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Unveiling the Transformative Potential of the European Framework Programme for Research and Innovation

A systemic analysis of the FP design from 2002 to 2023

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Unveiling the Transformative Potential of the European Framework Programme for Research and Innovation. ***A systemic analysis of the FP design from 2002 to 2023***

European Commission
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EUROPEAN COMMISSION

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Working Paper

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2024 Directorate-General for Research and Innovation

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ABSTRACT

This paper explores the European Framework Programme (FP) for Research and Innovation's (R&I) evolution over the last two decades, focusing on its integration of Transformative Innovation Policy (TIP) elements. Our objective is to assess whether the European Framework Programme for R&I has evolved to include elements of R&I policy for societal challenges and transformative change (Transformative Innovation Policy) and offer related policy recommendations. We do so by analysing the Framework Programme from 2002 to 2023 through within-case and cross-case studies using systems dynamics. It provides original insights into applying the TIP framework and system dynamics to evaluate R&I public policies targeting systemic societal shifts. We demonstrate that, while the EU FP for R&I has progressively incorporated transformative elements like demand articulation and policy coordination, room for improvement remains in terms of reflexivity. Our findings also emphasize the interdependence of transformative features, necessitating ongoing adaptations throughout the policy cycle to reinforce the FP's transformative nature.

1. Introduction

Research and innovation (R&I) policies face various interconnected challenges, including climate change, environmental degradation, biodiversity loss, global health, and geopolitical crises. Addressing these challenges requires innovations in technology, social systems, business models, and infrastructure (Bulkeley et al., 2013; Bolton and Foxon, 2015; Bolton and Hannon, 2016; Hoppe and de Vries, 2019; Van Waes et al., 2018). In the past decades, R&I policies have shifted from a strong focus on technological innovation to an approach that links societal and environmental needs with technological innovation (Geels, 2020), referred to as Transformative Innovation Policy (TIP) (Steward, 2012; Diercks et al., 2019; Schot and Steinmueller, 2018; Haddad et al., 2022).

At the EU level, sustainable development became first a policy objective following the Treaty of Amsterdam in 1999 and the Lisbon strategy in 2000, and then a legal commitment following the Lisbon Treaty in 2009. EU policies, including those aiming at fostering R&I, have progressively integrated the sustainable development goals (SDGs). Besides, the European Green Deal (European Commission, 2019), published in 2019, advocates for transformative policies, including R&I, to promote sustainable growth and deep societal transformations in the European Union.

In the European policy landscape, the Framework Programmes (FPs) for R&I are the main instrument of the European Commission to strengthen the scientific and technological base of the EU. In the initial Treaties on European Communities, there was little competence for the EU in R&I, only the Euratom Treaty 1957 aimed at promoting research in the field of nuclear energy. Following a debate that started in the 1960s, common research policy and dedicated services were created in 1967, and, in 1984, the first Framework Programme, FP1 was launched with a budget of EUR 3.75bn for a period of four years. Since then, the successive FPs have increased budget, integrated new policy instruments and new priorities, including sustainable development since 2000s, and provided the direction, the instruments and financial support for R&I activities in the European Union. The latest FP – Horizon Europe – has a budget of over EUR 95bn for a period of seven years (2021-2027).

Numerous studies have explored the evolution of European FPs, focusing on integrating SDGs and sustainable development into their objectives (among others, Abbott 2020; Young, 2015; Ulnicane, 2015; Pollex and Lenschow, 2018). Some experts have also examined transformative innovation policies and their characteristics and challenges (Haddad et al., 2022; Borràs and Serger, 2022). However, there is a lack of knowledge about the implementation of these policies (Parks, 2022) and insights into their operationalization and assessment (Mc Laren and Kattel, 2022; Wanzenböck et al., 2020; Casula, 2022; Ghosh et al., 2021).

This study aims to assess the evolution of EU R&I policies towards a systemic/transformative approach since the 2000s, using the TIP framework and focusing on the EU R&I FP. Additionally, it aims to contribute to operationalizing the TIP approach by analysing its core elements, interrelations, and implications for policy design. Therefore, our main research questions are: *How has the European FP for R&I evolved over the past twenty years? How has it embedded the building blocks of transformative R&I policy to tackle global societal challenges and accelerate the transition to a more sustainable society?* To achieve these goals, the study conducts a case study analysis of the FP's evolution from 2002 to 2023, employing a qualitative system dynamics methodology called causal mapping (Haraldsson and Sverdrup, 2004; Cavana et al. 2019; Senge, 1990). The analysis uses governance and budget assessments, as well as key policy documents, interviews, and continuous dialogue with European officials.

The paper is structured as follows. Section 2 and 3 will outline the conceptual and methodological framework respectively. Section 4 will

provide the results of the analysis and section 5 will draw and short discussion and conclusions.

2. Conceptual framework

This study relies on systems thinking (e.g., Senge, 1990; Midgley, 2000; Mingers, 2014) to operationalize the concept of Transformative Innovation Policy (Steward, 2012; European Commission, 2020; Schot and Steinmueller, 2018; Diercks et al., 2019; Haddal et al., 2022) and apply it to the analysis of the evolution of FP's transformative nature. In the literature, the TIP framework suggests key defining elements of a transformative innovation policy. Based on Haddad et al. (2022), as well as Schot and Steinmueller (2018), we focus on four features that we will use in our analysis:

- *Directionality and societal goal* – in the TIP framework, it refers to the intentional focus and orientation of policy measures and actions towards desired transformative outcomes, in link with major societal challenges, such as climate change, social inequality, and economic development, and Sustainable Development Goals.
- *Policy coordination* - how to steer the policymaking process so to produce coherent policy designs and allow for adaptive policy portfolios.

  Demand-articulation – refers to anticipating and learning about user needs to define a shared direction of change and enable the uptake of innovations by users. Here the main example in the FP is the involvement of stakeholders in co-creation for strategic planning and programming.

- *Reflexivity* – refer to providing spaces for policy learning and experimentation to keep options open to adjustments and deal with uncertainty along the policy cycle.

We also use Haddad et al. (2022)'s specific challenges for TIP implementation (see Annex 1 for more details). The authors group them into nine more generic "general themes" (second-order challenges) that they link with the specific details and examples of each general theme (Appendix B, table b). Our understanding of the links between Haddad et al.'s framework and TIP elements is shown in the table below. We categorize the general themes – taking into consideration their

specificities – under each feature of TIP to guide and substantiate our analysis and assessment of the evolution of the transformative nature of the FP.

Table 1 Synthesis of TIP elements and challenges

Elements of TIP	**Directionality**	**Policy coordination**	**Demand-articulation**	**Reflexivity**
Second order challenges	2. Translating societal goals into concrete policy targets and practices	3. Coordinating across policy domains and levels 7. Managing power struggles and conflicts of interests 9.Developing Institutional and Governance Capacity	1. Broadening perspectives on innovation policy 5. Empowering a broad set of stakeholders 6. Balancing influence from incumbent actors	4. Characterising and attributing policy effects 8. Navigating past policy dependencies 9.Developing Institutional and Governance Capacity

Source: Authors' elaboration based on Haddad et al. 2022.

For analytical purposes, we consider the FP as a policy mix, a system made of rules, institutional elements such as governance, budget, goals and objectives, instruments, and perceptions of those who analyse it. We consider that each of these elements are designed, approved, and implemented via means of interactions between European Commission's stakeholders and through exchange of information with other external stakeholders. We describe this exchange of information as feedback. Feedback is the process of interaction through which information is exchanged among different individuals or groups and learning is enabled (Richardson, 1991; Checkland 1981*).* By looking at these feedback interactions from the lenses of the TIP, it is therefore possible to gain a better understanding of how the different components of the FP policy mix – as a product of decision-making processes among different institutional and societal stakeholders – generate patterns that may or may not support the transformative capacity of the policy design.

The *conceptual and objective* boundaries of our system are therefore defined by the notion of policy mix (Pierson, 1993; Flanagan et al., 2011; Kern and Rogge, 2018; Wanzenböck et al., 2020), i.e., co-existence of different policy goals and objectives, instruments, and actions under a same strategy to enable transformations towards sustainability and the

elements of the TIP framework. Moreover, from a temporal perspective we analyse the FP during the period 2002-2023, i.e., from FP6 to FP9 (Horizon Europe). FP6, launched in 2002, was designed in the aftermath of the Treaty of Amsterdam, which entered into force in 1999 and enshrined sustainable development as an overarching objective of the European Union. In 2000, the European Union released the Lisbon strategy, the first action and development plan of the European Union designed to improve European's competitiveness with such as strong focus on economic, social, and environmental renewal and sustainability and in 2001, the European Council in Gothenburg adopted the first European Sustainable Development Strategy. We therefore consider that the focus on tackling societal challenges has become a basis for EU policies since the beginning of 2000s. Besides, scholars suggested that the Lisbon strategy has triggered major changes in the governance of the EU by changing the combination of innovative and existing instruments of governance (Hartlapp, 2007; Benz, 2009) and that these new instruments might have opened for new dynamics at the policy, politics, and polity levels of EU governance (Borrás and Greve, 2004).

3. Data and methodology

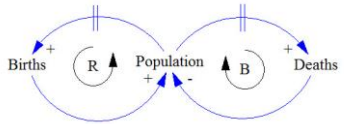
3.1 Methodology

The study adopted a qualitative and comparative case study approach (George & Bennett, 2005; Mjøset, 2006; Mjøset, 2009), combined with causal loop diagramming (CLD) (Haraldsson and Sverdrup, 2004; Cavana et al. 2019; Senge, 1990), to investigate the transformative capacity of FPs over the past two decades from FP6 to FP9. The comparative analysis builds on an in-depth within case analysis (Bennett & Elman, 2006; Cavicchi, 2016; 2018) of each FP where the CLD enabled the exploration of feedback dynamics among different elements of Transformative Innovation Policy (TIP) and their impact on the transformative nature of FPs. Its results can be found in Annexes 3 to 6. For analytical purposes and based on the structure of the FP Regulations, we have selected the following aspects as to be the main organisational components of the FPs: overarching goal, specific objectives, and pillars, instruments, and activities. The CLD of each FP follows and represents the interrelations among these components. The assessment of the feedback dynamics of each FP is done with reference to the conceptual framework presented in section 2. We use the same framework for the comparative analysis across FPs.

Box 1. Causal loop diagramming explained.

Causal loop diagramming enables the in-depth investigation of feedback dynamics resulting from the interrelation of multiple variables and processes, e.g., narratives and framings, goals, instruments, and principles. CLDs distinguish between reinforcing and balancing feedback loops, indicated as R and B in the diagrams. In a reinforcing loop, variables are positively related, and its polarity (or value) goes in the same direction (+). In a balancing loop, variables are inversely related, and its polarity goes in the opposite direction (−) (see Fig. 1). Arrows connect variables and indicate the causal influence between them (+, −). Wherever the loop reading may be started, the arrows value and loop polarity should not need to be changed (see Figure 1 below). Despite their weaknesses (e.g., the models cannot include flows and time delays), CLDs help the practitioner to understand how different elements (e.g., from goals to instruments and processes) stand together via feedback mechanisms. The paper acknowledges that causal loop diagramming is an oversimplification of reality, but as such, they can assist and enhance issue structuring, organizational learning and problem solving (Lane et al 2016; Lane and Kopainsky, 2017). CLDs indicate feedback relations between variables and can be used to explore and communicate the feedback processes underlying organizational dynamics (e.g., Lane et al. 2016).

Example of causal loop diagram



Various colours in the CLDs represent different TIP elements:

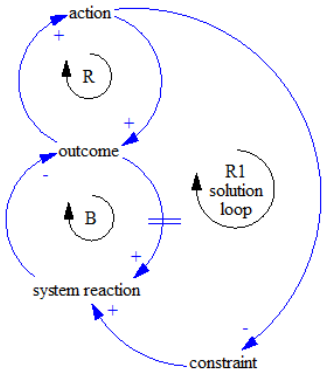
- green variables and arrows show the dynamics of policy coordination;
- orange variables and arrows show the dynamics of directionality;
- purple variables and arrows show the dynamics of demand-articulation;
- light blue variables and arrows show the dynamics of reflexivity; variables in darker blue and black represent variables that are not linked to TIP elements.

For ensuring validity and reliability, the study follows an iterative process, revising CLDs through rounds of analysis, external reviews, paper presentations, interviews and discussions with colleagues based on the presentation of our work (see Alvesson and Sköldberg, 2009; Shenton, 2004, Cavicchi, 2016). The dialogue with European officials allows to gather institutional knowledge, providing an additional opportunity for

cross-checking, and verify our interpretation. The iterative and reflexive process assists in checking and updating data collection process and diagramming until the final version of the CLD. The CLD analysis is complemented and consolidated by governance and budget analysis. Governance and budget analysis are used in the analysis of the evolution of the FP, more particularly to assess policy coordination and demand-articulation aspects, focusing on stakeholders and levels of government involved.

To support the comparative analysis (cross case study analysis), the study also uses system archetypes. System archetypes are ideal types that describe the most common but simplified patterns of behaviour (or mechanisms) recursively detected by system dynamics practitioners within a variety of organizations, under any circumstance, different levels and scales that range from internal dynamics to global relations (Senge et al., 2011; Kim and Anderson 1998; Cavana et al. 2019). They are useful to interpret, test and describe what the researcher or practitioner sees as the underlying structure of the problem under investigation. System archetypes, developed by Wolstenholme (2003, 2004), are used in this study to identify, and flesh out the main, key feedback mechanisms underlying the evolution of the FP transformative nature from one FP to the other and identify the challenges that were encountered and influenced the design of the next FP, with an emphasis on the underachievement archetype. This archetype reveals reinforcing and balancing loops that impact the success of initiatives over time, leading to subsequent interventions to address resource constraints. In our study, all the FPs analysed show the elements of an underachievement archetype as shown in Figure 1 where R and B describe the underachievement dynamics and R1 the intervention to fix the problems (Wolstenholme 2003). This kind of under-achievement archetype helps us to analyse whether the initiative or solution added to the FP in response to an identified issue in the evaluation of the previous FP is indeed mitigating the effects of the former action/intervention or not.

Figure 2. Underachievement archetype



3.2 Data

Our data integrates key policy documents, such as EU regulations, enabling frameworks, communications, staff working documents, strategies, official presentations, annual reports, impact assessment reports, interim and ex-post evaluations and fact sheets related to various European Framework Programmes (FPs) and their different parts from FP6 to FP9[1]. The identification of "landmark documents" was guided by institutional knowledge and web searches, complemented by secondary literature and academic papers. We also led semi-structured interviews with colleagues in DG RTD, identifying those who contributed to the design and development of the FP since 2002. Budget analysis relies on expenditure and revenue data from the Multiannual Financial Frameworks between 2002 and 2023.

Finally, for ensuring the validity and reliability, we have followed an iterative process to the development of the CLDs, analysis and recommendations (see Alvesson and Sköldberg, 2009; Shenton, 2004, Cavicchi, 2016). The iterative and reflexive process allows for repeated checking and updating of the data collection process and diagramming until the final version of the CLD is exhaustive and does not raise other

[1] (e.g., Regulation of FP6, Regulation of FP7, Regulation of Horizon2020, Regulation of Horizon Europe; ex-post evaluation FP6, ex-post evaluation FP7; interim evaluation Horizon 2020; analysis of ERA-NET co-fund under Horizon 2020, mid-term review of the public-private-partnerships under Horizon2020).

doubts or show inconsistencies. In our case, the study went through a process of multiple revisions of the CLDs based on reiterations between the CLD, policy documents analysis, interviews, CLD update, round of review by external reviewers, paper presentation and discussion with colleagues. The dialogue with European officials assisted with gathering institutional knowledge, providing an additional opportunity for cross-checking, and triangulating the policy document analysis to pursue verification of our interpretation of results. This combined approach was considered adequate for the goal of the research to analyse the evolution of the FP, how transformative it has become and its fitness to overcome specific challenges associated to TIP.

4. Results and analysis

This section will elaborate on the results of the analysis. It will first outline the general evolution of policy context, governance (Annex 2), and budget of the EU FP (Figure 4). It will then the results of the within-case analysis using the TIP framework. Second, it will dig into the across case-analysis and presents the weaknesses and achievements of the FP along its evolution considering the four TIP features.

4.1 Key facts about the evolution of the Framework Programme evolution FP 6 to FP 9

4.1.1 6th framework programme (2002-2006)

The EU's 6th Framework Programme (FP6) was launched in 2002 with a budget of EUR 18 billion. It was launched shortly after the creation of the European Research Area (ERA) in 2000 and it was designed to foster its rapid establishment. This marked an important development towards becoming a tool to promote broader R&I policy objectives. At the same time, FP6 became an integral part of the EU's ambitions adopted under the Lisbon strategy, which, in the area of R&I, was translated in the Barcelona target of 3% of GDP spending on R&D.

To achieve its objectives, FP6 was equipped with new tools. Alongside the co-operative research projects, which were the main support instrument under previous FPs, the programme introduced two new instruments: Integrated Projects (IPs) and Networks of Excellence (NoEs), which together accounted for nearly half of the budget. They were expected to strongly contribute to de-fragmenting the ERA and to create critical mass activity to enhance Europe's competitiveness. One of the new core instruments were also the Marie-Curie Actions (MCAs),

through which the European Commission aimed to foster the development of scientific and technical excellence, and cooperation across the ERA. Other instruments, such as specific targeted projects and Coordination Actions were meant to help small actors such as SMEs and associated countries to access funding opportunities, but most of the beneficiaries were major long-established players, limiting the FP's potential to reach smaller or alternative players. To support the coordination and collaboration of national and regional research programmes, the European Research Area Net (ERA-NET) scheme was launched. Finally, the EU regulation opened the possibility to create executive agencies to be entrusted with management tasks of Community programmes. This led to drastic changes in the governance of the FP, with the European Commission services progressively relieved from the implementation work to focus on policy design.

4.2.1 *7th framework programme (2007-2013)*

The 7th framework programme (FP7) was launched in 2007, with a significant increase in its budget from EUR 18 to 54 billion. This was due mainly to the enlargement of the EU to twelve new Member States between 2002-2007, but also to the relative increase of the budget dedicated to the FP.

FP7 placed a strong focus on enhancing private sector participation by incorporating new targeted instruments, including various forms of public-private partnerships (PPPs). This approach was a response to a significant finding from the evaluation of FP6, which highlighted the limited involvement of companies. Furthermore, in 2008, in response to the financial crisis, political decisions were made to strengthen support for R&I in the private sector, resulting in the establishment of new specialised instruments. During this period, PPPs gained recognition as a crucial tool for engaging private stakeholders and fostering stronger connections between the realms of science and business. Within its four pillars (Ideas, Cooperation, People, and Capacities), the Cooperation pillar, which included Joint Technology Initiatives and from 2008 onwards more contractual research Public-Private Partnerships (cPPPs), was endowed with the largest budget. The European Institute for Innovation and Technology (EIT) and its Knowledge Innovative Communities (KICs) were also established in 2008 first as an independent body and then merged under Horizon 2020. Finally, for the first time, funding rates were raised for some legal entities, e.g., SMEs. The maximum funding rates increased from 50% in FP6 to 75% in FP7 to facilitate their participation.

Another significant advancement in FP7 was the introduction of the European Research Council (ERC), a body responsible for allocating research funding solely based on excellence. Support through grants would typically go to individual beneficiaries and political, geographic, or economic factors had no influence on the decision-making process. Moreover, there are no thematic priorities set. This instrument under the Ideas pillar aimed at reinforcing the creation of a world leading research area.

A weakness of FP7, which was identified in its ex-post evaluation, was that it failed to fully foster intended synergies across its different parts and with other EU sectoral policies. The Cooperation pillar relied upon the thematic priorities introduced with FP6, which were directed at building synergies with other thematic programmes (e.g., LIFE), but this goal was not fully achieved.

Finally, in terms of governance, compared to FP6, executive agencies took on more responsibility of the programme management, as for instance with the SME-related actions and the MCAs.

4.3.1 8th framework programme - Horizon 2020 (2014-2020)

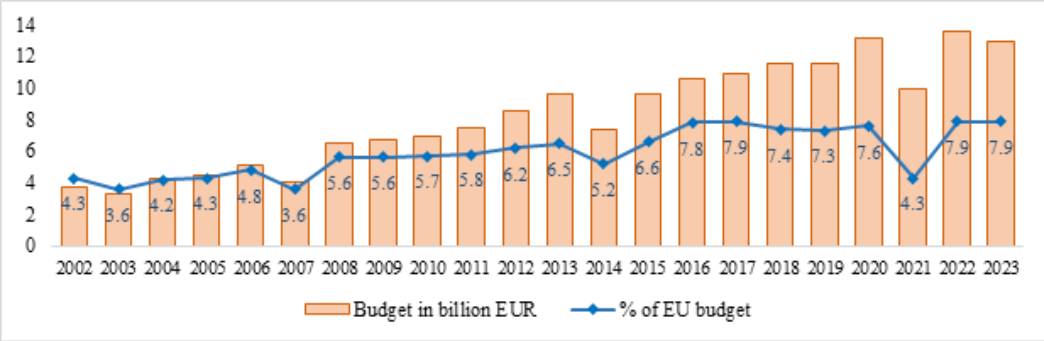
Horizon 2020, equipped with a budget of EUR 80 billion, was designed with a three pillars structure: Excellent science, Industrial leadership, and Societal challenges. The Excellent Science Pillar maintained its main instruments, the Marie Skłodowska-Curie Actions (MSCA) and the European Research Council (ERC), which have resulted in advancements in frontier research, research mobility, and publications. The Industrial Leadership pillar, which included the SME instrument, contributed to an increased small and medium-sized enterprises involvement (SMEs), access to risk finance and industrial driven research. Besides, the Societal challenges Pillar was a major novelty.

Alongside the goal of strengthening EU's competitiveness as stipulated in the Treaty, Horizon 2020's new key objective became tackling societal challenges and meeting the SDGs. The design of Horizon 2020 was aligned with the Europe 2020 strategy, which included the Innovation Union Flagship initiative. The strategy emphasized the importance of addressing societal challenges and encouraged innovation, particularly with engagement of the business sector. The Societal Challenges Pillar was initially divided into seven challenges aligned with the SDGs. However, the interim evaluation of Horizon 2020 highlighted that this approach lacked effective implementation through specific calls and actions. To address this issue, the Focus Areas instrument was

introduced to the pillar in 2018, during the implementation of Horizon 2020. The Focus Areas were designed to provide more targeted actions to address the implementation shortcomings and are considered the foundation of the EU Missions.

Compared to its predecessors, Horizon 2020 was designed with a comprehensive approach covering the entire innovation cycle, spanning from fundamental research to the integration of innovative solutions in the market (Ulnicane, 2015; Polex & Lenschow, 2018; Kim & Yoo, 2019). To achieve this, the programme made significant changes compared to its predecessors. Firstly, it merged funding for research, education, and innovation, implementing common rules and modalities, especially for the European Institute of Innovation and Technology (EIT). Secondly, while the previous FP (FP7) had integrated some PPPs instruments to involve the private sector, Horizon 2020 further expanded this integration. It introduced initiatives like the European Innovation Partnerships (EIPs), the Future and Emerging Technologies (FETs), and the Fast Track for Innovation calls, all aimed at fostering technology development and deployment. Lastly, to facilitate access to risk finance for innovative projects, the SME instrument became part of Horizon 2020, with the aim to bridge the gap between research and the market by providing funding and support to help innovative SMEs bring their ideas and technologies to the market. These changes in the program's structure and instruments aimed to streamline and support the entire innovation process, promoting collaboration between research and industry and accelerating the market integration of innovative technologies. These changes were accompanied by a significant increase in the programme's budget. For the overall period, Horizon 2020 channelled nearly EUR 80 bn in support of research and innovation. In relative terms, the budget went from an average of 5.2% of total EU yearly budget to 7.6% (around 12bn EUR). (Figure 4).

Figure 4 The European FP budget (EUR billion and percentage of EU budget), 2002-2023



Source: EU spending and revenue 2014-2020 | European Commission (europa.eu)

4.4.1 9th framework programme - Horizon Europe (2021-2027)

Horizon Europe was designed as a continuation of Horizon 2020 (following the motto “an evolution not a revolution”), with a focus on addressing global challenges and promoting innovation. It builds on the success of Horizon 2020 while aiming for even greater impact. Horizon Europe has a larger budget of EUR 95 billion, making it the biggest FP ever. It is also very sizeable in international comparison.

As in Horizon 2020, the first pillar, Excellent Science, remains focused on supporting top-notch research with key instruments like the MSCA and the ERC. The second pillar, Global challenges, and European industrial competitiveness, combines societal challenges and industrial leadership initiatives under one umbrella. This pillar includes two key actions: the clusters and the EU Missions (Mazzucatto, 2018), which were designed to address major societal challenges through mission-oriented policies.

In line with Horizon 2020, Horizon Europe also dedicates a specific budget and instruments to foster innovation and technology deployment in its third pillar, Innovative Europe. This pillar supports various forms of innovation, knowledge and technology transfer, and the exploitation of innovations. It includes important initiatives like the European Innovation Council (EIC), the European Institute of Innovation and Technology (EIT), European Innovation Ecosystems (EIE), and the SME Instrument. Following a successful pilot phase in Horizon 2020, the EIC was structurally integrated into this pillar. The primary goal of the EIC is to offer comprehensive support to promising innovators and assist them in bringing their breakthrough innovations to the market. Additionally, the

EIC addresses the issue of the EU's relative scarcity of scale-ups and unicorns in the EU compared to its global competitors (European Commission, 2021). Moreover, the EIT serves as a cross-pillar instrument linking Pillar 2 and Pillar 3. Funding is strategically deployed to achieve a more streamlined and targeted R&I landscape (Rathenau Instituut, 2020) and fewer, but more strategically chosen initiatives receiving co-funding/investment through three types of partnerships: co-programmed, co-funded and institutionalised partnerships.

Finally, for the first time, the FP benefitted from a major foresight exercise that supported the preparation of the Commission proposal, the Bohemia project (Kastrinos and Weber, 2020).

Table 2 below summarizes the main characteristics of the four FPs.

Table 2 Main characteristics of the four FPs

	FP6	FP7	Horizon 2020	Horizon Europe
	Main objective in the treaty of the functioning of the EU unchanged: "*strengthening its scientific and technological bases by achieving a European research area in which researchers, scientific knowledge and technology circulate freely, and encouraging it to become more competitive, including in its industry*".			
Main Objectives	Promote scientific excellence and strengthen ERA	Excellence in science, increase participation of the industry and linkages between science and business	Excellence in science, covers the whole innovation cycle (research to innovation uptake), tackle societal challenges.	Excellence in science, covers the whole innovation cycle (research to innovation uptake), tackle societal challenges.
Main structure	3 main blocs: *focusing and integrating the community research* (7 thematic priorities, including one on sustainable development), *structuring the ERA* (mobility and resources, RIs), *strengthening the foundations of ERA*	4 main blocs: Cooperation (9 themes); Ideas (ERC); People (mobility and human resources); Capacities (JTIs, RIs)	3 pillars: *Excellent science*, *Industrial leadership,* and *Societal challenges*.	3 pillars: *Excellent science, Global challenges and European industrial competitiveness, Innovative Europe*
Instruments (new instruments in bold)	- Marie Skłodowska-Curie Actions (MSCA) - Research Infrastructure (RI) - **ERA-NET** - **Integrated Projects (IPs)** - **Networks of Excellence (NoEs)** - Specific research projects for SMEs	- MSCA - RI - ERA-NET - **Joint Technology Initiatives (JTIs)** - **European Research Council (ERC)**	- MSCA - RI - ERC - ERA-NET **Co-fund** - **Pilot European Innovation Council (EIC)** - **European Institute for Technology (EIT) and Knowledge Innovation Communities (KICs)** - **SME instrument** - **Future and**	- MSCA - RI - ERC - ERA-NET Co-fund - EIT and KICs - FET - **Accelerator** (=SME instrument) - **EIC** - **European Missions** - **European innovation ecosystems (EIE)** - **European Partnerships**

			Emerging Techs (FETs) - **Fast Track for Innovation (FTIs) Pilot** - **Leadership in enabling and industrial technologies** - **Focus areas (2018-2020)**	

4.2 Results of comparative case study analysis: evolution of the FP's transformative nature

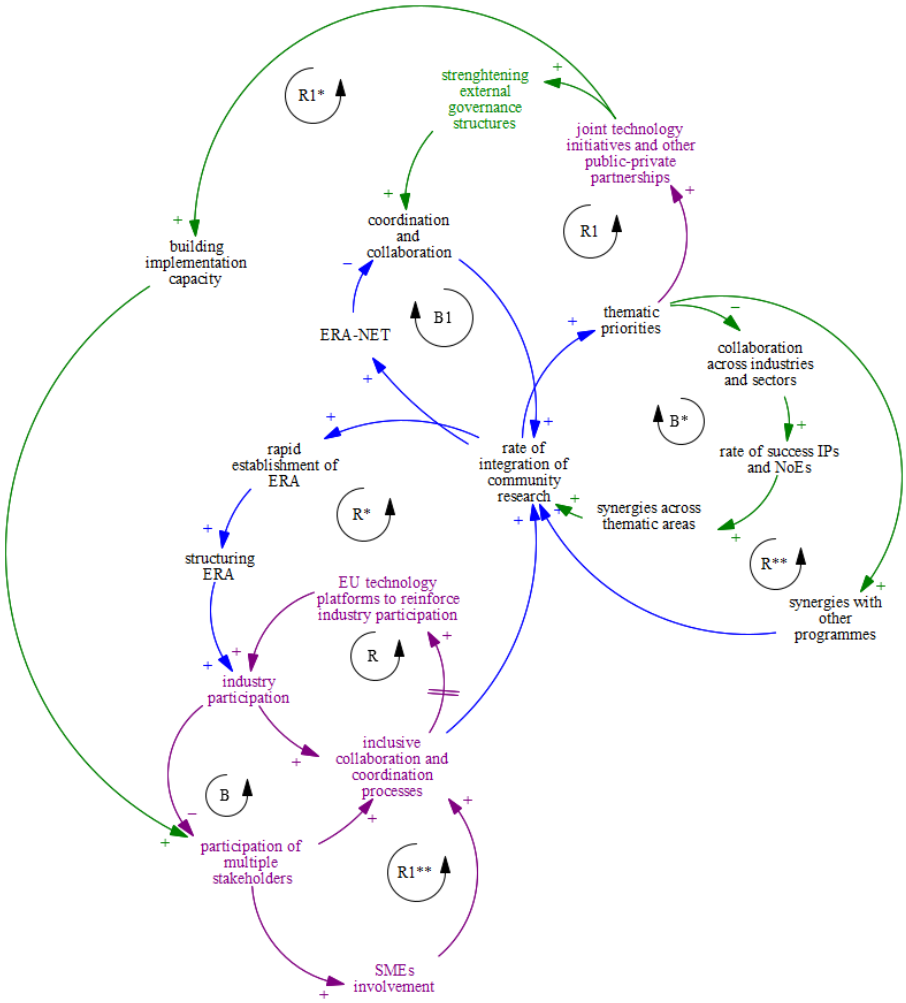
The FP design has increasingly embedded more of the TIP elements over time. Some of these changes were influenced by developments in the international politics arena (e.g., the adoption of the SDGs framework), while others were driven by both developments in the European policy landscape (e.g., Innovation Union, European Green Deal) and the results of the FP evaluation process.

In the following sub-sections, we will dive into the dynamics underlying the evolution from one FP to the other based on the conceptual framework presented in section 2 and provide evidence for the overall assessment of the evolution of the FP's transformative capacity.

4.1.2 From FP6 to FP7

The figure below shows the key dynamics that influenced the development from FP6 to FP7.

Figure 1 Problem-solution archetype: Evolution from FP6 to FP7



Directionality and demand articulation were rather weak or absent in FP6 and FP7. While FP6 and FP7 included orientations according to sustainable development, such as ‘combating major diseases’, most of the funding was allocated to thematic priorities, such as ‘aeronautics’ or ‘components and microsystems’, demonstrating weak directionality as defined in the TIP framework. As for demand-articulation, we consider

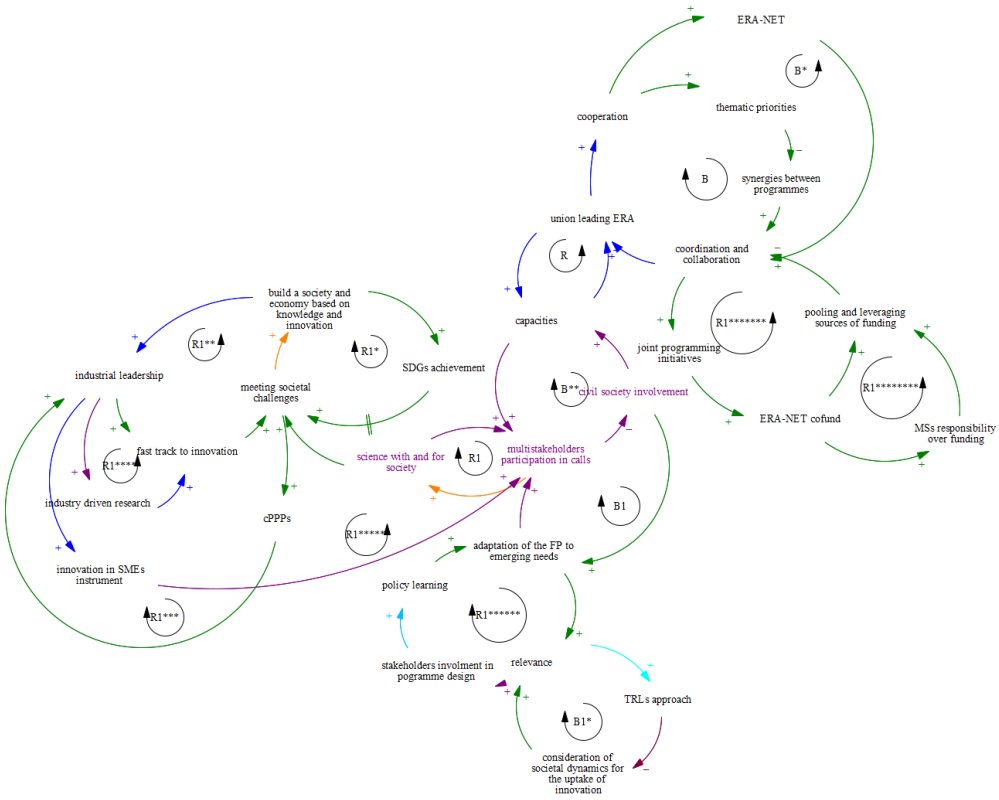
two categories of users of the EU FP for R&I, the direct users of the programme, its beneficiaries and the “indirect” users, the society, whose needs can be anticipated by promoting their involvement in the design of the policies In FP6 and FP7, we then find no reference to involvement of multiple stakeholders in the policy cycle. The focus was more on participation of multiple stakeholders in calls for funding. In this regard, demand-articulation was undermined by the dominance of incumbent stakeholders in FP6 (loop B-R) (European Commission, 2009) and then slowly started improving in FP7 through a stronger SMEs involvement (R1**) (European Commission, 2015).

Regarding policy coordination, based on the within case analysis (Annex 3 and 4), neither FP6 nor FP7 presented strong synergies between pillars and instruments (European Commission, 2015). A lack of synergies could be due to rather cohesive goals and objectives, mostly focused on competitiveness and knowledge creation. Moreover, the thematic priorities structure in FP6 and FP7 undermined the synergies across thematic areas (B*). However, in FP7, the introduction of Joint Technology Initiatives tackled the weakness generated by the thematic priorities structure by strengthening the external governance structure (R1) and building the implementation capacity (R1*). Conversely, we illustrate that the ERA-NET instrument for coordination and collaboration among national R&I strategies did not deliver on the expected outcomes, such as alignment between national R&I policies and programmes and synergies between other policies and programmes, especially in FP7 (B1) (European Commission, 2015).

Concerning reflexivity, we find that FP6 and FP7 did not include any elements of reflexivity. The policy process neither foresaw a structure of strategic plans and work programmes adapted through cycles of two or three years, nor it did include an experimentation angle. Besides, the lack of flexibility in the FP at the time is also demonstrated by the failure to integrate the new EU R&I policy instruments that were designed in the aftermath of the financial crisis, such as the European Technology Platforms or the contractual PPPs, launched one year after the start of FP7 as separate instruments and later incorporated in Horizon 2020.

4.2.2 From FP7 to FP8 – Horizon2020

Figure 2 - Problem-solution archetype: Evolution from FP7 to Horizon 2020



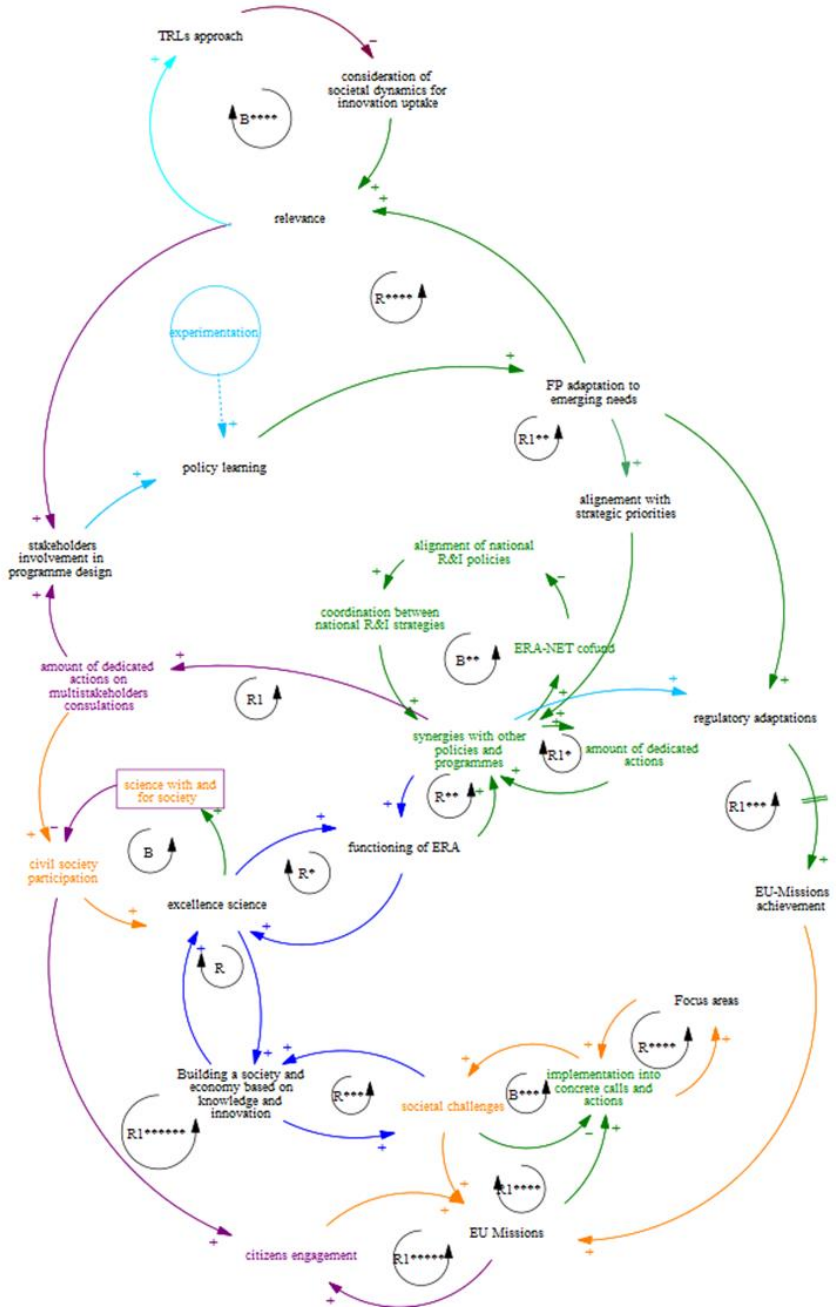
The comparative analysis FP7 shows an underachievement mechanism involving policy coordination (B, B*) and demand-articulation (B**). In this case, a low performance on the ERA-NET instrument, linked to fostering synergies between EU and national R&I programmes, affects the goal of achieving a Union leading Research Area (ERA). Alongside, the underperformance on civil society engagement affects the evolution of ERA (B**). The ex-post evaluation of FP7 stated that the overall aim of the FP was perhaps too ambitious given the modest resources allocated to the programme (European Commission, 2016). In this context, Horizon 2020 brought along a few important changes. First, consultation of external stakeholders was used more prominently to support the drafting of the impact assessment of the FP and the different Work Programmes (R1******). Additionally, with Horizon 2020, societal stakeholders started to be consulted during the evaluation of the programme, thus widening their participation in programme design. This

process improved policy learning withing the FP policy cycle and the FP adaptation to emerging needs detected through public consultations (R1******), thus mutually reinforcing both demand-articulation, reflexivity, and policy coordination (i.e., adaptation of the FP to emerging needs and its relevance to the goals). However, the report on the evaluation of relevance and internal coherence of H2020 stresses that the TRLs approach may not be sufficient to maximize the innovation uptake potential of higher TRLs solutions (p. 43). The TRLs approach weakens the relevance of the FP to its goals (societal challenges and SDGs) (B1*). When it comes to direct beneficiaries of the FP, steps taken to increase the reach out of the programme were not as successful as expected; approximately 50% of Horizon 2020 funding was allocated to just 376 organizations, representing the top 1% of participants.

Horizon 2020 also set the goal of meeting societal challenges and linked this to SDGs (R1*), strengthening directionality and building a thicker link with demand-articulation and reflexivity features. The societal challenges pillar aimed at responding to weaknesses in civil society engagement and disconnection between society and research found in FP7 (R1-B**). Connected to the societal challenges pillar, Horizon 2020 introduced the Industrial leadership pillar to boost the link between the industry and research (R1****) and innovation within in SMEs instrument (R1*****). Industrial leadership and societal challenges pillar were connected via the contractual public-private partnerships instrument (R1***). These thicker links between instruments and pillars reinforced synergies across the FP components, thus reinforcing policy coordination. However, civil society involvement remained a weakness also within Horizon 2020 (B1). Lastly, Horizon2020 responded to the weaknesses of FP7 related to vertical policy coordination (i.e., between EU and national R&I policies and programmes) (B, B*) via changing the ERA-NET instrument into the ERA-NET co-fund. Member States were made responsible for part of the funding of actions included within the instrument (R1********). The revision of the ERA-NET instrument aimed at improving pooling and leveraging sources of funding for R&D (R1*******).

4.3.2 From Horizon 2020 to Horizon Europe

Figure 3 - Problem-solution archetype: Evolution from Horizon 2020 to Horizon Europe



While performing quite well on promoting research excellence and the functioning of ERA more in general, the issues with civil society participation persisted in Horizon 2020. This dynamic could substantially weaken these positive effects (B), thus displaying how directionality and demand-articulation effects interrelate and may affect the achievement of the FP's objectives. Alongside, the FP shows limits to success also on the reflexivity feature. Especially, this is related to the lack of the experimentation angle, as for instance provided by policy experimentation or regulatory sandboxes. Other two underachievement dynamics are related to ERA-NET co-fund instrument and societal challenges. On the former instrument, based on the interim evaluation of Horizon 2020, the low performance on aligning national R&I policies affects the overall achievement of a better coordination between national R&I policies and programmes (B**) and functioning of ERA (R**), thus limiting the strength of policy coordination effects. On the latter pillar, the interim evaluation of Horizon 2020 emphasised issues with translating societal challenges into concrete actions calls for funding. These issues reflect into a weakness in the link between directionality and policy coordination (B***). The focus areas instrument was introduced during Horizon 2020 to respond to this challenge (R****) and so became a precursor of the EU-Missions.

Horizon Europe intervened on the key weaknesses of Horizon 2020. As a response to them, a dedicated number of actions on multi-stakeholders' consultations (R1) were added in the governance and policy design process to tackle problems with demand-articulation and directionality via increasing civil society participation and citizens' engagement into the implementation of the FP (R1******). Second, it added dedicated actions (R1*) to foster internal and external synergies between the FP instruments and other policies and programmes. This intervention may respond to the weaknesses related to ERA-NET co-fund in Horizon 2020 and synergies with other policies and programmes (R** and B**). Third, by formally acknowledging that activities supported by Horizon Europe should take advantage of and inspire innovation-friendly regulation, in line with the innovation principle, it paves the way to support regulatory learning and experimentation (R1***). In fact, though Horizon Europe does not yet make use of experimentation, in the past couple of years, DG RTD has increasingly taken up this notion and developed policy documents, which advocate for use of regulatory sandboxes, testbeds and living labs, but also policy experimentation. The New European Innovation Agenda (European Commission, 2022) pushes forward the need for experimentation in R&I policy and initiatives, while the newly published Staff Working Document on regulatory learning provides guidelines on how to run experiments with

regulatory sandboxes, testbeds and living labs (European Commission, 2023). These initiatives have the potential to reinforce policy learning (reflexivity) and the FP adaptation to emerging needs (policy coordination) (R1**). However, the TRLs approach is still used for project proposals assessment within the global societal challenges pillar, thus weakening the relevance of the FP to its objectives (B****).

Fourth, Horizon Europe removed ERA-NET co-fund and the remaining co-funded actions such as joint undertakings, public-private partnerships and co-programme partnerships have been directly embedded in the funding given through the work programme. The last intervention aimed at fixing problems with directionality and demand-articulation related to the societal challenges implementation. In this case, a loop with EU-Missions and citizens engagement for their implementation was added (R1**** and R1*****). It is not yet possible to assess the impact of the Horizon Europe set-up on the evolution of the FP's transformative capacity because the evaluations are being carried out.

5. Discussion and conclusion

In this paper, we analysed the evolution of the European Framework Programme transformative nature overtime. The study aimed to contribute to a) how to operationalize the TIP approach in practice, analyse its core elements and interrelations among them b) assess the evolution of the EU FP's transformative nature. To do so, we assessed the evolution of the FPs throughout a period from 2002 to 2023, using the TIP approach and systems dynamics methodology.

First, this study provides evidence of the interdependence of the Transformative Innovation Policy (TIP) elements.

Interestingly, directionality is interrelated with demand-articulation and reflexivity. In fact, although the FP directionality is rather top-down (i.e., the European Commission and MSs determine the goals and direction of R&I activities) - thus seemingly implying that public action becomes more interventionist, with an increased risk of government failure (i.e., making the wrong policy decisions) - public consultations and citizens engagement actions in EU-Missions may counterbalance with more bottom-up inputs. Ex-post evaluation of Horizon Europe will be important to understand the extent to which the explicit integration of directionality in the Framework Programme has successfully supported technological change in support of the transition. Some challenges have already been highlighted (European Commission, 2022), such as the implementation of the concept (in terms of design of calls, selection process, selection

criteria, management) and the need for a certain tolerance for failure, which is required for a high-risk, high-reward nature, such as for mission-oriented approach and raises the question of who takes responsibility for the risk.

Second, the results suggest that the introduction of new instruments and pillars (i.e., goals), such as the JTIs and other types of public-private partnerships in FP7 or the innovation in SME instrument in Horizon 2020, built capacity on demand-articulation through a higher participation in calls for proposal. On the same line, the introduction of stakeholders' consultations to collect insights on their needs and ideas in Horizon 2020 with a stronger involvement on strategic planning and programming cycles in Horizon Europe fed not only into the reinforcement of demand-articulation but also reflexivity. In fact, stakeholders' consultations prepared the ground for better policy learning and adaptation of the FP to emerging needs (i.e., policy coordination). However, policy experimentation (i.e., experimenting with new instruments, processes, governance structures) is yet not widely used for the design and revision of the FP, and neither is widely supported through the call for funding. There is more evidence of regulatory experimentation, e.g., sandboxes and test beds, yet much more can be done to support these initiatives. Another aspect that links reflexivity and policy coordination is the use of the TRLs approach, which undermines the consideration of societal dynamics in the uptake of innovation and therefore the relevance of the FP to its goals (i.e., societal challenges and SDGs).

Stakeholders' consultations for strategic planning and programming also reinforced the FP adaptation capacity to emerging needs and evolving policy priorities (i.e., reflexivity and policy coordination). In Horizon 2020 and Horizon Europe, policy coordination has been further structured and reinforced through increased links between instruments and pillars. For instance, Horizon 2020 introduced the Industrial leadership pillar notably to boost the link between the industry and research and innovation and the innovation with the SME instrument. Moreover, industrial leadership and societal challenges pillar were connected via the contractual public-private partnerships instrument (R1***). Lastly, the introduction of the societal challenges pillar in Horizon 2020, later combined with the industrial leadership and integrated with the EU-missions in Horizon Europe, introduced and reinforced the directionality feature in the FP. Based on this discussion, our main policy recommendations are:

- *Foster policy experimentation within the R&I policy cycle* by establishing dynamic and participatory spaces that ensure openness and inclusivity in the decision-making process. This

approach may encourage innovative solutions and broadens the range of perspectives considered during policy development.

- *Enhance the quality of public involvement by* building trust with the general audience. Improve communication about how public consultation outcomes will be incorporated at different stages of the policy cycle (R1). This transparency and responsiveness to public input may enhance the legitimacy and acceptance of R&I policies.
- *Strengthen synergies between different components of the Framework Programme (FP),* such as establishing better links between the European Research Area (ERA) and clusters. This may increase Member States' support for sectorial policy changes and encourage greater engagement from the research community, civil society, and industrial stakeholders in achieving EU R&I objectives, including fostering directionality in transitions.
- *Foster synergies with other policies and programs, recognizing that transformative R&I policies extend beyond traditional R&I domains.* To achieve this, implement complementary policy actions in areas like food systems and health. Examples include promoting green public procurement, setting standards, providing subsidies for users, encouraging behavioural changes among consumers, and implementing redistribution policies that shape innovation-friendly regulations. These integrated approaches may support comprehensive and impactful R&I policy changes.
- *Expand the use of systems approach in the evaluation and monitoring methodology for research and innovation policy and transitions:* using system dynamics has allowed to account for the complex interactions, feedback loops, synergies between policy instruments, and to trace not only direct outcomes, but also indirect effects. In the design of complex policy mixes, such as the EU FP for R&I, which gather numerous policy instruments, system dynamics and causal loop diagrams can prove key for policy makers to account for complex interactions of R&I public policies and aim for increasing their transformative capacity.
- *A rethinking of the TRLs framework*, either through the addition of a different assessment system or a replacement of it, could both go in the direction of reinforcing the cyclical aspect of technological progress, i.e., including needs for revisions and updates to the technology and its components as emerged during the testing phases, and embedding necessary behavioural and institutional changes to fully exploit innovation uptake and

acceleration of transitions. New frameworks could be tested on a small scale to do a feasibility check before upscaling their use.

Our conclusions and suggestions for future research are:

- The dynamics characterizing TIP elements are interrelated and their success or failure may depend on a) what kinds of new instruments and goals are introduced or revisions of existing ones (e.g., budget, functioning, goals) b) connectedly, how the other elements perform. This finding can inform future TIP research, especially case study research of R&I policies or policy mixes for transitions where different instruments and strategies are used for policy design and adaptation. Moreover, it can guide researchers and policy makers in how to design instruments and build synergies among them to yield a policy design that can support tackling societal challenges and deliver growth and innovation.
- Our study did not cover effects on socio-technical transitions. It is difficult to pin down causality. Many experts in the field of TIP advocate for changing the policy evaluation approach. Therefore, research on interrelations between policy goals, instruments and actions and their effects on transformative innovation will be essential to further advance our knowledge on how to design R&I policy in support of societal transitions.
- The use of system dynamics methodology proved key to analyse how the elements of TIP influence each other and interrelate to constitute the nature of the policy design. System dynamics methodology could be used in future research to provide a better understanding of the interdependence of TIP elements and their impact on policy outcomes. It is essential to consider the feedback relationship between different policy elements to ensure effective policy design and implementation.
- Challenges such as the implementation of directionality, the need for tolerance for failure, and managing power struggles in the fora for policy coordination both horizontally and vertically need to be addressed for more effective policy outcomes.

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APPENDIX 1. TIP elements and challenges

According to Diercks et al. (2018, 2019), one of the biggest challenges related to the TIP and the focus on grand challenges or missions is the need to define properly the innovation process. How narrowly or broadly the definition should be and what the process should include. It implies reconciling the different perceptions to address wicked problems, moving away from "technology-driven" and "supply-side" orientation (challenge #1). New "transformative failures" are flagged in the literature, including directionality, demand articulation, policy coordination, and reflexivity failures (Weber and Rohracher, 2012), as well as demand-side, supply-side, and user-supplier interactions failures (Chicot and Matt, 2018). Directionality failure refers to the failure to properly translate societal goals into concrete policy targets and practices (challenge #2).

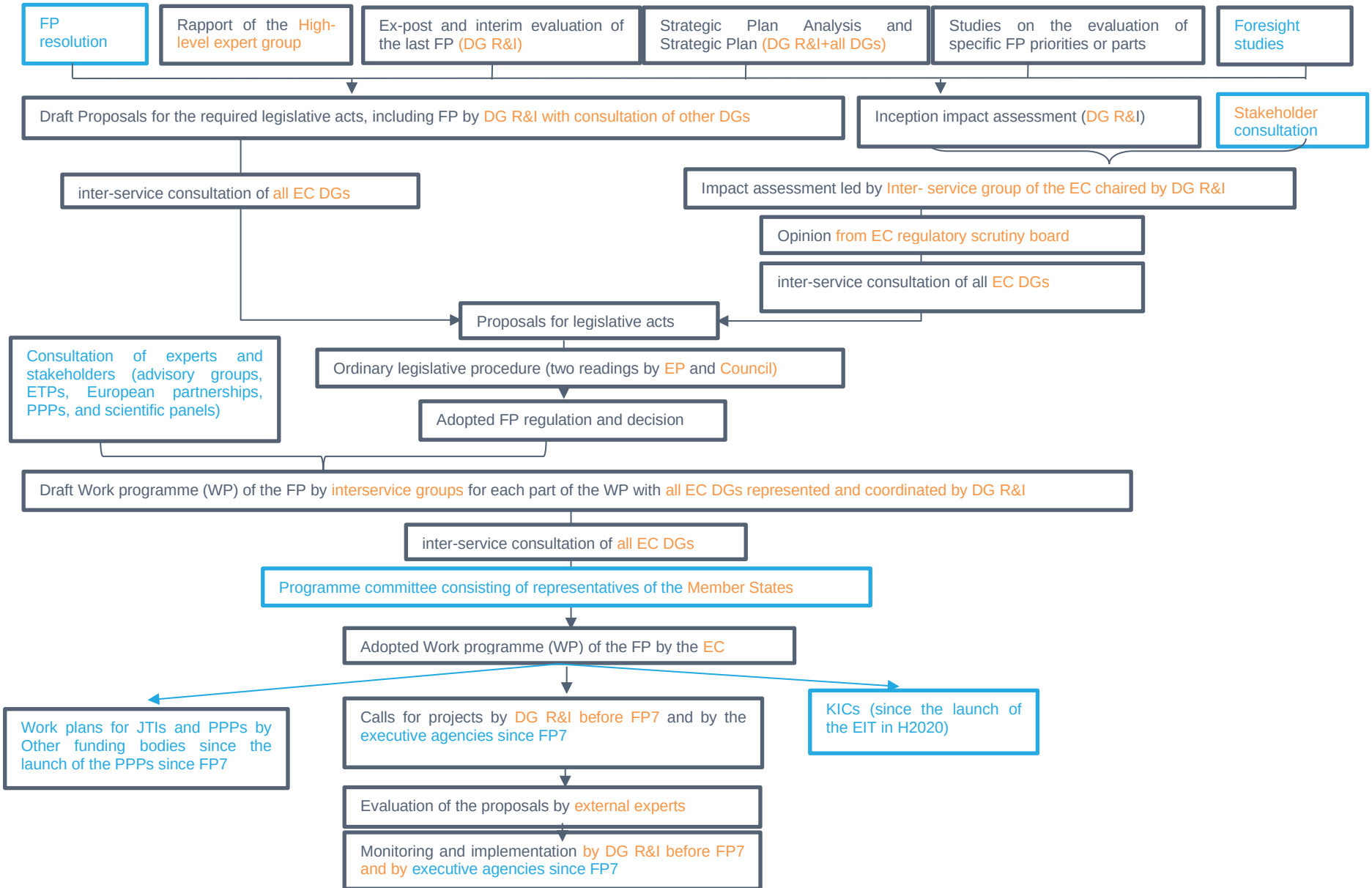
Haddad et al. (2022) also call for innovation in governance models to overcome the discontinuity and fragmentation across policy areas and governance levels and better coordination across policy domains (challenge #3) in link with the whole-of-government approach. TIP also involves complex policy mixes which constitutes a challenge for evaluators to account for synergies, conflicts, and other types of interactions between instruments (Janssen, 2019; Magro and Wilson, 2018). Policy effects must be characterised, isolated, and attributed to be evaluated (challenge #4). According to several studies, formative evaluation should be prioritized over summative evaluation, to allow for re-evaluation and adaptation of goals, strategies, and policy instruments
(Fagerberg, 2018; Janssen, 2019; ; Mazzucato, 2018; Weber and Rohracher, 2012). Finally, "behavioural additionality", i.e., how policy changes the behaviour of actors needs also to be taken into consideration when evaluating the policy (Amanatidou et al., 2014).

As TIP requires the involvement of a broad set of stakeholders, empowering them (challenge #5) can lead to more specific challenges ranging from trust-building (Coenen et al., 2015), empowerment issues (Magro and Wilson, 2018), stakeholder apathy (Bugge et al., 2017), difficulty in promoting institutional entrepreneurship and coordination of directionality across actor networks (Grillitsch et al., 2019). Another challenge related to the multitude of actors involved is to balance potential undue influences from incumbent actors (challenge #6), a challenge also well identified by Schot and Steinmueller (2018). Established actors in the socio-technical systems that are the object of a

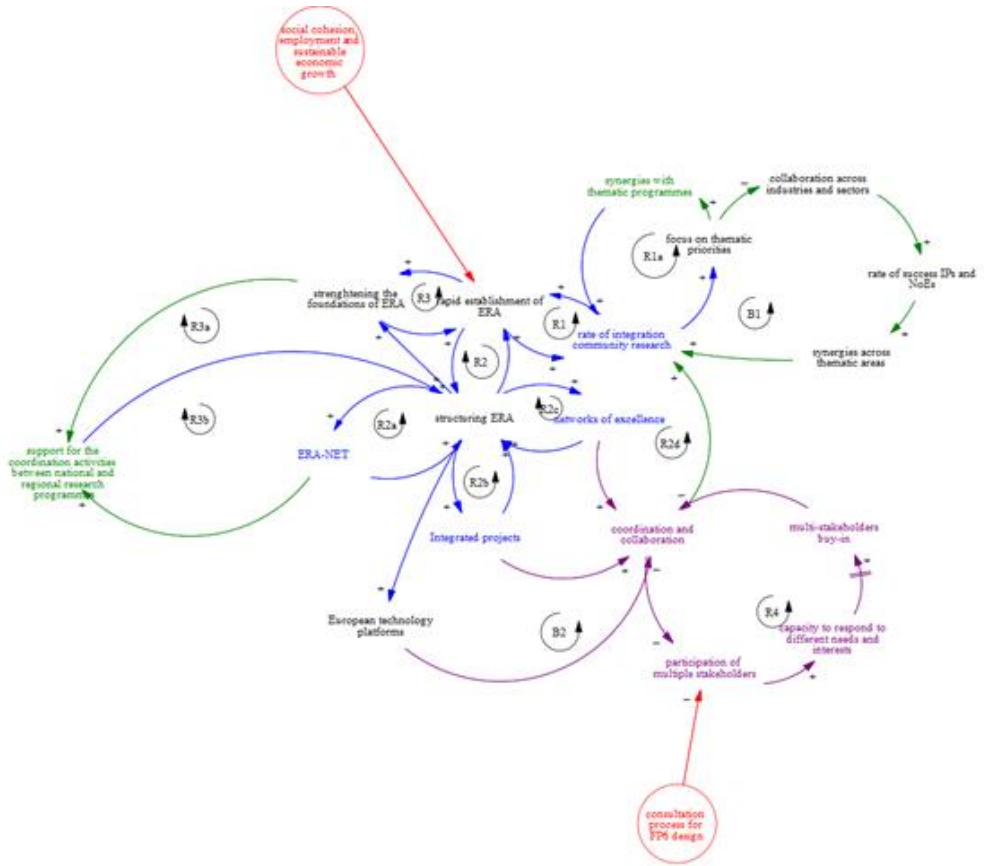
transformation might indeed attempt to influence policymakers towards their own agenda with different strategies for example by modifying the policy objective towards national security (“securitization”), hiding the full costs of the regime (“masking”), making old technologies look new or innovative (“reinvention”), or gaining political influence (“capture”) (Johnstone et al., 2017).

The institutional change required to implement TIP can trigger conflicts as well as power struggles that need to be properly managed (challenge #7). Such change implies modifying policy routine and navigating past policy path dependencies (challenge #8). Finally, developing institutional and governance capacity (challenge #9) by changing misaligned institutions to enable implementation and consider the constraints of the political system (political resistance), conditions and cultural context in which the policy is to be implemented remains one of the main challenges in implementing transformative innovation policy (Berkhout and Westerhoff, 2013).

APPENDIX 2. Evolution of the policy steps of the adoption of a FP



APPENDIX 3. FP6 Causal Loop Diagram



The European Framework Programme – FP6 funded research and innovation activities between 2002 and 2006 and was launched shortly after the creation of the European Research Area in 2000. In terms of governance, all steps, from design to implementation, monitoring, as well as evaluation were in the hands of the Directorate-General (DG) of the European Commission (EC) responsible for R&I, but consultation of other DGs was part of the policy design since the first FP through the boards of directors of different DGS. Two executive agencies were already responsible for the implementation of parts of the programme.
Unsurprisingly, the main objective of FP6 was to foster the rapid establishment of the European Research Area (ERA), especially to achieve sustainable economic growth, more employment and social cohesion with the goal of enabling the Union to become the world's most competitive and dynamic knowledge economy. The three key pillars of FP6 were: I) integrating Community research (e.g., thematic areas) (13.345bl euro) (R1) II) structuring the European Research Area (e.g., research mobility, research infrastructure) (2.605bl euro) (R2) 2) III) strengthening the foundations of the European Research Area (coordination and opening of national programmes) (320ml euro) (R3). Pillar I (ERA) received most of the funding, and within that priority thematic area a) and b).

Under pillar I (R1), the guiding priority thematic areas for research and innovation activities focused on a) life sciences, genomics and biotechnology for health; b) information society technologies; c) nanotechnologies and nanosciences, knowledge-based multifunctional materials, and new production processes and devices; d) aeronautics and space; e) food quality and safety; f) sustainable development, global change and ecosystems; g) citizens and governance in a knowledge-based society (R1a). The thematic priorities were expected to both boost synergies, between thematic programmes (R1a) to feed back into reinforcing the rapid establishment of ERA (R1). However, the FP6 ex-post evaluation highlights those thematic priorities did not fully support the process of integration of community research. The main reason is that thematic priorities affected collaboration across industries and sectors beyond the business sector's logic, thus decreasing the rate of success of the dedicated instruments (Integrated projects – IPs- and Networks of Excellence – NoEs) (B1).

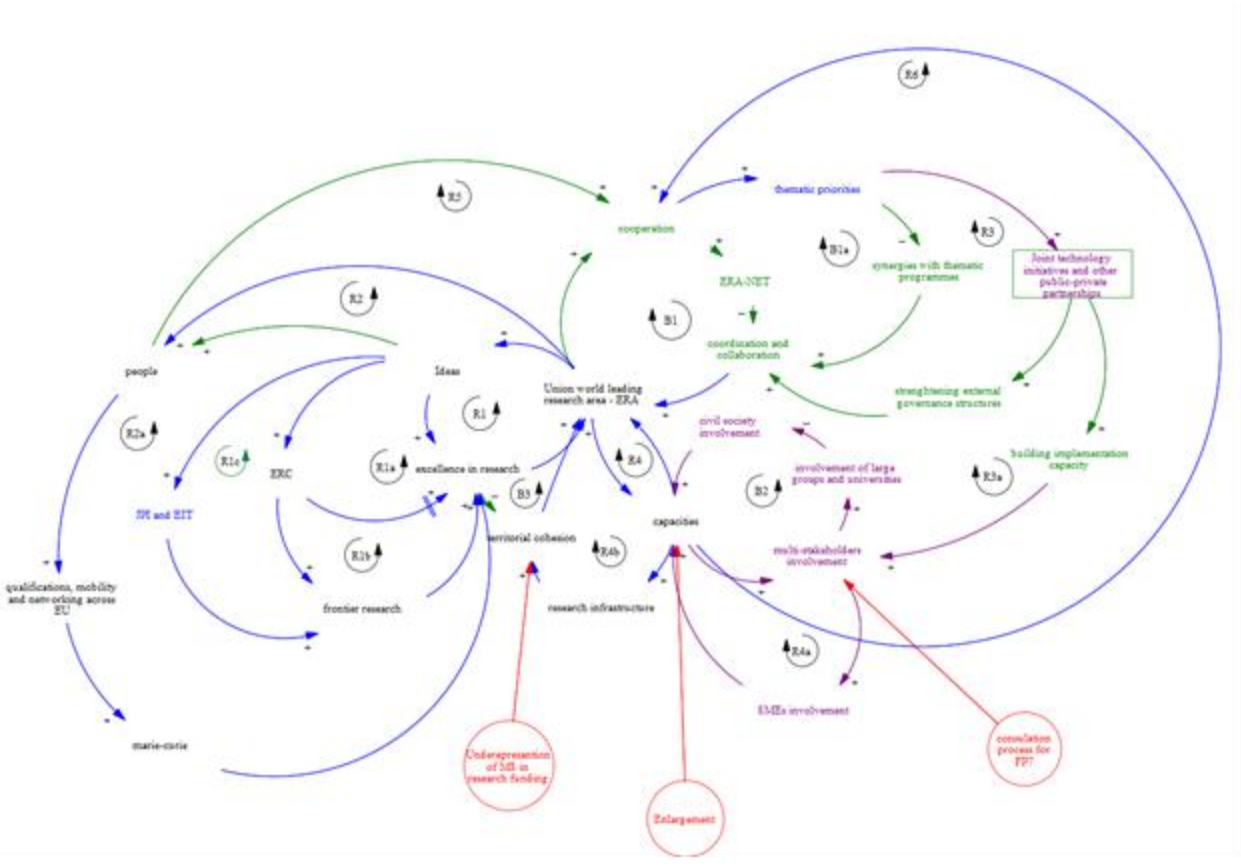
On the contrary, loop R2, which represents the Pillar 2, structuring the ERA, is a positive example of achieving the TIP feature policy coordination. Alongside, FP6 was particularly concentrated around the development of scientific and technical excellence and the coordination of the European research area and the integration of community research area (R2). ERA-NET (R2a), integrated projects (R2b) and network of excellence (R2c) played a major role. They were new tools, notably created to boost interaction between FPs and national programmes. According to Andrée (2009), during the FP1 - FP5 (1984 - 2002), national authorities were not engaged heavily in the preparation of research priorities and the various FPs were perceived as additional tools to national research activities, rather than an integral part of them. Specific targeted projects and coordination actions (R2a) were meant help small actors (e.g., SMEs) and associated countries to access funding opportunities. Networks of excellence progressively integrated activities of network partners through integrated projects, thereby creating "virtual" centres of excellence. Integrated Projects (R2b) were supposed to be of a substantial size, build up the "critical mass" in objective-driven research with clearly defined scientific and technological goals. On the same line, the European Technology Platforms should have contributed to reaching this goal. However, as pointed out in the ex-post evaluation of FP6 (European Commission, 2010), most players involved in funding and research activities were major long-established players (such as industrial actors) thus limiting the potential of the FP to reach small or alternative ones (B2 and R2d).

Loops B1 and R2d represent the interlinked dynamics of the TIP feature demand-articulation and policy coordination as well as loop R4, which shows that a limited variety of stakeholders were consulted in the policy design process. Citizens' participation was restricted to where "appropriate" areas.

The evaluation report of FP6 concludes that “there is reason to believe that a more transparent consultation with stakeholder communities and a more explicit ‘programme logic’ would have produced a more robust overall FP design[2]”. At the time, it was in accordance with the more general agenda of the European Commission to improve communication and efforts to better approach the citizens, following notably the failed EU constitution in 2005. These loops reflect reinforcing dynamics that can drive the system to underachieve or relatively achieve its goals, as shown in the connection between R4-R2d and R1. ERA-NET instrument (R1a) also further supported the III pillar, strengthening the foundations of ERA (R3-R3a) and loop R3 represents the TIP feature of policy coordination, which was reinforced through the mechanisms of ERA-NET.

[2] European Commission. 2009. Evaluation of the Sixth Framework Programmes for Research and Technological Development 2002-2006. EUR 24203

APPENDIX 4. FP7 Causal Loop Diagram



The EU 7th Framework Programme for Research and Innovation ran between 2007 and 2013 and the budget increased substantially, from 16.2 over five years to 46 billion EUR over seven years. Its main goal was to contribute to the Union becoming the world's leading research area through the launch of four pillars: ideas – R1 - (7.673bl euro), people – R2 - (4.777bl euro), cooperation – B1/R3 - (28.336bl euro) and capacities – R4/B2 - (3.772bl euro). Funding rates were raised for some legal entities, e.g. SMEs, for which maximum funding rates increased from 50% in FP6 to 75% in FP7, facilitating the participation of SMEs. Besides, in terms of governance, compared to FP6, more parts of the programme were managed by executive agencies, such as the SME-related actions, the Marie Curie Actions proposing grants for individuals and Space and Security research actions, and the agencies also provided more administrative and logistical support services to all programme areas.

The two main pillars of FP7 were ideas and cooperation. The *Ideas pillar* primarily focused on the promotion and investment in excellence in research (R1) and frontier research (R1b). In FP7 there was a strong emphasis on research independence, increase the human potential in research and technology in Europe not least through better education and research training, mobility and increasing the number of women in research. One of the main instruments to achieve excellence in research objectives was the European Research Council (ERC). The ERC (R1a) would be an agency independent of political, geographic or economic considerations, and with no attached thematic priorities. The ERC *should enjoy a high degree of autonomy to develop very high-level frontier research at the European level, building on excellence in Europe and raising its profile at the international level.* Altogether, these instruments and actions under the Ideas pillar were aimed at reinforcing the creation of a world leading research area (R1).

The *cooperation pillar* (B1, B1a, R3 and R3a) was the biggest in terms of budget. It strongly relied upon the thematic priorities formerly introduced with FP6 and corresponding to major fields of the progress in knowledge and technology, where research should be supported across the Union and beyond to address European social, economic, environmental, public health and industrial challenges, serve the public good and support developing countries (B1). The main thematic areas in terms of budget were Information and Communication Technologies, Health, Transport and Nano-sciences**.** The thematic priorities were also directed at building synergies with other thematic programmes (e.g., LIFE) but, as indicated in the ex-post evaluation of FP7, the FP failed to fully achieve this goal (represented by the balancing loop B1a). Another major component of the cooperation pillar was ERA-NET – coordination and collaboration between national and regional research programmes – which potential was not maximised (B1). Loops B1 and B1a reflect the feature of policy coordination, which has not been successfully achieved. The successful component of this pillar was the Joint Technology Initiatives (JTIs) and Public Private Partnerships PPPs (R3 and R3a), which had a few positive impacts, such as on strengthening the external governance structure (R3) and building the implementation capacity (R3a). These impacts feed back into two different pillars (i.e., cooperation and capacities respectively). As shown in these loops, PPPs and JTIs reflect both elements of policy coordination and demand-articulation. Concerning policy coordination, loops R3 and R3a show synergies between different instruments in the FP, namely the cooperation and capacities pillars.

The research Contractual Public-Private Partnerships (cPPPs) were set up in November 2008 as a response to the economic crisis. PPPs also had the advantage of having more participants in the FP and reduce competition as the funds were divided among a larger number of participants than for other types of grants. It has partly led to an increase of the participation of private partners over the course of FP7. *The Joint Technology Initiatives (JTIs) and other Public-Private Partnerships boosted industry participation, made it possible to realise strong leverage effects that contributed to the competitiveness of Europe's industries in areas as diverse as pharmaceuticals, aeronautics and fuel cells and hydrogen* (p1). The relevance of PPPs

as a tool in the fields of innovation, research and development at the EU level had been first recognized in the council conclusions of 2003[3], followed by a green paper by the EC published in 2004.[4] In 2005, the communication on Public-Private Partnerships and Community Law on Public Procurement and Concession [5], the *setting of PPPs as a policy was improved mostly by more strict regulations in private partnerships (Kalistz & Alusha, 2012). On the JTIs side it was also connected with flexibility, efficiency and effective management. That gave the JTIs the possibility of using open innovation business models (Vanhaverbeke & Cloodt, 2008).* Therefore, though the collaboration pillar was weakened by a lack of strong achievements on ERA-NET and synergies with thematic programmes, it led to a broader and more structured cooperation between actors within the research and innovation ecosystem. Evaluation of the programme stated that the "links between the action lines and the themes were not obvious and that it was therefore confusing to reconcile the programming documents" (European Commission, 2016).

The *people pillar* was very strongly linked to the *ideas pillar*. As the diagram shows, the two pillars feed into each other reinforcing positive dynamics (e.g., R2a), demonstrating that the TIP feature of policy coordination was reinforced through the synergies between these two pillars This pillar aimed at improving the qualifications, mobility and networking of researchers across the European Union, especially through the Marie Curie instrument and joint research in Cooperation-Programmes. The ex-post evaluation of the FP7 clearly states that the research capability of individual researchers and groups has increased since FP6, and that there has been continuity between the two framework programmes (R2a).

Lastly, the *capacities pillar* was set up with a clear mandate to reinforce the European research infrastructures, their use and development across Europe. Though the budget was smaller than for the other pillars, it focused on a variety of target groups and policy goals, including SMEs and society, the construction of new research infrastructures and creation of regional networks; support to international cooperation and the coherent development of research policies and research driven clusters (European Commission, 2015). The activities financed by this pillar managed to strengthen territorial cohesion and SMEs involvement (R4b and R4a). Particularly, the contribution of the FP to territorial cohesion through the improvement of the EU research infrastructure was remarkable and successful when it comes to strengthening quality and relevance in national infrastructures – and at the same time contribute to transnational access, which is at the heart of ERA. The FP7 contribution to support ESFRI projects has been important. However, the limited budget constrained the FP's ability to respond to most of the needs in a European context. Coherence remained an issue in the second half of FP7 and has continued to be an issue in Horizon 2020, although several improvements have been implemented (European Commission, 2015). The pillar failed on involving civil society and citizens in decision-making processes and bodies relevant to FP7 (B2). Loops B2 and R4a are clear examples of demand-articulation through involvement of a variety of stakeholders in the actions of the FP and its formulation. FP7 did not succeed in including civil society and citizens but broadened the involvement of SMEs.

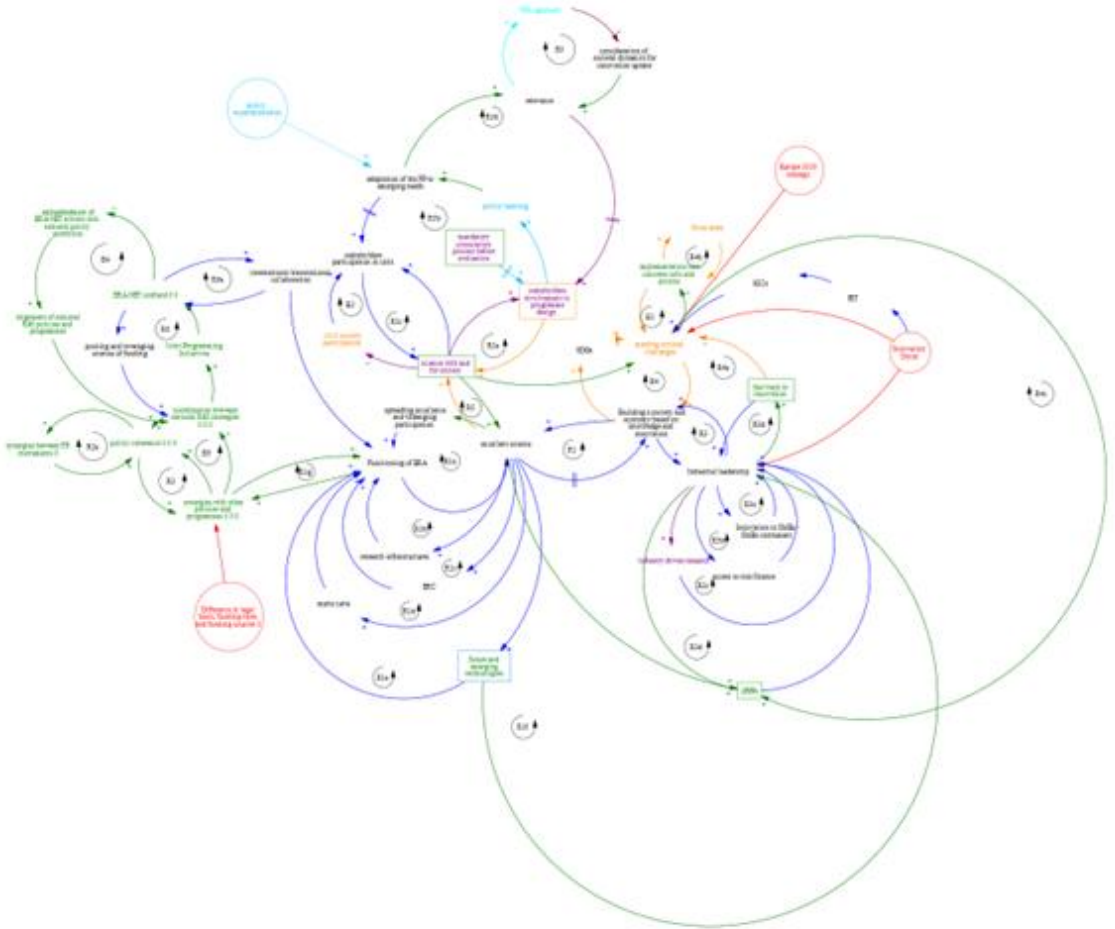
[3] Conclusions of the Presidency, Brussels European Council, 12 December 2003

[4] Green Paper on public-private partnerships and Community law on public contracts and concessions. COM/2004/0327

[5] Public-Private Partnerships and Community Law on Public Procurement and Concessions. COM/2005/0569

FP7 had an overall positive impact on international cooperation was achieved through joint efforts of the people, capacities and cooperation pillar (R5, R6 and B1) (reference to the ex-post evaluation FP7).

APPENDIX 5. Horizon 2020 Causal Loop Diagram



Horizon 2020 programme was released with the ambition to represent a break with the previous editions6, and for the first time, it was not simply referred to with its sequential number, but it was given a unique name. It ran from 2014 to 2020 and was built in the shadow of the 2008-2009 financial crisis. With Horizon 2020, internal coordination processes were reinforced, with more regular meetings of services interested in given areas and the set-up of inter-service groups to design directly the proposals for the legislative acts. The DG responsible for R&I was restructured. Sectoral units were reduced or merged; from three units working on health, only two remained and instead of two units working on materials, and one on industrial transformation was created, following the focus on the societal challenges. Finally, one of the executive agencies responsible for the implementation of the programme, the Research Executive Agency was entrusted with the management of most of Horizon 2020, including research infrastructures, materials of tomorrow, coal and steel, together with projects going beyond R&I. The aim of these changes was twofold; relieving the DG from the implementation work to focus on policy design and allowing more synergies between implementation of R&I and other projects on some specific sectors. In Horizon, with the aim to improve the MS participation, programmes committees composed of MS representatives were created for consultation on the draft proposals. In this same spirit of coordination and cooperation, Horizon 2020 also covered the operational costs of COST, an intergovernmental framework for European Cooperation in Science and Technology designed to help coordinate nationally funded research at EU level, as well as the intergovernmental EUREKA initiative to promote international, market-oriented R&I.

The interim evaluation of Horizon 2020 clearly states that, when Horizon 2020 was conceived, Europe suffered from a number of critical weaknesses in its R&I system, contributing to low productivity, declining competitiveness and the inability to move to a new sustainable economic model. Europe's innovation gap was identified as the key problem driver, with the following structural problem drivers underpinning it: the need to strengthen the science base; insufficient technological leadership and innovation capability in the private sector; insufficient contribution of research and innovation to tackling societal challenges; and insufficient trans-national coordination.

The fight against climate change was also high on the international agenda, the Paris agreement which were to be held in 2015 was already in preparation, discussions to decide upon new targets to replace the Millennium development goals had been kick started and the Europe 2020 Strategy, published in 2010 was explicitly oriented towards tackling grand societal challenges and has formulated ambitious policy objectives for climate change, energy security, demographic ageing and resource efficiency. Moreover, while FP7 was still focused, as its predecessors were, on research, Horizon 2020 has evolved to cover the whole innovation cycle: from ideas and fundamental research to market integration of innovative solutions (Salmelin, 2013; Galsworthy & McKee, 2013; Young, 2015; Ulnicane, 2015; Polex & Lenschow, 2018; Kim & Yoo, 2019). Before Horizon 2020, EU funding for research, education and innovation was covered by separate EU programmes (FP7, the innovation-related part of the Competitiveness and Innovation Programme (CIP), and the European Institute of Innovation and Technology (EIT), with different rules and implementation modalities. This ambition that Horizon 2020 should expand the scope of its intervention was nurtured under the Europe 2020 Flagship

[6] European Commission. 2017. Interim evaluation report of Horizon2020. COM/SWD(2017) 220

initiative called the Innovation Union, also described at the time as “antidote to the financial crisis […] a way of creating jobs and growth through research and innovation”7.

These novelties translated into the framing of Horizon 2020 objectives. Though, as for the previous editions, Horizon 2020’s main objective is to contribute to the Union becoming the world's leading research area, a second, as prominent, objective was added in the regulation: “Encouraging the Union to advance towards […] a more competitive and sustainable economy in respect of its industry”, leading to promote smart, sustainable and inclusive growth (and innovation and industry-driven research. The three pillars of Horizon 2020 were: excellence science, industrial leadership and societal challenges (R1a, R2, R3). The total budget of Horizon 2020 accounted to 77.028 billion euro. The total budget was split between pillars as follows: pillar I, excellent science 24.441 billion euro; pillar II industrial leadership 17015 billion euro; pillar III societal challenges 29.679 billion euro. The remaining instruments were assigned: spreading excellence and widening participation 816.5 million euro; science with and for society 462 million euro; EIT 2.711 million euro.

The pillar of excellence science is directly linked to contributing to the functioning of the European Research Area (R1a) and to the general objectives of building a society and economy based on knowledge and innovation (R1). The pillar is also linked to the priority spreading excellence and widening participation (R1a), thus contributing to internal policy coordination. The focus on the promotion and investment in the principle of excellence in research and frontier research were kept from FP7; and for all proposals, excellence remained as a guiding principle and the main proposal evaluation and selection criterion.8 The key instruments of the excellence science pillar were: future and emerging technologies (R1e) – linked also with the industrial leadership pillar (R1f) and an example of internal policy coordination; Marie-Curie actions (R1d); ERC (R1c) and research infrastructures (R1b). The key achievements of this pillar resulted in advancements in frontier research, research mobility and number of publications.

Civil society stakeholders appeared to be more integrated in Horizon 2020 than they were in FP7. From facilitating the “involvement of citizens where appropriate” in the regulation of FP7, Horizon 2020 added priorities on widening participation, including society, to make progress in generating science for and with the society.9 Despite the limited budget and funding lifetime, as well as the under-representation of parts of society and lack of clear objectives in the funded projects, the interim evaluation of Horizon 2020 (European Commission, 2017) suggests improvements in the involvement of society in excellent research (R5 and R5c). The loop is not a strong driver of science with and for society nonetheless, but among other factors, it paved the way to a great stakeholder’s consultation in ex-ante and ex-post programme design (R5a and b). However, the participation of civil society remains low, with a gap in society’s understanding of the relevance of publicly funded research (B2) (European Commission, 2017: 234). Loops of the R5 bundle (R5 to R5e) represent reinforcing feedback mechanisms of the FP’s capacity to strengthen reflexivity, policy

[7] European Commission. 2013. Europe’s Innovation Union. Innovation Union | Research and Innovation (europa.eu)

[8] European Commission. 2017. Interim evaluation of Horizon 2020. COM/SWD(2017) 220

[9] European Commission, 2017, Interim evaluation of Horizon 2020. COM/SWD(2017) 220

coordination and demand-articulation elements, but also a common understanding and agreement on Directionality among various societal stakeholders (R5-R5a). In H2020, reflexivity has been boosted through stakeholders consultations along the policy cycle (R5b, R5d), allowing for policy learning and adaptation to emerging needs via strategic plans and work programmes structure (R5b). The addition of reflexivity to the FP feeds into and strengthens its relevance to the overarching goals (R5d), with a possible long-term effect on increased stakeholders involvement and participation in the FP design (R5a, b). Nevertheless, H2020 does not use forms of policy experimentation that could be used to test new instruments, processes and tools before implementing them thus allowing for learning from failure and success. “Compared to FP7, stakeholders are much more closely involved in the programme design through the 19 Horizon 2020 Expert Advisory Groups which have been set up as consultative bodies for the individual programme elements of Horizon 202079, targeted and open public consultations on future research themes80, European Technology Platforms (ETPs), which develop R&I roadmaps for action at EU and national level in some sectors, and Programme Committees composed of representatives from Member States and European Innovation Partnerships (EIPs).”(European Commission, 2017: 59). In addition to this, the report on the evaluation of relevance and internal coherence of H2020 (European Commission, 2023) stresses that the TRLs approach may not be sufficient to maximize the innovation uptake potential of higher TRLs solutions (p. 43). Instead, we could assume that the FP’s transformative capacity would benefit from a more holistic and systemic approach to track necessary behavioural changes for the replication of innovations (B5).

The industrial leadership and societal challenges pillars were designed to respond to the innovation and societal driven objectives. They represented respectively 22% and 32% of the total budget of Horizon 2020. Industrial leadership (R3) was business driven and Societal challenges (R4) responded directly to grand societal challenges and aimed to stimulate a critical mass of research and innovation efforts to help address these. These two Pillars have been designed to reinforce each other, as through fast-track to innovation (R4a) and contractual public-private partnerships (R4b). Moreover, the two pillars were dedicated to promoting research, innovation and market integration of sustainable solutions. The industrial leadership pillar was composed of different instruments, including the SMEs instrument (R3a), which successfully contribute to an increased involvement of SMEs in funding and programme design; access to risk finance (R3b) and industrial driven research (R3c). “Greater interest is prominent thorough Horizon 2020, but especially for the SME Instrument which has generated more than 30 000 proposals compared to around 5000 in FP7 (under Research for the benefit of SMEs). Overall, in Horizon 2020, SMEs submitted 99 434 applications in eligible proposals, which is around 26.2 % of the total for Horizon 2020 (against 23.7 % in FP7).” (European Commission, 2017: 60). In addition, the pillar co-finances Contractual Public-Private Partnerships (CPPPs) with the societal challenges pillar (R3d, R4d), thus being an example of internal policy coordination. According to evaluations of FP7 and FP6, industrial participation was assessed as low, even if it has increased towards the end of FP7, notably with the launch of PPPs, which indirectly reduced competition for projects as more partners were involved in one partnership. Research Contractual Public-Private Partnerships (PPPs) continued to be incorporated more widely (European Commission, 2017), to fulfill the objectives of Horizon 2020, through the Future and Emerging Techs, the EIT, the Fast Track for Innovation calls, but also under the Strategic Energy Technology Plan and their European Technology and Innovation Platforms. The concept of European Innovation Partnerships (EIPs) is also introduced by the Innovation Union Flagship Initiative, with a particular emphasis on the engagement of the business sector. Participation of consortium of public and private partners has also been a way to reinforce and strengthen a European Research Area that would better integrate public and private researchers and innovators.

One main instrument to direct investments towards innovation is the European Institute of Innovation and Technology (EIT), before a separate instrument, now incorporated into the FP. The Innovation Union flagship fed into both industrial leadership and societal challenges and implemented through EIT and KICs among other initiatives. Concerning the societal challenges, the interim evaluation of Horizon 2020 (European Commission,

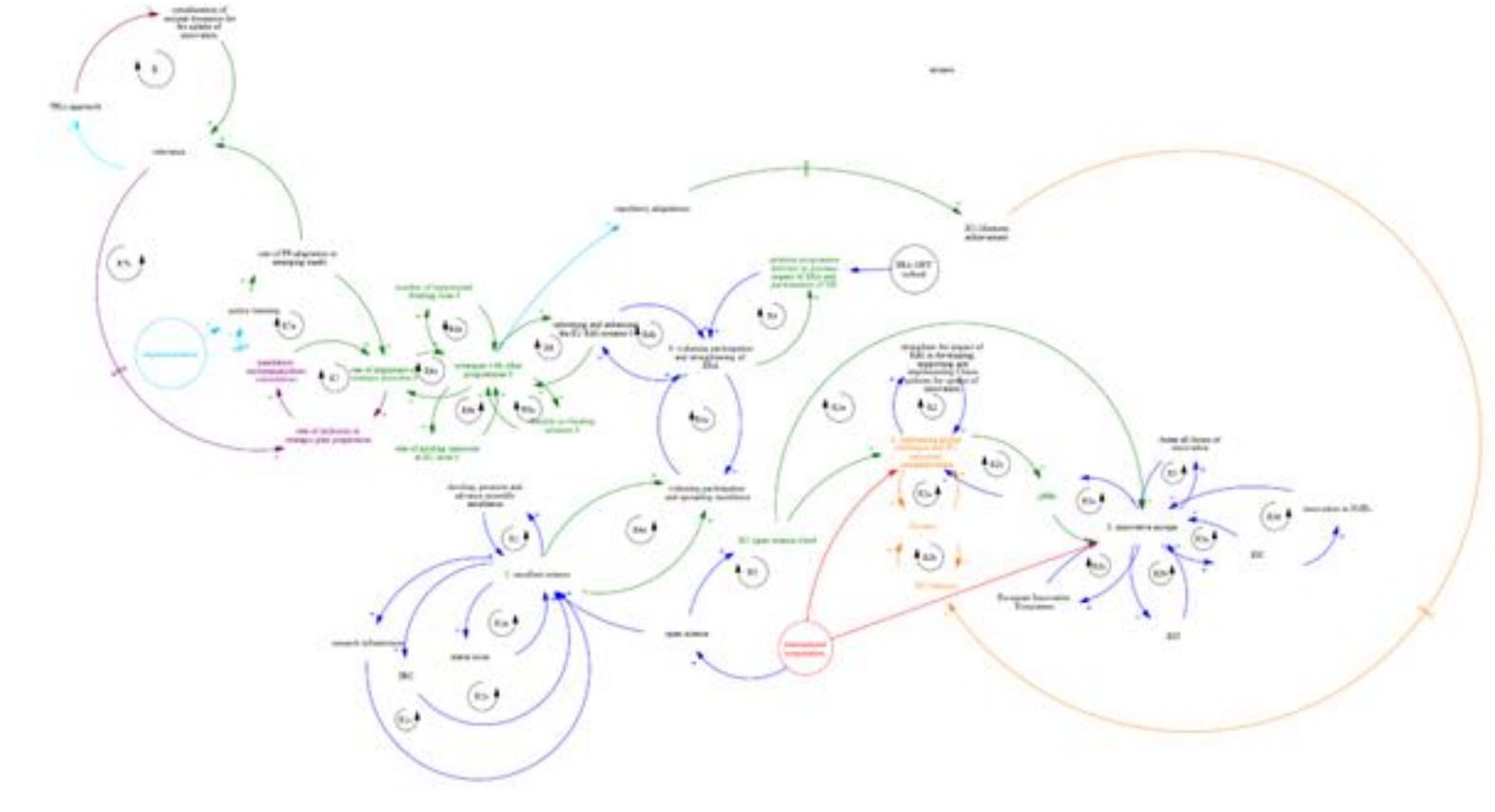
2017) indicates that the pillar struggled to be reflected into an effective implementation of concrete calls and actions (B1). To tackle this and other bottlenecks (R4), in 2018, an additional tool targeting consortiums of public and private R&I actors and called Focus Areas was added during the implementation phase of Horizon 2020. Focusing on strategic areas, defined using the framework of societal challenges, they attracted some political attention as they were designed in support of the future implementation of the European missions, one of the flagship tools of Horizon Europe.10 The loops connected to the societal challenges pillar are a clear example of links between directionality, policy coordination and demand-articulation as they link to the goals recognised as part of providing a mixed bottom-up and top-down direction to research and innovation activities and actions (Mazzucato, 2018).

In Horizon 2020 and later in Horizon Europe, international cooperation became mainstreamed. In 2011, an advisory body of the European Council, called the Strategic Forum for International Science and Technology Cooperation (SFIC), provided the forum to discuss the priorities among the MS (Member States). It delivered a report which called for building strategic approach to internationalization and international cooperation with more coherence and actions big enough to make a difference and have clear impacts at EU level and beyond focusing on global challenges and the design of targeted initiatives for strengthening cooperation in prioritized areas.

Lastly, as the interim evaluation of H2020 suggests, the FP made steps forward in building and strengthening internal synergies between parts of the FP and coherence (European Commission, 2017: 237) (R2a). In the model, this is shown with green arrows between science with and for society and societal challenges; fast track to innovation and societal challenges; PPPs and all three pillars; industrial leadership and future emerging technologies (excellence science pillar). Synergies with other programmes and policies has also improved compared to FP7 (R2). However, given the existence of different funding sources and funding rules, and legal basis it is difficult to build on synergies at project level. Alongside, as pointed out in the dedicated evaluation of ERA-NET cofund actions (European Commission, 2016), it remains difficult to foster synergies between national R&I policies and programmes (B4) mostly due to limited national budgets and long-term national commitments (B4 – R6). ERA-NET cofund is instead very successful in fostering international and transnational cooperation, thus positively contributing to improving the functioning of ERA (R6a-R1g). Therefore, there are mostly positive dynamics related to policy coordination with balancing effects coming from low performance on the synergies between national R&I policy and programmes.

[10] European Commission, Directorate-General for Research and Innovation, Bening, J., Bergmans, J., Bieszczad, S., et al., Opportunities and challenges in targeted funding of Research and Innovation : lessons learnt from the Horizon 2020 : focus areas and implications for Horizon Europe missions, Publications Office of the European Union, 2021,

APPENDIX 6. Horizon Europe Causal Loop Diagram



Horizon Europe is the FP running from 2021 to 2027. Before its launch, the DG responsible for R&I went through a major restructuring, which included the creation of a Common Policy Centre (CPC) with the role to act as a common service across the European Commission to reinforce internal coordination for programming and planning, programme monitoring and evaluation, budget management and horizontal questions of the FP, including those related to the European partnerships and missions. In 2021, the delegation of the implementation of the programme to the executive agencies was reinforced with 15% of the DG RTD's staff to move to executive agencies, with a net reduction of DG RTD staff from 50 to 43 and the number of executive agencies increasing from 29 to 48.

The interim evaluation of Horizon 2020 assessed the programme as being well performing and attractive, notably for newcomers. The integration of R&I into a single programme helped to increase internal coherence. The programme proved that it is simpler, flexible and can respond to emergencies like the Ebola and Zika virus outbreaks ([source: interim evaluation of H2020]). However, several areas for improvement were identified ([source: Lamy report LAB-FAB-APP and interim evaluation of H2020]) and the ambition was to address these issues in the next Framework Programme, Horizon Europe. Underfunding was also a major issue of Horizon 2020, with a success rate of 12% over its first three year and only 1 in 4 high quality proposals that could be funded, which could be explained to a certain extent by the high attractiveness of the Programme, which has led to a sharp increase in the number of eligible proposals compared to FP7 ([source: IA HE]). This was addressed to a certain extent with an increased budget (also in light of the withdrawal of the UK from the EU) for Horizon Europe, which has become the largest R&I programme in Europe so far. Horizon Europe also has a larger budget for 'widening' measures than the previous FP, increasing from 1.8% to 3.3% at the urging of the European Parliament. The budget increase addresses a sensitive issue in previous framework programmes; the uneven distribution of allocated research budgets across the Member States, in part because 'research excellence' served as a selection criterion.

In terms of design, Horizon Europe was presented as 'an evolution, not a revolution' compared to Horizon 202011 and the programme design focused on redesigning pillars without overhauling the programme structure. The objective of the Programme followed this continuation logic, being to strengthen the scientific and technological bases of the Union and foster its competitiveness; to deliver on the EU's strategic priorities and objectives and contribute to tackling global challenges, including the SDGs and to strengthen the ERA. However, for the first time, with Horizon Europe, the design of the FP benefitted from a major foresight exercise that supported the preparation of the Commission proposal, called the BOHEMIA project (Kastrinos & Weber, 2020). The ambition was to introduce novel elements of reflexivity into the preparatory phase of the EU R&I policy for the period 2021–2027. It triggered the inclusion of novel elements in the Horizon Europe proposal, notably attention to SDGs as normative orientation, the importance of preparedness and adaptivity, the need for ownership and participation and for giving room for alignment and experimentation.12

Mayer and Schuch (2019) show that SDGs are integrated in most positions of Horizon Europe and come with a set of measurable indicators. As for Horizon 2020, the first pillar focused on excellent science and high-quality knowledge (R1) to meet the specific objective of developing, promoting and

[11] 'Evolution, not revolution' will guide next EU research funding programme – Jean-Eric Paquet | Research and Innovation.

[12] Sustainable development goals in the research and innovation policy of the European Union - ScienceDirect

advancing scientific excellence. The key instrument of this pillar are the Marie-Skłodowska Curie Actions (R1a), European Research Council (R1b), and Research Infrastructures (R1c). This pillar is horizontally linked to another part of the FP, which is the widening participation and strengthening of ERA (R4). Widening and strengthening ERA underlies all the other pillars and actions and responds to the specific objective of optimising programme delivery to increase the impact of ERA and participation of Member States (R4). In particular, the objectives are implemented by continuing to support and build capacity of low-performing countries in R&I, spreading excellence (R4a) and reforming national R&I systems (R4b). Widening participation and spreading excellence is the bridge with Pillar 1 (R4c). Loop R4b reforms and enhances the EU R&I systems and is also connected to fostering synergies with other programmes (R6), through also flexible funding schemes (R6a), pooling resources at EU level (R6b), alignment of strategic priorities (R6c), and harmonised funding rules (R6d). With Horizon Europe, an inclusive strategic planning process continues and includes a mandatory requirement to involve multiple stakeholders, including interservice consultations, thus linking policy coordination to reflexivity (R7, R7a, R7b). According to interviewees, public consultation outcomes have been carefully analysed and taken into account in the design and strategic planning of Horizon Europe. Along the same lines of H2020, it is believed that this system of public and interservice consultations can foster policy learning and an adaptive policy portfolio, i.e., the adaptation of the FP design to emerging needs (R7a) (points 68/69 of the EU regulation establishing Horizon Europe), thus reinforcing the link between the feature of reflexivity and policy coordination into the FP design (R7, R7a, R7b). Moreover, the European Commission formally acknowledged in the Horizon Europe regulation that activities supported by Horizon Europe should, where relevant, take advantage of and inspire innovation-friendly regulation, in line with the innovation principle, to support a faster and more intensive transformation of the Union's substantial knowledge assets into innovation (recital n. 6, Horizon Europe Regulation). In the CLD, this is shown in the connection between synergies with other programmes which reinforces regulatory adaptations and EU-Missions achievement (Commission Staff Working Document, 2018). Additionally, alike H2020, Horizon Europe does not foresee a broad use of policy experimentation thus weakening its capacity to learn from from failed and successful experiments on new policy instruments, tools and processes. However, the TRLs approach is still used for project proposals assessment within the global societal challenges pillar, thus weakening the relevance of the FP to its objectives (B).

A full Appendix13 of the Horizon Europe regulation stressed the need to continue and reinforce synergies with other EU policies (notably the European Structural and Investment Funds – ESIF, but also several other EU programmes) to develop a comprehensive R&I ecosystem and ensure uptake of R&I where it adds value to the EU objectives. These synergies were also highlighted in support of the principle of directionality, with the introduction of R&I missions, building to a certain extent on the idea of focus areas already introduced in Horizon 2020, but whose multiplication led to some confusion14 in designing Horizon Europe, the aim was to maximise synergies across the Multiannual Financial Framework programme to focus on the areas with the greatest potential to deliver on the SDGs. In 2021, a network of R&I managing authorities responsible for research and for structural measures has been setup in order to ensure operational synergies between Horizon Europe and R&I-related Cohesion Policy funds.

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[13] Annex IV – Synergies with other Union Programmes in Regulation (EU) 2021/695 establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, and repealing Regulations (EU) No 1290/2013 and (EU) No 1291/2013.

14 European Commission. 2018. Impact assessment of Horizon Europe Proposal. SWD(2018) 307 final

The governance of ERA has also evolved with the set-up of a Forum for transition where the EC and the Member States define, agree and implement an ERA policy Agenda. Hence, in addition to the 35% target for climate action (as was in Horizon 2020), Horizon Europe implemented a limited number of EU-wide R&I missions (Mazzucato, 2018; Mazzucato, 2019) with ambitious goals to tackle major societal challenges for Europe (on climate change, healthy oceans, climate-neutral and smart cities, and soil health and food). At first, missions are meant to be relatively small in scale, with a maximum of 10% of the annual budget of Pillar II being earmarked for missions during the first three years of the programme. The ambition of the missions is to develop their portfolio approach step by step.

EU-Missions have been inserted in Pillar 2, i.e., 'Global Challenges and Industrial Competitiveness' (R2) integrated the Horizon 2020 'Societal Challenges'. Pillar 2 meets the goal of generating knowledge, strengthening the impact of R&I in developing, supporting and implementing Union policies and support the access to and uptake of innovative solutions in European industry, in particular SMEs, and in society to address global challenges, including climate change and the SDGs (R2). Pillar 2 is made of especially one key action, clusters (R2a) and the connected EU-Missions (R2b). In terms of governance, for each mission, one board was created to advise on the content of the work programmes and their revision as needed during implementation. The EC has mandated the mission boards to engage the public in programming and in carrying out mission-oriented research.

A cross-pillar instrument is the Contractual public-private partnerships (R2c) which links Pillar 2 to Pillar 3. The Horizon Europe Partnerships were also designed in order to drive EU-wide transformations towards a greener, socially relevant and digitally enabled society and economy15 and to directly support the priorities of the Commission. Therefore, it is considered that Horizon Europe deploys them more strategically than the previous FPs (Rathenau Instituut, 2020). However, before Horizon Europe, the EU R&I funding landscape was seeing a growing number of funding schemes that led to high complexity and called for rationalisation. Hence, the approach to partnerships under Horizon Europe was to also have a a rationalised R&I landscape, with fewer, but more targeted initiatives receiving co-funding/investment from the Framework Programme (with three types only, co-programmed, co-funded and institutionalised partnerships).

Pillar 3, Innovative Europe, meets the goal of fostering all forms of innovation, technological development, transferring knowledge and technology, strengthening the deployment and exploitation of innovations (R3). Innovative Europe includes different instruments as EIC (R3a), EIT (R3b), EIE (R3c) (European Innovation Ecosystems) and the innovation in SMEs instrument (R3d). In particular, after a pilot phase in Horizon 2020, the European Innovation Council (R3a) was structurally integrated in this pillar in order to better support to breakthrough market-creating innovation and scale-up, offering a one-stop shop for high potential innovators aiming at tackling the long-standing issue of lack of scale-ups and unicorns in the EU compared to its main international competitors (European Commission, 2021). It also aims at increasing cooperation with innovation ecosystems and actors (R3c). It has built and expanded on several Horizon 2020 instruments to aim at better alignment is to better align the framework programme for research and innovation with the EU's industrial policy.

[15] European Commission. 2018. Impact assessment of Horizon Europe Proposal. SWD(2018) 307 final

In the continuity with Horizon 2020, international cooperation was mainstreamed with several forms of collaboration allowed: Coordinated Calls between the EU and a third country with legally separate calls which run in parallel; joint Calls are jointly managed with a third country; the contracting of a third-party entity as a regular participant in a call. The Commission issued a bi-annual report on the implementation of the international cooperation strategy, that includes a set of country-specific roadmaps for R&I cooperation. In the international cooperation action are rooted the principle of open science and the EU open science cloud (R5). The latter feeds into both Pillar 2 and 3.

APPENDIX 7. Methods and data sources

The main source of data collection was policy documents and other key texts such as EU regulations, mission statements, enabling frameworks, decision texts, communications, staff working documents, strategy, official presentations, white papers, annual reports, impact assessment reports, interim and ex-post evaluations and fact sheets (e.g. Regulation of FP6, Regulation of FP7, Regulation of Horizon2020, Regulation of Horizon Europe; ex-post evaluation FP6, ex-post evaluation FP7; interim evaluation Horizon 2020; analysis of ERA-NET confound under Horizon 2020, mid-term review of the public-private-partnerships under Horizon2020). The identification of such "landmark documents" was largely based on our institutional knowledge and on web searchers complemented by secondary literature (e.g., reports from the European Parliament) and an extensive literature review of academic papers on the impacts and evolution of the FPs on different aspects. In addition to these documents, we use semi-structured interviews with three colleagues in DG RTD to collect institutional memory and knowledge on the governance of the FP starting with FP6. These interviews shed light on the governance structure and processes of the FP and its evolution overtime as shown in figure 3 section 4.1 below. We have also collected information and insights by presenting the paper to colleagues from different Units within the Directorate G at an internal seminar. As for the budget analysis, we used expenditure and revenue under the 2021-2023 Multiannual Financial Framework, as well as FP data coming from CORDA database.

For ensuring the validity and reliability, we have followed an iterative process to the development of the CLDs, analysis and recommendations (see Alvesson and Sköldberg, 2009; Shenton, 2004, Cavicchi, 2016). The iterative and reflexive process allows for repeated checking and updating of the data collection process and diagramming until the final version of the CLD is exhaustive and does not raise other doubts or show inconsistencies.

In our case, the study went through a process of six revisions of the CLDs based on reiterations between the CLD, policy documents analysis, interviews, CLD update, round of review by external reviewers, paper presentation and discussion with colleagues. First, we built a draft of the CLD based on our prior knowledge of each FP and their respective regulation. We used this as a working hypothesis. Notably, in the second phase, the CLDs of each FP were revised as we collected new data from evaluation reports we went back to our first CLDs and updated them with new variables and links. In the third phase, we tailored the CLDs to the elements of TIP (i.e., colours of arrows and loops) to show the feedback dynamics between them and their evolution over time. In the fourth phase, we had interviews with three colleagues to collect institutional knowledge and went back to both regulations and other documents and the FP's CLDs to update them.

After this stage, we started building the system archetypes to identify the main dynamics underlying each FP. The development of the system archetypes

showed some inconsistencies and missing links in the main CLDs. In the fifth phase, we therefore updated the CLDs by cross-checking inconsistencies (e.g., in FP6 and FP7 there were missing variables in the loops related to synergies with other programmes) with regulatory and evaluation documents. In the sixth phase, we prepared the aggregated CLD with systems archetypes of each FP, while the paper went through a round of external review. This double process allowed to again do minor adjustments to the CLDs and to the conceptual and methodological frameworks but without impacts for the CLD analysis. The paper was then presented to colleagues to check the validity and consistency of the analysis. The dialogue with European officials assisted with gathering institutional knowledge, providing an additional opportunity for cross-checking and triangulating the policy document analysis in order to pursue verification of our interpretation. This combined approach was considered adequate for the goal of the research to analyse the evolution of the FP, how transformative it has become and its fitness to overcome specific challenges associated to TIP.

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This paper explores the European Framework Programme (FP) for Research and Innovation's (R&I) evolution over the last two decades, focusing on its integration of Transformative Innovation Policy (TIP) elements. Our objective is to assess whether the European Framework Programme for R&I has evolved to include elements of R&I policy for societal challenges and transformative change (Transformative Innovation Policy) and offer related policy recommendations. We do so by analysing the Framework Programme from 2002 to 2023 through within-case and cross-case studies using systems dynamics. It provides original insights into applying the TIP framework and system dynamics to evaluate R&I public policies targeting systemic societal shifts. We demonstrate that, while the EU FP for R&I has progressively incorporated transformative elements like demand articulation and policy coordination, room for improvement remains in terms of reflexivity. Our findings also emphasize the interdependence of transformative features, necessitating ongoing adaptations throughout the policy cycle to reinforce the FP's transformative nature.

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