthcare network shows a strong overlapping between H2020 healthcare and COVID-19, since mild lock-in, especially for the core of the partnerships, favors the network's stability and smooth the interaction among the partners, which are both desirable to tackle the pandemic.

As said, the presence of extreme cases of partnership overlapping between FP7 and H2020 projects indicates the presence of a strong lock-in effect, a mark of path dependence in the system. Our interpretation of the less extreme partnership overlapping between H2020 healthcare projects and COVID-19 projects is that, pushed by the need to cope with major shock forces, institutions tend to develop more heterogeneous networks, based on a high reputation of partners and a history of cooperation only among core members of the partnership.

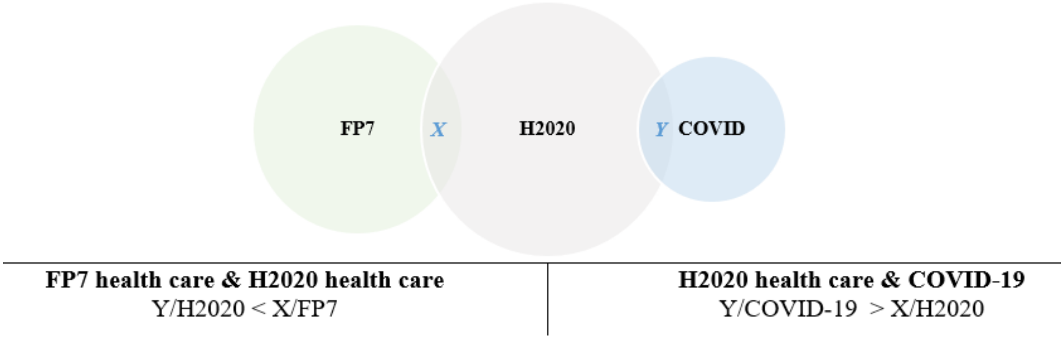


Fig. 3.7 Comparison of both networks

To deepen our understanding of the process of partnership formation, we perform community detection and evaluate the modularity (Newman, 2001) associated with the determined partitions of both R&I networks. This measure of the network's structure weights the internal strength of a network's communities with respect to inter-community connectivity.

Table 3.5 Networks' modularity

	FP7 healthcare & H2020 healthcare	**H2020 healthcare & COVID -19**
Modularity	Q = 0.293335 --- Number of elements: 1461 Number of lists: 15	Q = 0.535987 --- Number of elements: 307 Number of lists: 15

Table 3.5 shows that the number of communities in both networks is the same (15). However, modularity for the newer programs, H2020 healthcare & COVID-19, is slightly less than twice the older programs' modularity, FP7 healthcare & H2020 healthcare. This result supports the previous interpretation of milder lock-in of partnerships on the verge of an emergency. Indeed, it indicates that the community structure of the H2020 healthcare & COVID -19 network is much more apparent than the one observed in the previous program's network. Such a decomposability of the system suggests that single projects in the COVID-19 initiatives concern complementary facets of the emergence and involve the leading actors in the specific sectors crucial to the project development. Such a request for high standards of partners in the given (non-overlapping) sectors determines the system's decomposability and reduces the lock-in phenomenon. It is finally worth mentioning that decomposability also guarantees the

system's robustness to failure. It reduces interdependencies among clusters in a complex system, which is quite desirable under urgency needs (Simon, 1996).

3.3.3 Analysis of the case studies

Following Tumminello *et al.* (2011), we interpret the communities to understand the network evolution, which means "to characterize them in terms of the attributes shared by the elements belonging to the same community" (Tumminello *et al.*, 2011, p. 2).

3.3.3.1. H2020 healthcare and COVID-19 networks

The previously presented calculations demonstrate that COVID-19 initiatives, such as CARE, RECOVER, and EU-RESPONSE projects, are strongly linked to previous EU initiatives (Fig. 3.9). An analysis of these three initiatives' composition indicates that a limited number of unique actors represent the three most prominent communities of the COVID-19 network. Overall, this network is constructed by 313 unique knowledge actors, meanwhile, in the FP7 – 3630, and in the H2020 – by 3839.

In the network connecting the H2020 healthcare program to the COVID-19 program, the leading positions are taken by private for-profit companies (PRC[43]) and Higher Education Institutions (HES), with very limited participation of the public bodies and another type of organizations (for example, NGOs) (Fig. 3.8). The PRC's involvement is based on an institutional financial contribution to these R&I actions almost in all cases. Nonetheless, basic research involves high-level investment risk. PRC is willing to support such an activity with its funds.

[43] Abbreviations:
PRC: Private for-profit companies
HES: Higher education establishments
REC: Research organisations
PUB: Public bodies
OTH: Other entities

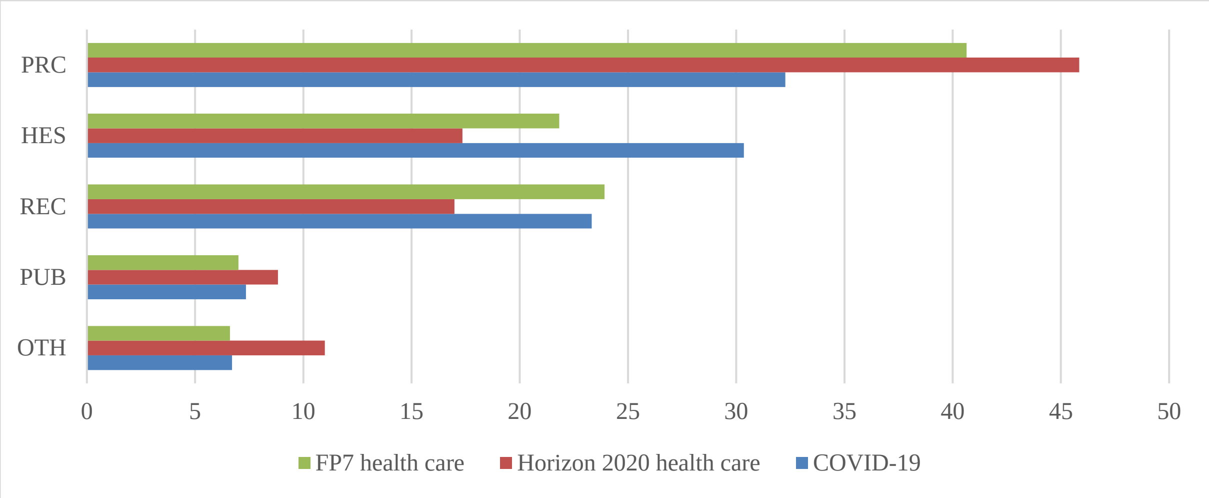


Fig. 3.8 FP7 healthcare, H2020 healthcare, and COVID-19 unique actors (% per type)

Having specific knowledge and infrastructure which permits them to take part in these actions, the PRC accepts a high risk knowing that a winning result can guarantee their financial sustainability for decades. Taking into consideration the TOP3 COVID-19 projects' goals and composition, three big objectives to overcome the actual (and any future) pandemic in Europe can be identified:

1. *Development and application of new medical solutions that rapidly and efficiently address the COVID-19.* **Case study***:* Corona Accelerated R&D in Europe (CARE), topic: IMI2-2020-21-01.
2. *Development of EU knowledge base for preparedness and response to future diseases.* **Case study***:* Rapid European SARS-CoV-2 Emergency research Response (RECOVER), Call: SC1-PHE-CORONAVIRUS-2020.
3. *Mobilization of the international experiences and practices for a major impact on epidemic control.* **Case study***:* European Research and Preparedness Network for Pandemics and Emerging Infectious Diseases (EU-RESPONSE) topic: IBA-SC1-CORONAVIRUS-2020-3.

A significant part of the three consortium members is firmly rooted in previous FPs. The CARE project overlaps participants greater or equal two 2 (i.e., participants who have already collaborated) with 140 H2020 projects, represented by 426 participants. Meanwhile, the list of CARE participants is constructed by 29 unique organizations (PRC–11, HES–10, REC–4, PUB–3, and OTH–1). Similarly, the RECOVER project has an overlapping of participants with 100 H2020 projects, represented by 237 participants, and the RECOVER list of participants is constructed by ten unique organizations (HES–6 and REC–4). The EU–RESPONSE project interacts with 74 H2020 projects that involve 191 participants. The list of partners in the EU-

RESPONSE project includes 17 unique organizations (HES–8, REC–4, PUB–3, PRC–1, and OTH–1). This result ties well with previous studies of Tóth *et al.* (2018) – partners for the projects are to found among partners' networks, reducing the uncertainty factor with already existing trust mechanism. As it was mentioned in the previous parts, public-private partnerships are essential to combat an external shock. However, these three projects demonstrate domination of the HES in the networks. However, it is crucial to underline that the PRC's role is significant in all the network structure, with less presence in the presented three case studies.

In line with previous studies of Balland *et al.* (2019), the actors of the projects are represented by classical R&I country actors (France, Germany, Italy, Belgium, Switzerland, and others) and global leader academic institutions (Karolinska Institutet (SE), Academisch Ziekenhuis Leiden (NL) and others), reputable and competent private partners – pharmaceutical companies (such as PFIZER Ltd and XENOTHERA (UK), NUVISAN ICB GMBH (DE), NOVARTIS PHARMA AG (CH) and others), and other actors such as non-EU funding bodies, e.g., the Bill & Melinda Gates Foundation (USA). For example, RECOVER originates from partners of the FP7 funded project called Platform for European Preparedness Against (Re-) emerging Epidemics. Both projects are leaded by the University of Antwerpen (Belgium). The other two projects are managed by Institute National de la Santé et de la Recherche Medicale (France). All the projects also involve non-EU actors: in FP7, the non-EU link was based on cooperation with Australia. Meanwhile, in COVID-19 RECOVER, non-EU ties are based on collaboration with China (Institute Pasteur of Shanghai, Chinese Academy of Sciences), in CARE, with the USA (Bill & Melinda Gates Foundation and ABBVIE INCA) and China (Global Health Drug Discovery Institute), and in EU-RESPONSE project, with Turkey (Hacettepe Universitesi).

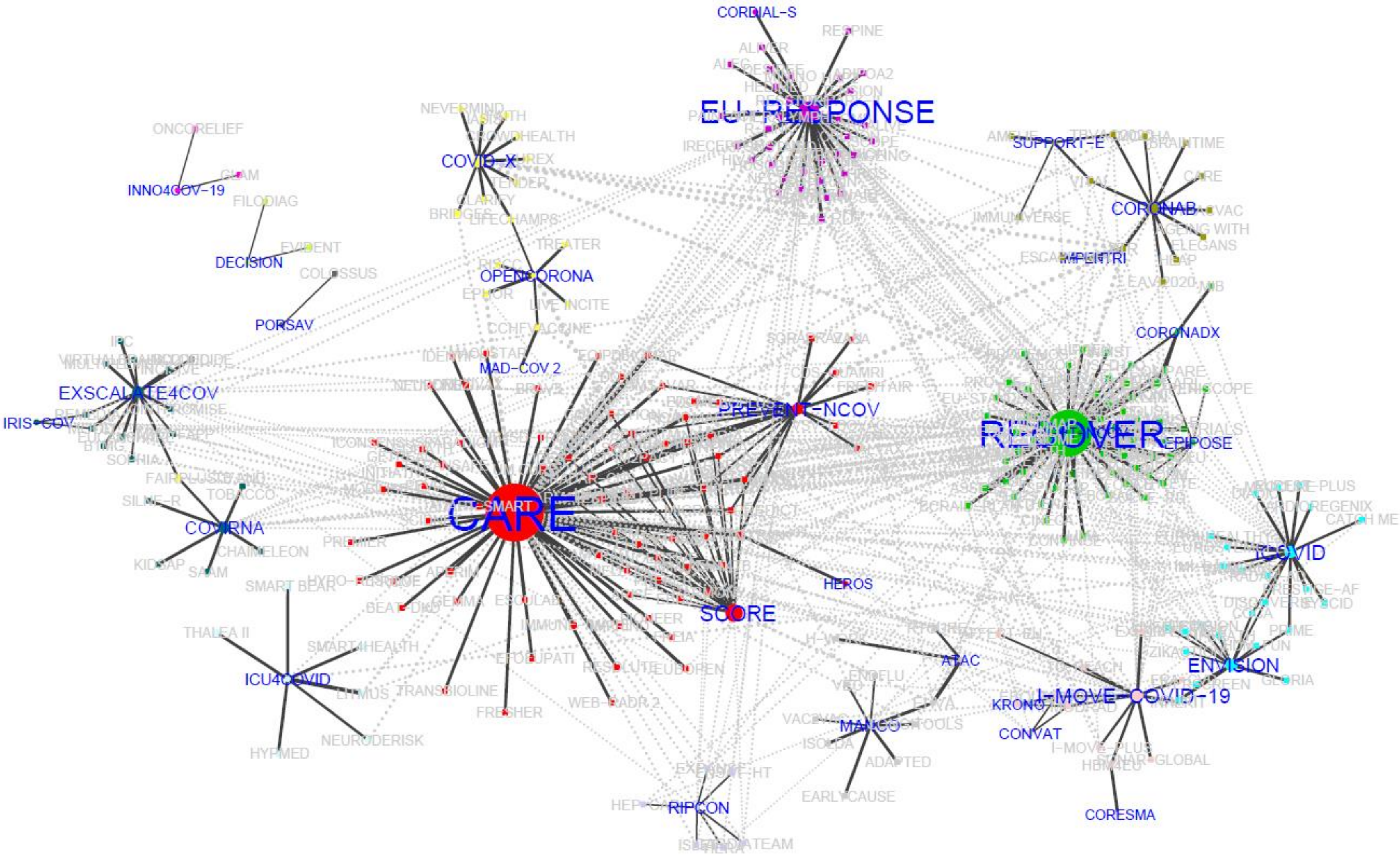


Fig. 3.9 Horizon 2020 and COVID-19's interaction of the networks' projects

Meanwhile, in COVID-19 RECOVER, non-EU ties are based on collaboration with China (Institute Pasteur of Shanghai, Chinese Academy of Sciences), in CARE, with the USA (Bill & Melinda Gates Foundation and ABBVIE INCA) and China (Global Health Drug Discovery Institute), and in EU-RESPONSE project, with Turkey (Hacettepe Universitesi). The openness for cooperation with the top countries in the pharmacy sector, such as the USA and China, the first country that gained know-how on COVID-19, demonstrates an EU collaborative pathway for outbreak management based on worldwide efforts. However, these links are limited, and the network is, of course, rooted at the EU level.

Below are presented examples, which explain the network's openness for new collaborations. As stated previously, 33 projects are funded under Horizon 2020 Calls SC1-PHE-CORONAVIRUS-2020, IBA-SC1-CORONAVIRUS-2020 calls, and six projects funded under the IMI2 COVID-19 call. Two projects are selected from the COVID-19 program to demonstrate their openness to creating new links within the already existing R&I network. In particular, both the selected projects (first column of Table 3.6), CORDIAL-S and EPIPOSE (COVID-19), show a limited overlapping of participants with projects from the H2020 program. Here, we focus our attention on miniNO and EBOVAC3 (H2020).

Table 3.6 Horizon2020 healthcare and COVID-19 case studies

PROGRAMMES		**PARTICIPANTS**			**OVERLAPPING MEASURES**			
COVID-19 (N)	**H2020 (P)**	n_P	n_N	$n_{P\&N}$	$n_{P\&N}/(n_P\, n_N)^{0.5}$	$n_{P\&N}/(n_{P+}\, n_{N-}\, n_{P\&N})$	$n_{P\&N}/n_P$	$n_{P\&N}/n_N$
CORDIAL-S	miniNO	10	7	2	0.239	0.133	0.200	0.286
EPIPOSE	EBOVAC3	7	6	2	0.309	0.182	0.286	0.333

All four projects are fully funded by the EU Commission, except two partners within the EBOVAC3 project, are Coalition for Epidemic Preparedness Innovation (REC, NO) and Janseen Vaccines and Prevention BV (PRC, NL). These four projects are represented by the partners from 13 countries with the leading position of FR (9 pax[44]), BE (5 pax), CH, and the UK (3 pax) (other countries are represented by one participant, and they are IE, IL, NL, IT, CD, NO, SL, DE, and EL). Such a composition demonstrates the existence of a strong know-how cluster in central Europe, a cluster made of leading institutions and companies that (at most) marginally directly collaborated together in the past, which gather together and created a critical mass of expertise, infrastructure, and means to tackle to COVID-19 outbreak, that is, a major exogenous shock. Participation in and the H2020 healthcare and COVID-19 calls' goals require specific competencies and support infrastructures from the knowledge actors. For example, the project CORDIAL-S propose to develop a POC test (C-POCT-S): a rapid (< 30 min), sensitive

[44] Pax – abbriviation of participant

(200 vps/mL), selective (SARS-CoV-2), and inexpensive (< 20 Euros) solution, to address the screening of the presence/absence of the SARS-CoV-2 virus in nasal and saliva samples. The partnership aims to complete product optimization, performance validation in a clinical setting, and manufacturing quality control for Point of Care Testing and completion of its technical file. The EpiPose intends to answer questions about the epidemiological characteristics of 2019-nCoV, the social dynamics of the outbreak, and public health preparedness and response to the current epidemic, as well as estimate its economic impact. The miniNO project aims to identify the critical causative mechanisms of the lifelong multimorbidity associated with preterm birth. Finally, EBOVAC3 (IMI2) supports the remaining clinical and manufacturing activities required for licensure in the EU and the US of a candidate heterologous prime-boost prophylactic vaccine regimen against Ebola virus disease under development at Janssen Vaccines & Prevention B.V. (UK). These collaborations bring together experts in medication and vaccine research, infectious disease mathematics and statistical modeling, participatory surveillance systems, and health economic analysis.

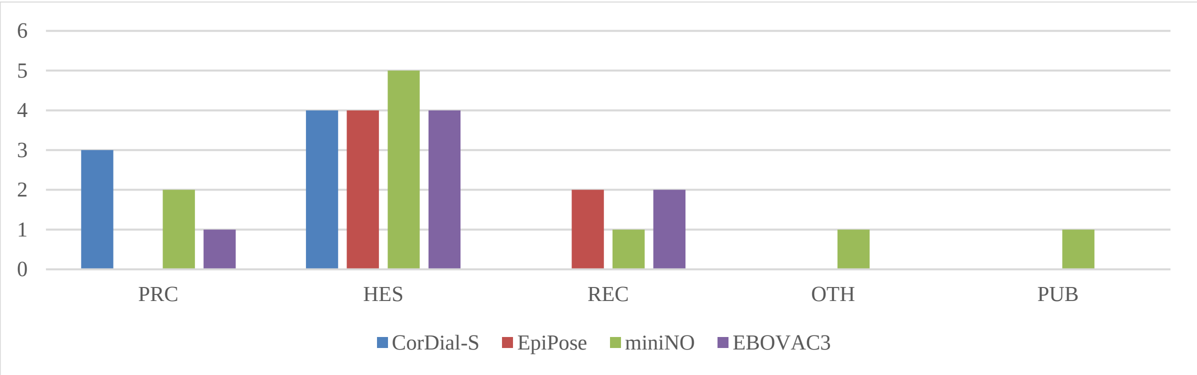


Fig. 3.10 Composition of the projects by nature of the actors

The dominance in these partnerships is represented by HEI, with an almost equal contribution in all the projects by the PRC, REC, and, only in miniNO, by another type of organizations - Research Center for Genetic Treatment of Genetic Diseases of Pedicology (EL) and Public actor (hospital) Centre Hospitalier Universitaire Vaudois (CH).

Taking into consideration the overlapping, which is equal to two knowledge actors in both groups of the projects, we notice that CorDial-S and miniNO are linked by two sister HES organizations from France: Université de Lille and Centre Hospitalier Regional et Universitaire de Lille, and additionally is led by the Institut National de la Sante et de la Recherche Medicale. It is apparent that these actors together already form a local cluster based in France with significant experience and excellent reputation-the hospital takes part in 13 H2020 healthcare projects and the University in 53.

The EpiPose and EBOVAC3 projects are linked by two strong EU HES in the healthcare sector from Belgium and the UK – Universiteit Antwerpen and London School of Hygiene, and

Tropical Medicine Royal Chapter. The first one participates in 153 H2020 healthcare projects and the London School in 46. All other actors of the mentioned projects are institutions with a long list of expertise in EU FPs (for example, Universite Catholique de Louvain – HES, BE, Universite de Geneve– HES, CH; INSERM TRANSFERT SA – PRC, FR; BIOGAZELLE NV – PRC, FR; Janseen Vaccines and Prevention BV - PRC, the NL, and others) or collaborations with new actors for H2020 healthcare R&I, for example, MAGNOSTICS LIMITED – PRC, IE; COLMERIS MEDTECH SAS – PRC, FR; PHOTONICSYS LTD – PRC, IL; Universite de Kinshasa – HES, CD and others). These new links appear based on the need to have partners with specific skills, such as a specialization in photonics and optical solutions (the case of PHOTONICSYS LTD in the CorDial-S proposal), and sometimes local know-how (the case of the Congo institution - Universite de Kinshasa – in the Ebola virus project).

At the end, all the COVID-19 network demonstrates persistence stickiness and irreversibility in community cores, which, partly was expected, as this kind of link is unavoidable due to the specificity of the sector. Accordingly, this system reveals a robust path dependence mechanism between actors, which demonstrate the know-how concentration of the system and linkage to the (i) innovation potential of already familiar actors and (ii) limited potential of the use of the knowledge absorptive capacity from other "unusual" actors for cooperation within/or out of the network.

3.3.3.2. FP7 and H2020 healthcare networks

To provide a characterization for describing the actors' behavior passing from the FP7 healthcare to H2020 healthcare projects, we present an in-depth description of several cooperation as a case study. Three project couples are selected for this analysis (Table 3.7).

Table 3.7 FP7 and H2020 Healthcare case studies

PROGRAMMES		**PARTICIPANTS**			**OVERLAPPING MEASURES**			
H2020 (N)	**FP7 (P)**	n_P	n_N	$n_{P\&N}$	$n_{P\&N}/ (n_P\, n_N)^{0.5}$	$n_{P\&N}/ (n_{P+}\, n_{N-}\, n_{P\&N})$	$n_{P\&N}/n_P$	$n_{P\&N}/n_N$
SHIPS	EPICE	13	14	10	0.7412	0.5882	0.7695	0.7143
ORTHOUNION	REBORNE	24	11	9	0.5539	0.3462	0.3750	0.8182
EUROLINKCAT	EUROMEDICAT	9	23	7	0.4865	0.2800	0.7778	0.3043

These three examples present three different behaviors of the partnerships. The first example demonstrates a strong lock-in effect. The second – is asymmetrical, and the final one – knowledge absorption of the previous program by the new one due to continuous actions started in the first program. This behavior is based on the specific skills necessary to implement the planned objectives (Table 3.8). In some cases, such existence of these skills is vital for the project's sustainability and re-use of the already exiting know-how by the future initiatives (example 1 and 2), or necessity for continuous research in the field, so the logic to change a partner would create risks on continues work of the partnership (example 3).

Table 3.8 Objectives and funding of projects[45]

The objective of H2020 project & funding	The objective of the FP7 project & funding
SHIPS: 2993175 EUR (EU contribution)	EPICE: 3967513.79 EUR (2999708 – EU contribution)
This project uses a resource – the EPICE cohort of 6675 babies born before 32 weeks of gestational age and surviving to discharge home in 18 geographically diverse regions in 2011/2012 – to assess the impact of these screening programs on health, care, and quality of life for very preterm infants and their families as well as on coverage, ability to meet needs, health equity and costs at the population-level.	This project aims to improve infants' survival and long-term health and development.Objectives: (i) to build an empirical knowledge base concerning how scientific evidence is translated into health service provision in maternity and neonatal units by measuring the use of key medical interventions in clinical settings, identifying the factors associated with the adoption of evidence-based practices, and providing updated information on the effectiveness of medical practices; (ii) to assess decision-making and knowledge implementation processes within units and regions to identify catalysts for evidence-based practice; and (iii) to propose intervention strategies to achieve behavioral change.
ORTHOUNION: 5999150.87 EUR (EU contribution)	REBORNE: 15472075.44 EUR (11935340 – EU contribution)
The main aim is to assess the clinically relevant efficacy of an autologous ATMP with GMP multicentric production in a well-designed, randomized, controlled, three-arm clinical trial under GCP, versus bone autograft, gold-standard in fracture non-unions. The secondary aim includes innovative strategies to increase manufacturing capacity and lower costs to pave translation into routine clinical treatments, biomaterial refinement to facilitate surgery, personalized medicine supportive instruments for patient selection and monitoring, and health economic evaluation.	Its objective is to perform clinical trials using advanced biomaterials and cells triggering bone healing in patients.
EUROLINKCAT: 7348072.75 EUR (EU contribution)	EUROMEDICAT: 3956151.6 EUR (2996100 - EU contribution)
EUROlinkCAT will use the EUROCAT infrastructure to support 21 EUROCAT registries in 13 European countries to link their CA data to mortality, hospital discharge, prescription, and educational databases. This enhanced information will allow optimisation of personalised care and treatment decisions for children with rare CAs. Findings will provide evidence to inform national treatment guidelines, such as concerning screening programs, to optimise diagnosis, prevention, and treatment for these children and reduce health inequalities in Europe. An economic evaluation of the hospitalization costs associated with CA will be provided	This project will develop and test an efficient pharmaco-vigilance system for the safety of drugs during pregnancy in relation to teratogenicity by (i) enhancing the information regarding drug exposure in the EUROCAT database, through linkage to electronic databases containing prescription information, and by linkage to chronic disease cohorts (ii) analyzing the enhanced EUROCAT database in relation to four drug groups of public health concern, (iii) interrogating healthcare databases to monitor the effectiveness of drug safety recommendations and pregnancy prevention programs through drug utilization studies, and to provide an exposure profile for pregnant women (iv) conducting a scoping study of the implications for drug safety of growing internet use by pregnant women, in terms of access to safety information about teratogenicity, and access to drugs with teratogenic potential.

The below-presented figure demonstrates that in these partnerships, the leading positions are taken by the core countries for the healthcare sector in the EU: FR, UK, and IT (Fig. 3.11). The same result was visible in the COVID-19 case as well. As we can see, taking the sum of the project actors per group, the leading positions are taken by HES and REC actors leaving at the end of the "tail" public and private organizations (Fig. 3.12). However, it is essential to underline that the role of the PRCs is crucial for this sector, as they provide financial resources to support investment costs and reduce or better allocate risks. Besides having market knowledge and facilities, they stimulate a faster innovation process for a need and support new policy mechanisms for healthcare management.

[45] Source: Project description, https://cordis.europa.eu/

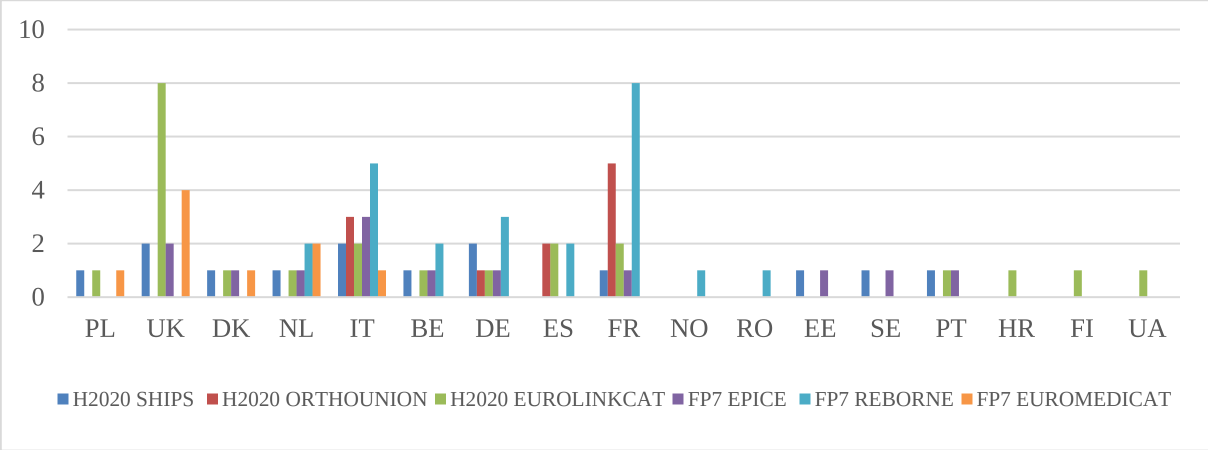


Fig. 3.11 Composition of the projects by actors/country

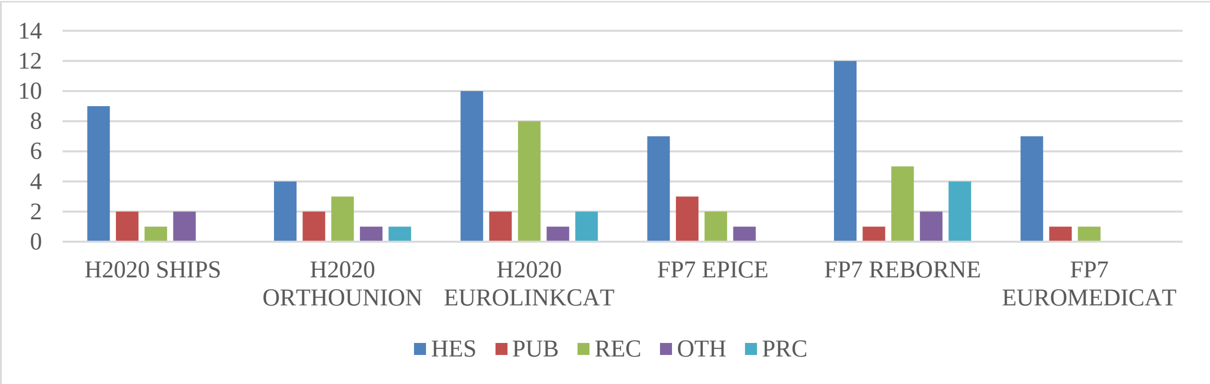


Fig. 3.12 Composition of the projects by nature of the actors

Even if the EU healthcare sector, specifically, pharmaceutical industry, shows one of the highest labor productivities and can be characterized by high complexity and heterogeneity of actors[46], nevertheless, the EU FPs demonstrate (i) existence of a strong overlapping between the knowledge actors in this system and (ii) a long list of firmly rooted actors in the framework programs. For example, in the case of the SHIPS and EPICE, ten organizations are in common. Both projects are managed by the L'Institut national de la santé et de la recherche médicale (INSERM, 1964) – one of the oldest research organizations in the EU for healthcare issues. More than 80% of these ten organizations are represented by highly ranked HES based in central in north EU mainly: Uniwersytet Medyczny im. Karola Marcinkowskiego w Poznaniu (PL), Philipps-Universität Marburg (DE), Tartu Ülikool (EE), Stichting Katholieke Universiteit (NL), Karolinska Institutet (SE), U.Porto (PT), University of Leicester (UK) and Regione Lazio (IT, PUB), and Italian hospital - Ospedale pediatrico Bambino Gesù. We can state that these projects' innovation potential is based on lock-in mechanisms linked to the already applied research, continuity, and sustainability.

In the second case, ORTHOUNION and REBORNE, almost 40% of the FP7 project actors represent 80% of the H2020 project actors, with only one PRC passing from one project

[46] Source: Healthcare Industries, https://ec.europa.eu/growth/sectors/healthcare_en

to another. This is BIOMATLANTE (France) - a "pioneer in biologics solutions"[47] who sells a product in over 50 countries. To add, the company's website presents that the company's R&D collaborates strongly with the French National Centre for Scientific Research and INSERM (SHIPS and EPICE, and REBORNE cooperation). Both projects' overall composition is firmly based in France, which underlines the local level's rich-club effect.

Finally, the third example is linked to EUROLINKCAT and EUROMEDICAT. It should be mentioned that the logic of partnership creation is framed by the core aim of both proposals, which are linked to sustain, re-use and update the resources, such as registers, which are already a part of the EUROCAT - European Concerted Action on Congenital Anomalies and Twins common database. The EUROCAT is a European organization founded in 1979. Its content is built on existing European databases and expertise. Based on the specific need of the network and updates necessary for the registers, the partnership changes its structure and coordination. EUROCAT requires continuous data updates and entries. As it is written, this seems to reflect the need for constant data updates from strong knowledge actors. In the EUROMEDICAT group, they are represented by seven HES from the UK (4), PL (1) and NL (1), one REC (IT), and one PUB (DK). In the EUROlinkCAT: HES – UK (5), PL, FR, DE, NL, IT (1); REC – UK, FR, HR, DK, FI, IT, PT (1) and ES (2), PUB – BE (1), PRC – UK (2), and OTH – UA (1). In this case, the other type is represented by the International Charitable Fund "OMNI-Net for Children," a not-for-profit organization founded in 2004. PRCs are represented by BioMedical Computing Ltd (software development services) and Redburn Solutions Ltd (portals, mobile, and business intelligence). 30% of EUROMEDICAT actors represent 78% of the new H2020 initiative – EUROLINKCAT, and they are Region Syddanmark (DK, PUB), Consiglio Nazionale delle Ricerche (IT, REC), Uniwersytet Medyczny im. Karola Marcinkowskiego w Poznaniu (PL, HES), Swansea University (the UK, HES), University Medical Center Groningen (NL, HES), the Queen Mary University of London (HES, UK) and University of Ulster (HES, UK). In this context, evaluating the project's aims and the list of actors, a path dependence of technology is not avoidable.

To summarize, the discussed case studies demonstrate not significant to all the system changes.

3.4 CONCLUSIONS

Throughout history, it is known that a crisis stimulates progress. From one side, it creates a strong negative economic and social impact. From the other side, it spurs a new wave of cooperation and, as a result, accelerates knowledge growth and innovations, changing the

[47] Source: About us: https://biomatlante.com/en/corporate/about-us

decision-making process and innovation management within an organization. The specificity of the COVID-19 pandemic is represented by the complexity of taking coordinated actions and implementing coordinated changes in the healthcare system at a worldwide level. In turn, it requires a high degree of cooperation among governments, policymakers, corporations, and other stakeholders to foster the accelerated growth of innovations for the development of new health services and products. In the past, the healthcare sector was described by long innovation processes, testing, and standardization procedures (Bierly and Joseph, 2004). Today, we can state that the pandemic has changed such dynamics. New partnerships and business models are under development, potentially bringing forth specific knowledge on innovation development, supporting the fight with the pandemic, and reformulating the working framework in the healthcare sector. Swaithes *at el.* (2020, p. 184) writes that "increased flexibility within healthcare systems to accommodate change has enabled knowledge to be translated and implementation decisions to be made, with traditional system processes and "red tape" no longer being prohibitive." The present crisis's urgency is shifting the sector to test new working paths to prevent new waves of a pandemic.

To answer the research questions proposed in this chapter, the nature, and structure of the data concerning EU FP7 and H2020 programs, as well as the COVID-19 R&I calls, favor the application of network analysis concerning other approaches, aiming to understand the EU R&I cooperation networks' evolution under exogenous changes. In these FPs, the EU acts as a public actor, favoring and spurs cooperation between heterogeneous knowledge actors aiming to boost innovations supported by various policy actions. Moreover, our dataset includes the IMI initiative, representing the biggest healthcare PPP R&I in the world. Analyzing the data of more than two thousand R&I unique healthcare projects spanning more than a decade, we provide several conclusions about cooperation evolution in the EU R&I sector.

Our results underline two opposite behaviors of the actors in the EU FPs R&I healthcare sector networks: (i) highly innovative partnerships and (ii) strong lock-in effects. Above all, the carried-out work demonstrates that even under exogenous changes, some partnerships in the EU R&I healthcare networks, even large ones, persist over time. A strong overlapping between FP7 healthcare and H2020 healthcare, and H2020 healthcare and H2020 COVID-19 exists, and this favors the network's stability and conservative behavior of actors in the healthcare R&I projects. In our opinion, such an evolution is firmly linked to characteristics such as trust, specialization, and infrastructure owned by the actors. Based on specific exogenous and endogenous factors, these sector-oriented knowledge actors manage their interdependency based on interactions reported by Foss (2020): pooled, sequential, and reciprocal. However, the more extreme cases are visible in different frames: network's openness to new cooperation in the COVID-19 calls and strong lock-in in the H2020 program, representing a system's path dependence. However, milder lock-in effects are also apparent among COVID-19 initiatives. Such path dependence is based, partly, on IMI clusters. This can be evaluated positively, as the IMI initiative can be positioned as a collaboration incentive of more robust link creation between healthcare companies, previously competitors and now partners, and direct stakeholders, such as patient groups. Other findings are linked to the R&I policy regulations and the nature of the actors.

This work's results go beyond previous studies, showing that urgency conditions push policymakers to demonstrate vital flexibility and adaptability of the EU R&I Calls to the societal needs. Urgency fostered several necessary changes in the analyzed R&I projects: COVID-19 affected policies and processes related to R&I proposal preparation and evaluation period of the R&I proposals for COVID-19 outbreak. Also, the funded projects demonstrate a shorter implementation life span than other R&I healthcare projects. Moreover, we underline that in urgent conditions, the PPPs' power is essential, as actors mobilize funds and knowledge to provide innovation. In COVID-19 calls some actors participated as monetary support providers (for example, Bill & Melinda Gates Foundation), one of the main elements for innovation production. Policymakers demonstrated their efforts in mobilized policymaking and regulations for such R&I partnerships, research actors – provided their knowledge for innovations, and civic society – supports resilience actions dedicated to overcoming crises of communities.

At the same time, the list of knowledge actors in FPs is changing remarkably. As expected, the strong mobilization of the classical EU healthcare actors has been observed. However, partnerships among them tended to change with respect to previous programs as forced by the urgency. More generally, it appears that the COVID-19 response demanded such expertise, facilities, and means that the paradigms of mutual trust and adaptation, as incentives to re-propose already tested collaborations, deteriorated in favor of other paradigms fitness, reputation, and selection (of the fittest). As mentioned in part 3.3, 124 countries took part in FP7 healthcare calls and 107 in H2020 healthcare calls. The mentioned classical actors represented by the solid geographical clusters within the EU do not leave leading positions in the sector. During the COVID-19, they are more open for closer and faster cooperation than ever. However, they do not appear in the same collaborations as before.

Additionally, we can see that non-EU countries demonstrated strong cooperation and co-creation openness under the exogenous shock. This reflects a willingness to search for non-standard solutions to the outbreak, capitalize on the resources for everyday welfare purposes, and scaling up medical capacity for treatment and testing based on solid partnerships, as PPPs.

In such conditions, the list of the COVID-19 calls is limited to 35 countries with the top ten leading positions taken by the core of EU countries: Germany, France, Italy, the Netherlands, Italy, Spain, the United Kingdom, Sweden, Switzerland, and Austria. However, the list of 35 countries also underlines non-EU R&I healthcare leaders in this R&I cooperation, such as the United States of America, China, and Canada. This demonstrates a worldwide openness to finding common innovative solutions for the outbreak, mobilizing resources for welfare purposes, and scale-up medical capacity for treatment and testing. As so, the nature and extent of SARS-CoV-2 outbreak acted as a force of aggregation at a higher level (trans-continental level), which, at the same time, resulted as a force of disaggregation of consolidated and localized clusters of cooperation. In other words, it reduced competition among continents in favor of collaboration, which, in turn, removed the primary motivation behind tight and consolidated collaboration (lock-in) at a local level, which was to be more competitive at a global level. Our findings also highlight that in such specific context as healthcare R&I networks under exogenous shock, the urgency policy and the shock itself stimulate stronger lock-in within the core of the consolidated local networks: a few institutions geographically close and with a history of consolidated collaboration act together as a single one to better fit the needs and the (high) standards of a worldwide collaboration. This is influenced by the need to react fast and mobilize the best knowledge for the appeared challenge. Also, persistent path dependence in a network supports success and innovative performance during the pandemic by capitalizing on increased resource commitment and incentive alignment with the partners. This is based on Page (2006) findings regarding the impact of the path dependence on the system: lock-in, self-reinforcement, and increasing returns. According to our results, the words of Tomasello *et al.* (2014) “that exogenous shock plays a smaller role than endogenous mechanisms in the network formation” seem to apply only to the (regional) components of the trans-continental collaborations that emerged to face the pandemics.

The three most significant COVID-19 initiatives demonstrate a strong dependence on the overall R&I network. The newly created COVID-19 partnerships can be understood as a knowledge selection from the previous collaboration of the H2020 communities. These initiatives foster innovation development for three significant EU objectives: (i) development and application of new medical solutions to rapidly and efficiently address the COVID-19 pandemic, (ii) development of EU knowledge base for preparedness and response to future disease outbreaks, and (iii) mobilization of the international experiences and practices to improve epidemic control.

In all the analyzed networks, the leading positions are taken by HES and REC in FP7 healthcare and partially in H2020 healthcare, but the tendency is changing in COVID-19 partnerships, where the private – for-profit companies (PRC) are leading. Almost in all cases, the PRC's participation in these R&I actions is based on its institutional funds, without EU contribution. Knowing that basic research is usually connected with high-level risk, PRCs are still willing to support such an activity with their funds when it comes to COVID-19. That may be due to the perception that such an unprecedented global mobilization of governments and institutions may lower the risk of investing in basic research. Having specific knowledge and infrastructure that permits them to take part in these actions, the PRC accepts high R&D expenditures, knowing that a winning result can guarantee their financial sustainability for decades (Bierly and Joseph, 2004). In all the urgency networks, the PPPs act as a pillar for, so called by Casady and Baxter (2020), "the emergence of coalitions and maintenance of information flow between them (p. 7)". Being a formal social structure and represented as a governance network structure, these partnerships provide a framework for aligning public and private needs around healthcare. They are project-driven and act as a strategic tool for resource acquisition, problem-solving/regulation mechanism, and policy development instrument.

Finally, we would like to underline that network analysis turned out to be a suitable research tool for developing new knowledge regarding cooperation evolution under exogenous shocks. This work proposes a methodological approach that can be fruitfully re-used by the stakeholders working on healthcare system improvement through the EU R&I framework programs.

From the managerial point of view, this work can be a guidance document for the SMEs and other types of organizations who are willing to participate in the EU FPs but do not have access to necessary data for link creation. The annexes provide lists of the healthcare projects, actors of which can be found on www.cordis.europa.eu, helping to understand who are the leaders of the sector, with whom these leaders cooperate at national and international levels. So, they can be addressed by the SMEs and other types of organizations for potential link creation and presentation of innovation potential, which is hidden in the external R&I healthcare network's environment.

3.5 LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

This work presented the impact of an exogenous shock, such as the worldwide COVID-19 pandemic, on R&I networks in the context of the EU R&I framework programs. Even having access to big data provided a rich spectrum for analysis; still, we recognize that this study has several limitations. One limitation of this work is linked to the construction of a dataset. The absence of data on non-funded projects is not presented in our dataset, as this type of data is not accessible for third parties due to the EU data protection law. Such information would undoubtedly allow a better representation of the healthcare R&I network formation and its evolution and the role of other "worldwide big innovator", like Russian Federation, which does not appear in the COVID-19 dataset. Secondly, our dataset included projects representing the IMI program; in other words, the biggest PPP. However, PPPs do not represent a significant part of our dataset. So, it is challenging to provide any robust conclusion about their role in R&I in the time of this pandemic. The research on PPPs' role during the outbreaks has excellent potential for future works. The next limitation is linked to the research methods applied. In this work, no qualitative approach was used. We believe that panel interviews with the coordinators of the proposals (both funded and not funded) would enrich scholars' understanding of the consortium formation logic and collect tacit knowledge regarding R&I networks' evolution. This would support the systemization of research knowledge on the role of informal mechanisms (such as a trust) followed by network actors. Finally, we firmly believe that networks' evolution can be studied not only based on the data directly linked to the knowledge actors. It can support the study, aiming to provide an overview of the changes applied in the R&I funding process (such as duration of the proposal development, limitation of the calls, etc.) for emergency calls.

We believe that this research, even with its limits, contributes to scholars' knowledge base and interests (i) to study R&I network evolution under the exogenous shock and (ii) developing a framework for improved organizational preparedness within PPPs and other collaborative partnerships for future outbreaks further.

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CONCLUSIONS

Sustainability and sustainable development represent a paradigm of the harmonious functioning of social, environmental, economic, and political systems for the benefits of the present and future generations and strongly imply policy and business transformation, which is spurred by the introduction of innovative thinking. This thinking entails changes in all organizational areas, including forming strategic inter-organizational partnerships, rethinking their governance, and increasing innovations linked to sustainability through glocal actions worldwide. Knowing that science of sustainability is not an independent discipline and represents a complex field of research that requires the interaction between scholars and practitioners, we stress its request for scientifically contested and proactive policy interventions in all R&I fields and an improved understanding of the R&I network's dynamics. Understanding the dynamics supports applying coherent management strategies for future actions linked to the organizational expectations about this future.

With this work, we underline the complex nature of the EU R&I field, which permits us to analyze and characterize key dimensions, drivers, and outcomes of the R&I networks based on the theory of complex systems and network analysis as a prominent research tool for the raised research questions. The research questions that this work focuses on are explored within the high potential EU R&I policy and funding tool – i.e., the EU framework programs.

After a brief introduction of the sustainability phenomenon and developing the most potent policy and funding instrument at the EU level – the EU R&I framework program – this thesis provides three groups of empirical findings for the organizational management literature.

Recent literature stresses the fact that sustainability is based on two pillars: innovations and glocal actions. Hence, Chapter 1 addresses the necessity of management scholars to conceptualize sustainable innovations and critically reflect on the stakeholders of these innovations. This chapter reflects managerial practices related to the inter-organizational resource-management of sustainable innovation applied by organizations in the sustainability era. The chapter argues that sustainable innovations are still linked to environmental issues strongly in the research literature, mainly addressing classical groups of stakeholders, such as customers, policy makers, investors, and others. However, a change in mindset is necessary, as sustainable innovations should target all the Sustainable Development Goals. Thus, scholars need to reflect on a more complex framework of sustainability, not limited to environmental factors, stressing why organizations are changing their business models and target sustainable innovation strategy more actively: due to internal forces, external motivators (needs of customers, impact of local action groups, policy incentives or pressure), or both.

Additionally, fragmented literature on stakeholders' involvement practices requires a more systematic approach to investigate this issue based on collaborative practices with non-governmental organizations interests' groups, local associations, citizens, and other glocal actors, like media. Their role is critical in solving local problems and contributing with their know-how to solutions for global challenges. However, these dynamics reshape policy (sometimes positively or sometimes negatively) at the local level, changing the system's power balance, regime, and niche practices, which should be studied by scholars aiming to develop successful policies and a conceptual framework for sustainable innovations.

The other two chapters of this thesis concentrate on two levels of aggregation within inter-organizational networks, namely, the mesoscopic and microscopic levels[48], providing insights into the policy impact on the network's dynamics and the networks' reaction to exogenous shocks as COVID-19. Both chapters investigate research questions in the two latest Framework Programmes (FP7 and H2020), representing collaborative R&I projects at the EU level. More than 50,000 unique projects are included in the analysis of the meso- and micro-dynamics. These networks provide a systemic view regards a policy application (the FPs) to promote specific cooperations and activities (university-industry collaboration, training of researchers/individuals) oriented towards sustainability goals.

The mentioned programs facilitate partnerships for excellent knowledge and technologies through developing, supporting, and implementing the EU policies for global challenges. Innovation, or so-called cluster policy, provides different funding mechanisms (such as increased funding rate for actors, more flexible application process, shorter project evaluation period within the emergency conditions) to spur the region's innovativeness. Passing from FP7 to H2020, the R&I network still demonstrates high heterogeneity. However, under policy changes, the new H2020 network presents more robust clusters and sporadic participation of the new actors in this complex system. As the H2020 network becomes more diverse due to the new entries (mostly public and other types of actors), we hypothesize that such diversity in the actors' composition is linked to the context of the special calls linked to glocal issues and this may act as a research hypothesis for future research.

Also, we argue that the EU cluster policy for R&I, has slowly displayed its impact on partnership formation. The rich-club phenomenon supports the functioning of the system along the line of creating excellence clusters and, through a positive feedback mechanism, increases the assortativity of the system. This fosters a closer cooperation between organizations similar to each other in terms of reputation, expertise, and size, and a weaker cooperation between heterogenous organizations. Rooted participation of these organizations in the networks

[48] In this work, the concept of "*mesoscopic*" level refers to the analysis of evolution organizations' communities in the network, whereas, "*microscopic*" refers to the network's patterns linked to single projects.

underlines the fact that the EU funding and R&I investments support the research consortia, based on the innovation potential of *excellent* actors, which is not necessarily equivalent to funding *excellent* projects. Under the policy change, the logic undergirding link creation for collaboration is influenced by the classical R&I actors with limited support of newcomers, who demonstrate a short-lived tendency within the system. Basically, the latter actors are represented by local formal and informal knowledge actors (for example, municipalities and non-governmental organizations) or "average class" R&I actors (regional higher education institutions or research organizations), who are needed to address specific calls of the program (for example, linked to local actions, responsible research, and innovation, smart specialization). The appearance of new actors with limited participation in the program partly demonstrates a transition path that, being more inclusive, appears more sustainable in the long run. However, such behavior is fragmented and does not represent "a must," notably changing and re-constructing the network's structure. The prominent actors (hubs) support the region's stability and value creation; however, the increasing stability of their involvement in the projects, together with the tendency to gather together in the same projects, represents a "lock-in" phenomenon that may impair innovativeness: most of the support goes to fund well-established institutions and main-stream research. Newly adopted and launched, the Horizon Europe program implements several policy incentives as well (closer experts' cooperation with the applicant in the project evaluation phase, blind review of the proposals in the first stage application, establishment of specific and flexible funding instruments for SME's and start-ups' R&I activities, and others). These changes aim to open the collaborative partnerships to a broader list of new actors, or actors representing "middle-class innovators". To evaluate the next changes in this complex system, a minimum five-year period is needed. It is critical to assess if the short-lived actors would resist the system's selection process, reshape reach-club modalities, and provide a more substantial contribution to these R&I networks based on newly published Horizon Europe R&I calls, which promote Sustainable Development Goals systematically.

Based on the empirical analysis reported in the thesis, we argue that the existing R&I system demonstrates three patterns of network evolution passing from one FP to the next: persistent knowledge stability, knowledge spread, and knowledge aggregation. These patterns depend also on the nature of the actors. Due to their specialization, some actors can demonstrate stability passing from one program to another (ICT, Transport, and Energy calls). Others demonstrate a hybrid nature (Science with and for Society), which stimulates their adaptative behavior (knowledge aggregation or spread) within the EU R&I calls. Indeed, the domination in the system is rooted in core EU institutions from the classical innovation countries (the

United Kingdom, Germany, Italy, Spain, France, and Belgium) and in their role in specific fields, such as Information and Communication Technologies, Food, and Nanosciences.

As an R&I policy tool, these networks should demonstrate capacities and potential for innovation to overcome socio-economic crises that appeared due to various external conditions. This thesis analyzes the R&I network's reaction to a relevant external shock, such as the ongoing worldwide pandemic of the coronavirus disease 2019 (COVID-19). Healthcare was the first sector impacted by the pandemic, which called for a mobilization of the knowledge actors to develop the products and services that are necessary to tackle the outbreak. The COVID-19 pandemic demonstrated that sustainable development should go beyond national policies and strategies. The special R&I calls linked to the outbreak and published by the EU invited to change the view on collaboration formation and pushed organizations to rethink partnerships and business models. Questioning which changes appear under these conditions in the EU R&I framework, we concentrate on the evolution of the collaborative healthcare projects, comparing the FP7, H2020, and Innovative Medicines Initiative (IMI) partnerships with the newly established ones, which target to respond the special COVID-19 calls. The initiative represents the most significant healthcare Public-Private Partnership (PPP). According to scholars, the actual force to overcome the crises is kept by the PPPs' potential. Our results indicate that the EU R&I healthcare actors show two typical patterns of aggregation under an exogenous shock: extreme lock-in and, at the opposite, highly innovative partnerships. In our understanding, such behavior is firmly linked to trust, specialization, infrastructure, professional links, and other resources, that induce the sector's classical actors group together to form (reliable) clusters of excellence. This path-dependent behavior of the system is apparent within the IMI community, whereas it is softer in the H2020 Healthcare Calls. Systematically, the strongest geographical characters (Germany, Austria, France, Belgium, Italy, and Switzerland) link to the network's classical knowledge actors and demonstrate separate and strong clusters with specific regional specializations and cooperation practices. We notice that under the exogenous shock and urgency of COVID-19, the healthcare actors apply lock-in and self-reinforcement more than is apparent in other conditions. This behavior responds to the urgent situation and calls for mobilized efforts with well-known partners, and strengthens the endogenous mechanisms' role within the partner selection process.

Additionally, we observe how the system opens to cooperation with non-EU countries at the verge of pandemic response. Indeed, the United States of America, China, and Canada demonstrated significant involvement in the COVID-19 calls. Their participation in the EU calls indicates the tendency to collaboratively respond to an exogenous (and catastrophic) shock. Thus, reducing competition and increasing the trust among the partners through lock-in at the local and global level.

Moreover, it is to notice that (under urgency conditions) policymakers demonstrate flexibility and adaptability of the funding rules to solutions for a global pandemic response. The COVID-19 projects can be characterized by a shorter evaluation period, an increased mobilization of the funds, a proactive start of the actions, and a shorter life span of the proposals.

This research is subject to several limitations, solutions to which would enrich our results. One is linked to the dataset and the other to the methodology. We communicated within chapters 2 and 3 that only access to the funded projects' dataset was granted, which limits the information about cooperation patterns carried by the R&I network. Having a list of non-funded projects would help us reflect on the system's dynamics more accurately, in particular on the trade off between partnerships' excellence and innovativeness of the projects in the selection process. However, the dataset of funded projects that we have analyzed in the thesis is more suitable to revail path dependencies across the two programs. Of course, network analysis is a powerful tool to use for such studies. However, we believe that qualitative studies that, for instance, involve in-depth interviews to the projects' coordinators would enrich our findings with the specific tacit knowledge linked to creating the collaboration ties. Thus, we invite management scholars to extend the presented analysis with qualitative research. To conclude, we should recognize that this thesis's scope does not overcome the specific EU R&I field considered.

Even considering the limitations of this study, we stress the work's managerial and policy application. A solid body of research acknowledges the influence of inter-organizational networks on an organization's innovation performance. Moreover, scholars underline that maintaining sustainable relationships within the network helps create and extract considerable value for the market. In parallel, we know that the organizations' innovativeness is fostered by the innovation policies, which are essential external factors for collaboration and promotion of "new" societal and business values, such as sustainability. Also, we know that sustainability is an outcome of the stakeholders' collaboration in this complex environment. In this regard, we claim that in such a specific and powerful field as the EU R&I framework programs, which support new policy directions (for example, SDGs), the balance between "classical" actors, "middle-class innovators," and newcomers is essential for developing sustainable innovation. This balance can be stimulated by applying updates to the R&I projects' selection criteria, for example, based on the blind review of the proposals. Changes recently introduced with the Horizon Europe Programme also demonstrate that the regions spur the "classical" actors (also titled as innovation leaders), SMEs, and start-ups, limiting the participation of the "middle-class innovators." They can be represented not only by institutions, for instance, higher education institutions that are not leading in the ranking lists, but also by developing R&I countries, such as Czech Republic, Poland, Lithuania, or other so-called moderate innovators. So, even after 30 years of the program's life, there is room for improvement and adaptation to the glocal needs. At the same time, we believe that the evaluation period should be minimized, as the long time period (almost one year) dedicated to the project preparation, evaluation, and grant agreement preparation minimizes innovation's actuality. The European Commission represents an excellent example of the application of new administration rules within the COVID-19 Calls. Simplified and fast procedures guaranteed the creation of potential collaborations to overcome the crisis.

The reader may argue that sustainability and innovations are challenged by organizational boundaries, such as resources, knowledge capital, local policies, conflict of interests, and other limitations. This is why this thesis calls for the attention of policymakers, practitioners, and stakeholders to take a systemic view on the topic and invites for more critical revision of the EU R&I framework for effective and efficient collaboration practices.

APPENDIX

3.1 The list of country ISO codes

The list of country ISO codes, as described in the ISO 3166 international standard, used in this chapter.

BE – Belgium
CD – Congo (the Democratic Republic of the)
CH – Switzerland
CI – Cote D'Ivoire (Ivory Coast)
DE – Germany
EL – Greece
ES – Spain
FI - Finland
FR – France
IE – Ireland
IL – Israel
IT – Italy
JM – Jamaica
KG – Kyrgyzstan
LU - Luxembourg
ME – Montenegro
MG – Madagascar
NC – New Caledonia
NL – Netherlands
NO – Norway
PA – Panama
PY – Paraguay
SE – Sweden
SL – Sierra Leone
SR – Suriname
SZ – Swaziland
TJ – Tajikistan
UK – The United Kingdom
USA – The United States of America

3.2. Common number of actors between FP7 Health and H2020 Health projects

Proj_H2020 (NEXT)	Proj_FP7 (PREV)	N_INST_ PREV	N_INST_ NEXT	N_INST_ OVERLAP	STAND_ GEOMETRIC _MEAN	STAND_ UNION	STAND_ PREV	STAND_ NEXT
TRANSCAN-2	TRANSCAN	29	32	23	0.7550	0.6053	0.7931	0.7188
TBVAC2020	NEWTBVAC	35	46	19	0.4735	0.3065	0.5429	0.4130
EJP RD	ERA-NET NEURON II	23	89	15	0.3315	0.1546	0.6522	0.1685
NEURON COFUND	ERA-NET NEURON II	23	23	14	0.6087	0.4375	0.6087	0.6087
ERA-CVD	TRANSCAN	29	23	13	0.5034	0.3333	0.4483	0.5652
JPCO-FUND	ERA-NET NEURON II	23	26	13	0.5316	0.3611	0.5652	0.5000
E-RARE-3	E-RARE-2	18	27	13	0.5897	0.4063	0.7222	0.4815
E-RARE-3	TRANSCAN	29	27	13	0.4646	0.3023	0.4483	0.4815
ERA PERMED	ERA-NET NEURON II	23	32	13	0.4792	0.3095	0.5652	0.4063
EJP RD	E-RARE-2	18	89	13	0.3248	0.1383	0.7222	0.1461
EJP RD	TRANSCAN	29	89	13	0.2559	0.1238	0.4483	0.1461
E-RARE-3	ERA-NET NEURON II	23	27	12	0.4815	0.3158	0.5217	0.4444
JPCOFUND2	ERA-NET NEURON II	23	29	12	0.4646	0.3000	0.5217	0.4138
PERFORM	EUCLIDS	16	18	11	0.6482	0.4783	0.6875	0.6111
ERA-CVD	E-RARE-2	18	23	11	0.5406	0.3667	0.6111	0.4783
NEURON COFUND	E-RARE-2	18	23	11	0.5406	0.3667	0.6111	0.4783
NEURON COFUND	TRANSCAN	29	23	11	0.4259	0.2683	0.3793	0.4783
DIAMONDS	EUCLIDS	16	28	11	0.5197	0.3333	0.6875	0.3929
TRANSCAN-2	E-RARE-2	18	32	11	0.4583	0.2821	0.6111	0.3438
ERA PERMED	TRANSCAN	29	32	11	0.3611	0.2200	0.3793	0.3438
TBVAC2020	ADITEC	52	46	11	0.2249	0.1264	0.2115	0.2391
ZIKALLIANCE	EVIMALAR	39	55	11	0.2375	0.1325	0.2821	0.2000
EJP RD	RD-CONNECT	30	89	11	0.2129	0.1019	0.3667	0.1236
SHIPS	EPICE	13	14	10	0.7412	0.5882	0.7692	0.7143
COCA	AGGRESSOTYPE	26	17	10	0.4757	0.3030	0.3846	0.5882
JPCO-FUND	TRANSCAN	29	26	10	0.3642	0.2222	0.3448	0.3846
JPCOFUND2	TRANSCAN	29	29	10	0.3448	0.2083	0.3448	0.3448
EUROSTEMCELL	EUROSYSTEM	25	31	10	0.3592	0.2174	0.4000	0.3226
ERA PERMED	E-RARE-2	18	32	10	0.4167	0.2500	0.5556	0.3125
TBVAC2020	EVIMALAR	39	46	10	0.2361	0.1333	0.2564	0.2174
EJP RD	JUMPAHEAD	13	89	10	0.2940	0.1087	0.7692	0.1124
ORTHOUNION	REBORNE	24	11	9	0.5539	0.3462	0.3750	0.8182
VSV-EBOVAC	ADITEC	52	13	9	0.3462	0.1607	0.1731	0.6923
RELENT	INTRICATE	12	15	9	0.6708	0.5000	0.7500	0.6000
JPSUSTAIND	JUMPAHEAD	13	15	9	0.6445	0.4737	0.6923	0.6000
ERACOSYSMED	TRANSCAN	29	15	9	0.4315	0.2571	0.3103	0.6000
SPIDIA4P	SPIDIA	17	19	9	0.5008	0.3333	0.5294	0.4737
JPI-EC-AMR	E-RARE-2	18	19	9	0.4867	0.3214	0.5000	0.4737
JPI-EC-AMR	ERA-NET NEURON II	23	19	9	0.4305	0.2727	0.3913	0.4737
…..								

3.3. Common number of actors between H2020 Health and H2020 Health projects

Proj_COVID. (NEXT)	**Proj_H2020 (PREV)**	**N_INST _PREV**	**N_INST _NEXT**	**N_INST_ OVERLAP**	**STAND_ GEOMETRIC _MEAN**	**STAND_ UNION**	**STAND_ PREV**	**STAND_ NEXT**
I-MOVE-COVID-19	I-MOVE-PLUS	29	20	14	0.5813	0.4000	0.4828	0.7000
CARE	CONCEPTION	53	37	9	0.2032	0.1111	0.1698	0.2432
CARE	ZIKALLIANCE	55	37	9	0.1995	0.1084	0.1636	0.2432
CARE	MELLODDY	17	37	8	0.3190	0.1739	0.4706	0.2162
CARE	EUBOPEN	22	37	8	0.2804	0.1569	0.3636	0.2162
CARE	IMMUCAN	28	37	7	0.2175	0.1207	0.2500	0.1892
CARE	EQIPD	29	37	7	0.2137	0.1186	0.2414	0.1892
CARE	TRIALS@HOME	31	37	7	0.2067	0.1148	0.2258	0.1892
CARE	DO-IT	36	37	7	0.1918	0.1061	0.1944	0.1892
CARE	AIMS-2-TRIALS	48	37	7	0.1661	0.0897	0.1458	0.1892
CARE	HARMONY	56	37	7	0.1538	0.0814	0.1250	0.1892
RECOVER	ECRAID-PLAN	13	10	6	0.5262	0.3529	0.4615	0.6000
RECOVER	ZIKALLIANCE	55	10	6	0.2558	0.1017	0.1091	0.6000
EU-RESPONSE	C4C	47	21	6	0.1910	0.0968	0.1277	0.2857
EU-RESPONSE	EJP RD	89	21	6	0.1388	0.0577	0.0674	0.2857
CARE	CARDIATEAM	21	37	6	0.2152	0.1154	0.2857	0.1622
CARE	IM2PACT	27	37	6	0.1898	0.1034	0.2222	0.1622
CARE	PHARMALEDGER	28	37	6	0.1864	0.1017	0.2143	0.1622
CARE	ETRANSAFE	28	37	6	0.1864	0.1017	0.2143	0.1622
CARE	BIOMAP	32	37	6	0.1744	0.0952	0.1875	0.1622
CARE	PREFER	33	37	6	0.1717	0.0938	0.1818	0.1622
CARE	C4C	47	37	6	0.1439	0.0769	0.1277	0.1622
CARE	3TR	70	37	6	0.1179	0.0594	0.0857	0.1622
CARE	EJP RD	89	37	6	0.1046	0.0500	0.0674	0.1622
SCORE	ZIKALLIANCE	55	8	5	0.2384	0.0862	0.0909	0.6250
COVID-X	CUREX	17	10	5	0.3835	0.2273	0.2941	0.5000
ICU4COVID	SMART4HEALTH	19	19	5	0.2632	0.1515	0.2632	0.2632
I-MOVE-COVID-19	HBM4EU	43	20	5	0.1705	0.0862	0.1163	0.2500
CARE	EBISC2	16	37	5	0.2055	0.1042	0.3125	0.1351
CARE	ESCULAB	20	37	5	0.1838	0.0962	0.2500	0.1351
CARE	IMMUNE-IMAGE	22	37	5	0.1752	0.0926	0.2273	0.1351
CARE	EHDEN	22	37	5	0.1752	0.0926	0.2273	0.1351
CARE	PRISM	23	37	5	0.1714	0.0909	0.2174	0.1351
CARE	H2O	23	37	5	0.1714	0.0909	0.2174	0.1351
CARE	RHAPSODY	28	37	5	0.1553	0.0833	0.1786	0.1351
CARE	IMSAVAR	28	37	5	0.1553	0.0833	0.1786	0.1351
CARE	ERA4TB	31	37	5	0.1476	0.0794	0.1613	0.1351
CARE	MOBILISE-D	34	37	5	0.1410	0.0758	0.1471	0.1351
CARE	PARADIGM	35	37	5	0.1389	0.0746	0.1429	0.1351
CARE	ADAPT-SMART	35	37	5	0.1389	0.0746	0.1429	0.1351
MANCO …..	ISOLDA	7	8	4	0.5345	0.3636	0.5714	0.5000