Zientziak eta berrikuntzak garrantzi handiko sistema tekno-sozial handia osatzen dute, bertan zientziaren, teknologiaren eta gizartearen arteko elkarreragin dinamikoa gauzatzen delarik. Hemen, Euskal Ikerketa eta Berrikuntza sistema aurkezten dugu, sistema horrek aurrean dituen erronkak aztertzen ditugu eta erronka horiei nola aurre egin dakiekeen hausnartzen dugu, betiere ikerketa eta berrikuntza arduratsu bati eutsiz.

Giltza-Hitzak: Ikerketa. Berrikuntza. Gizartea. Sistema. Sistema Tekno-Sozial Handiak.

La investigación y la innovación constituyen un gran sistema tecno-social de especial relevancia en una interacción dinámica entre ciencia, tecnología y sociedad. En este trabajo, se presenta el Sistema Vasco de Investigación e Innovación como sistema tecno-social y se analiza cómo abordar desde el mismo los retos de nuestra sociedad desde una perspectiva de investigación e innovación responsables.

Palabras Clave: Investigación. Innovación. Sociedad. Grandes Sistemas Tecno-Sociales.

La recherche et l'innovation constituent un grand système techno-social d'une importance fondamentale dans l'interaction dynamique entre la science, la technologie et la societé. Ce document traite du système technico-social de recherche et d'innovation Basque, et on analyse comment faire face aux défis de notre societé dans une perspective de reserche et d'innovation responsables.

Mots-Clés : Recherche. Innovation. Société. Grand Systèmes Techno-Sociaux.

Basque Research and Innovation as a learning techno-social system: organization, policies, and challenges

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Introduction

Since the very beginning of human nature, our society has been changing constantly, now more rapidly than ever, with the emergence of techno-social systems in a dynamic interplay between science, technology, and society, an interplay that has become particularly complex during the last two or three decades. Indeed, we are facing structural transformations in the ways we produce and use goods and services, our individual and collective behaviours are changing accordingly, and we are facing new societal and environmental challenges, all closely linked to the development of scientific research and innovation. New capacities are being developed, which help us solve the societal and environmental challenges we are facing nowadays and, at the same time, give rise to new challenges (Allenby, Sarewitz 2011). Here, we focus on (i) research and innovation, as a techno-social system of basic importance to understand the interconnection between technology and society, (ii) the concept of Responsible Research and Innovation (RRI), which has been used during the last few years mainly within the last Framework Programs (FP) of the European Union (EU), and (iii) the models that are being developed worldwide and, in particular, in the Basque research and innovation system (Flink, Kaldewey 2018; Rodríguez *et al.* 2019; Macnaghten 2020).

The techno-social complex –including scientific research, technology, and innovation– had been generally based for many years on two assumptions: demarcationism and determinism. On the one hand, scientific research and society were supposed to represent well-defined independent dimensions –demarcationism–, and, on the other hand, a unidirectional causal relationship was expected to occur between scientific research and societal changes –determinism– (Arthur 2009). Based on these two assumptions, specific problems were addressed either within science or within society, with a *linear* model that would take us from one phase (science) to the other one (society) or viceversa (Stokes 1997; Godin 2006)[1].

We know, however, that science and society are nowadays intrinsically entangled parts of a techno-social system that cannot possibly be described with the use of linear models. Society is an integral part of an interconnected techno-social system, and technological developments cannot be conceived in the absence of the social relations underlying technological change and innovation (Jasanoff 2004). Hence, there is a need to understand innovation as part of a complex process of interactions involving flows of knowledge, technological development, and the interplay between actors and institutions. This reorientation brought, towards the 1980s, the incorporation of a systemic perspective to the study of innovation in the so-called National Innovation Systems approach (Freeman 1987, 1995; Lundvall 1992, 2002; Edquist 1997). Innovation does not occur within isolated organizations; it is, instead, the result of knowledge exchange between scientific organizations, industry, policy makers, and the society as a whole. These are the so-called 'innovation systems' that emphasize the importance of the interplay between all actors of the system rather than a linear progression going from fundamental science to applications (Schot, Steinmueller 2018). In this context, 'blue sky' fundamental science, i.e., 'curiosity driven' science in domains where 'real-world' applications are not immediately apparent, still plays a key role, precisely due to the fact that (i) there is no linear progression from fundamental science to innovation and (ii) a great variety of innovation opportunities would be missed in the absence of true fundamental research.

[1] Linear models of innovation follow the influential report prepared by Vannevar Bush just after World War II (Bush 1945). These models became in the 1950s, 1960s, and 1970s the paradigm of public science and technology policies, first in the USA and then in Europe and other parts of the world. They established, for at least three decades, that (i) government funding of fundamental research would naturally stimulate applied research and innovation in a more-or-less linear manner and (ii) scientists should be allowed to freely choose their projects in accordance with their own interests (Merton 1973).

Innovation systems were originally mainly focused on the interplay between scientific research and industrial development. One needs to realize, however, that science and technology should go well beyond the goal of industrial development, as it should target all kinds of environmental and societal challenges. Indeed, in this new approach a well balanced technological development should bring, in principle, a better distributed range of benefits thanks to an active involvement of the final users in identifying the challenges and devising how to approach them. Particular aspects of this broader approach are: the economics of technological change and innovation (von Hippel 1976; Dosi 1988; Lundvall 1992), the sociology and politics of technology (Knorr-Cetina 1981; Hogwood, Gunn 1984), the organizations (Scott 1981), the co-construction of science and technology (Callon 1992, Bijker 1995), technology assessment (Rip 1992), and inclusive technologies (Winner 1988; Jecquier 1979; Ahmad 1989; Gupta *et al.* 2003). All these aspects bring innovation well beyond macroeconomic goals, in an attempt to reach a wider social, political, and environmental scope, thereby involving not only the traditional actors of knowledge generation and innovation (scientists, engineers, and policy makers) but also the ultimate users of innovation.

Along these lines, the Basque research and innovation system was launched soon after the approval of the Basque Devolution Act (*Gernikako Estatutua*) in 1979 and the Betterment (*Nafarroako Foru Hobekuntza*) in 1982. This system was originally targeted, in a large extent, towards the regeneration of the Basque industry landscape, with the launch in the 1980s of a number of technology centers, strengthening, at the same time, both fundamental and applied research at Basque universities; but it has later evolved substantially in the context of a more systemic approach as discussed above. The purpose of this paper is to discuss, in particular, Basque research and innovation as a large learning techno-social system, where societal challenges are expected to be addressed in a systemic way with the inclusive involvement of all members of our society (Jolly *et al.* 2006). Furthermore, we elaborate on the idea of an *adaptive* 'learning system', where individuals and organizations are enabled to face societal challenges by generating new knowledge, thus improving the results (Florida 1995). In this context, a number of learning processes are built, based on the interests and expectations of the societal actors.

The Basque case has been presented by a number of scholars as a good example of a localized learning system (Malmberg, Maskell 2005), in an effort to emphasize the important role played by localized institutions and territorial networks (Cooke *et al.* 1998; Morgan 1997). In the 1980s and 1990s, these networks were developed through the launching of business clusters, particularly successful in the Basque Country (Porter 1990; Ahedo-Santisteban 2006), which allowed the promotion of innovation networks with the involvement of technology centers and companies (Castro *et al*. 2008)[2]. In the following decades, territorial networks were developed in the framework of 'learning regions' (Morgan 1997; Florida 1995). In the Basque Country, a novel learning region was built based on the development of an innovation policy that went hand in hand with research policies with a focus on intensive-knowledge fields such as, e.g., biotechnology and nanotechnology. The resulting science, technology, and innovation system differs from the outcome from cluster policies[3]; nevertheless, the development in the Basque Country of a number of instruments to establish knowledge-based connections among different agents and to pursue a variety of scientific, technological, institutional, and societal goals have been valued very positively (Castro Spila *et al.* 2011).

The remainder of the paper is organized as follows. In Section 1, we first present a brief historical overview of the origins of Basque science and technology, and we then describe (i) the original construction of the Basque science, technology, and innnovation system in the period 1980-2000, targeted towards the

[2] This technology and innovation policy was, however, not necessarily connected to the ongoing policy of scientific research (Moso, Olazaran 2002).

[3] Cluster policies are intensive and operate by social enclave. Learning systems, however, are extensive and operate by social dissemination of competencies (Oughton *et al.* 2002).

regeneration of the Basque industry lanscape, and (ii) the strengthening of the system in the period 2000-2010, oriented to the development of a true learning techno-social system. In Section 2, we describe the Basque science, technology, and innovation system as it is today, which is, to a large extent, oriented to the achievement of specific scientific, economic, and social outcomes in a country –the Basque Country– that is fully integrated in the EU and its policies. Section 3 is devoted to the concepts of RRI and Open Science (OS), as pillars for the evolution, in the Basque Country and the EU, of *adaptive* learning techno-social systems oriented to face the existing environmental and societal challenges. Section 4 summarizes the ongoing Basque science, technology, and innovation system from a RRI perspective. We then present a summary and our conclusions.

1. The launch of the Basque Research and Innovation system (1980-2010)

1.1. Loose seeds for the development of Basque science and technology

Over the years, Basque science and technology have been very closely linked to the social, political, and economic development of the country. In the framework of the *scientific* revolution (XVI-XVIII centuries) that was laying the foundations of modern science in Europe, the Basque church and social elite launched a few higher-education schools and universities, such as the University of the Holy Spirit in Oñati (1540-1901) or the so-called Royal Basque Patriotic Seminary in Bergara (1776-1930). In this context, the Basque Society of the Friends of the Country (*Euskalerriaren Adiskideen Elkartea*) was founded in Azkoitia in 1764 with the aim of promoting the economy of the area. At that time, however, the large majority of Basques were unliterate, and the connection between science and society was very limited (Artetxe 2010).

With the advent of the *industrial* revolution in the XIX century, two important institutions were founded in the Basque Country: the University of Deusto, launched in Bilbao in 1886 by the Society of Jesus, following the desire of the Basque Country to have its own university, and the Engineering School, launched also in Bilbao in 1897 by the City Council and the regional government of Bizkaia to respond to the needs of the ongoing industry lanscape, shipbuilding and steel industry in particular. Within the University of Deusto, an important Business College was founded in 1916, which shaped the elites of the Spanish administration of a major part of the XX century. Later on, the Basque Studies Society (*Eusko Ikaskuntza*) was founded in 1918 by the governments of the four peninsular regions (Bizkaia, Gipuzkoa, Araba, and Nafarroa) of the Basque Country, a polytechnic school was founded in Mondragon in 1943, on the initiative of the catholic priest Jose M. Arizmendiarrieta –founder of the well-known Mondragon cooperative experience–, with the aim of boosting new industrial activity in the region, and the University of Navarre was founded in Iruñea in 1952 by the catholic priest Jose M. Escriva, founder of the Opus Dei.

The first Basque public university was founded in Bilbao in 1936 by the Basque Government during the Spanish second republic, but it was shut down as soon as Franco's armies entered Bilbao in 1937. Only towards the end of Franco's regime the University of Bilbao was founded again, in 1968, which would later (in 1980) be designated to be the University of the Basque Country; and the *unofficial* Basque Summer University (*Udako Euskal Unibertsitatea*) was launched in Donibane Lohizune in 1973 after the success of the so-called Basque Weeks of Baiona in 1970-1972. The Public University of Navarre would be created later in Iruñea in 1987 by the regional government of Navarre, and the Institute of Advanced Industrial Technologies (*École Supérieure des Technologies Industrielles Avancées* - ESTIA) was founded in Bidart in 1996 as a French engineering graduate school (*Grande École*).

These loose seeds were, however, not sufficient to build a research and innovation landscape in the Basque Country. At the time the Basque Devolution Act and the Betterment were approved in 1979 and 1982, research was hardly going on in the Basque Country. Indeed, the Spanish Research Council had opened 92 research centers already, but none of them was located in the Basque Country.

Here, we focus on the Basque innovation system that has been developed and is still being developed by the Government (*Eusko Jaurlaritza*) of the three peninsular Basque regions Bizkaia, Gipuzkoa, and Araba (the so-called Basque Autonmous Community) in the framework of the Basque Devolution Act of 1979.

1.2. Building capacities for a Basque innovation system (1980-1996)

Towards the end of the 1970s and the beginning of the 1980s, the Basque Country suffered a deep economic and social crisis, as it was heavily specialized in mature sectors (shipbuilding, steel industry, white goods, etc.) which, at the time, were entering a worldwide recession (Castro-Spila *et al.* 2011). In this context, the Devolution Act of 1979, the establishment of the Basque Government in 1980, and the entry into force of the Basque Economic Agreement (*Kontzertu Ekonomikoa*) in 1981 were seen as a great opportunity to overcome the ongoing economic crisis and rebuild the country from a multidimensional perspective (Bilbao-Osorio 2009)[4]. In 1981, a public society was launched for the promotion and regeneration of Basque industry (*Sociedad para la Promoción y Reconversión Industrial* - SPRI) and in 1982 the Basque ministerial departments of Industry and Energy, on the one hand, and Education, on the other hand, joined efforts to launch a network of technology centers with the aim of boosting a technology-based industrial regeneration and development (Navarro 1990). At the same time, new programs were launched to support research and development at industrial companies, and also both fundamental and applied research were strengthened at Basque universities.

Within the SPRI, two important strategic plans where launched in the 1990s, which started to shape the Basque Innovation system. These were a Technology Strategic Plan for the period 1990-1992 and an Industrial Technology Plan for the period 1993-1996. In the first plan, strategic priority was given to new materials, manufacturing, and information technologies, and a number of financial tools were launched to fund (i) specific strategic projects carried out by technology centers, (ii) cooperation projects performed by associated companies –consortia–, (iii) strategic projects run by individual companies, and (iv) technology actions –developed by university research groups– for the identification of new long-term technology trends. The second plan incorporated for the first time the idea that innovation is a systemic process where interactions between all agents play an important role, and it was very much focused on the technologies demanded by the Basque industrial clusters that had just been created in areas of special interest for the potential development of Basque economy. Also, in this second plan environmental technologies were added to the list of prioritized technologies. A number of programs were launched as well to strengthen –at Basque universities– research infrastructures and scientific production, which were still very limited at that time.

In summary, the 1980s and 1990s were focused on the building of new capacities that would settle the basis for a Basque innovation system. A network of technology centers was launched, and a special effort was made for the integration of new technologies at local companies, thus fostering the regeneration of a traditional industry that was facing an important structural crisis.

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[4] At the beginning of the 1980s, no more than 0.069% of the gross domestic product was invested in Research, Development, and Innovation in the Basque Autonmous Community. That 0.069% (which in Spain was about 0.3%) was multiplied by 30 over the following 30 years, whereas in Spain it was multiplied by 3 or 4 (Garmendia 2021).

1.3. Towards a knowledge-based economy (1997-2010)

In the late 1990s, the Science and Technology Plan 1997-2000 was launched, in an effort to integrate –for the first time– science and technology as strategic pillars of a knowledge-based economy; and in the framework of this plan, a diagnostic was conducted –partially funded by the European Regional Development Funds–, which allowed to incorporate the innovation dimension in the next strategic plan: the so-called Science, Technology, and Innovation Plan (*Plan de Ciencia, Tecnología e Innovación* - PCTI) 2001-2004. A Basque Technology Council had been launched in 1993, which became in 1997 the Basque Science and Technology Council –with the participation of the university– and in 2007 the Basque Science, Technology, and Innovation Council. Along the same lines, a Basque Network of Technology was created in 1997, which became in 2000 the Basque Network of Science and Technology and in the year 2002 the Basque Network of Science, Technology, and Innovation (*Red Vasca de Ciencia, Tecnología e Innovación* - RVCTI). This network was complemented from the very beginning with the so-called *Saretek* network, which in 2007 would become the Basque Innovation Agency *Innobasque*, with the aim of becoming 'the' European innovation reference.

In the PCTI 2001-2004, the groundwork was laid for the development of a knowledge-intensive economy in a number of strategic areas, such as biotechnology and nanotechnology. In this plan, both scientific knowledge and the strengthening of technological and social infrastructures in these areas were seen as the basis for competitiveness. Supply capacities would be developed through the generation of new infrastructures, the acquisition of advanced technological equipment, international cooperation, and the training of new researchers and technologists. In the framework of this plan, two important initiatives were launched, both in 2002, with a focus on strategic research: the so-called Cooperative Research Centers (CICs) and the Etortek program. A number of CICs would be created in the areas of biotechnology, microtechnologies, advanced manufacturing, nanotechnology, and energy, and a few diversification strategies were developed, such as Biobasque 2010 and Nanobasque 2015.

The PCTI 2001-2004 was followed by the PCTI 2010 (for the period 2005-2010), which laid the basis for the current Basque innovation system with the consolidation or launching of (i) CICs[5], (ii) BERCs, (iii) the Basque Foundation for Science Ikerbasque, (iv) the Basque Science, Technology, and Innovation Council, (v) Innobasque, and (vi) the Basque Innovation Fund, established in 2007 by the Basque Council of Finance, the allocation of funds being determined by the Basque Science, Technology, and Innovation Council chaired by the President of the Basque Country. This represented a great opportunity to launch an *integral* innovation system under the umbrella of the Basque Science, Technology, and Innovation Council and the Basque Innovation Fund, beyond the need for research centers and Ikerbasque to belong to specific government departments, as recognized in the review of regional innovation in the Basque Country performed by the Organization for Economic Cooperation and Development (OECD) in 2011 (OECD 2011). This integration, however, was never realized, with Ikerbasque professors at CICs, for example, not being able to participate in the general basic and applied research program run by the Department of Education, simply because CICs are supposed to *belong* to another department.[6]

In summary, during the first decade of the present century we have been moving from the supply policies of the early years in the 1980s and 1990s, whose goal was to lay the foundations for a renewed economic

[5] In 2019, four CICs would get integrated in the newly created Basque Research and Technology Alliance (BRTA), together with 13 Technology Centers. BRTA includes only two types of members of the Basque Network of Science, Technology, and Innovation: CIC's and Technology Centers. Other types of members of the network are: (i) Singular Agents (e.g., BRTA itself and Ikerbasque), (ii) Universities, (iii) Basque Excellence Research Centers (BERCs), (iv) Agents for the Dissemination of Science, Technology, and Innovation, (v) Health Research Institutes, (vi) Healthcare R&D organizations, (vii) R&D Units, and (viii) Suply-Demand Intermediation Agents.
[6] CIC's base funding comes from the Department of Economic Development, Sustainability, and Environment, while BERC's are funded by the Department of Education.

structure of the Basque Country, to a supply/demand policy seeking to lay the foundations of a knowledge-based economy and a strong innovation system oriented to (i) meet both business and social needs and (ii) diversify our strategies with the target of value creation.

2. Target-oriented Basque innovation system and the European strategy

The PCTI 2010 (for the period 2005-2010) was followed by the PCTI 2015 (for the period 2011-2015) and then by the PCTI 2020 (for the period 2016-2020), which coexisted with the EU's research and innovation funding program Horizon 2020 (for the period 2014-2020). This funding program (Horizon 2020) reconceptualized somehow the nature of innovation, the role that science and technology should play in our society, as well as the systemic relationship between the various agents of the innovation system and the character of public policies. In this section, we first analyze the PCTI 2020 in the framework of Horizon 2020, and we then focus on the ongoing PCTI 2030 (for the period 2021-2030).

2.1. Research and Innovation Strategy for Smart Specialization (RIS3)

Horizon 2020[7], launched by the European Commission in 2013, represented the financial instrument to implement the *Innovation Union*, one of the seven flagship initiatives of the so-called Europe 2020 strategy for smart, sustainable, and inclusive growth[8].

Horizon 2020 revises the concept of innovation, thus abandoning the traditional linear scheme and focusing on a single complex innovation cycle that ranges from fundamental research to experimental development and integrates both demonstration activities and the phases closest to putting products into the market. This unifying scheme seeks to guide research and innovation towards the achievement of specific results with an economic, environmental, or social projection. In this context, Horizon 2020 is divided into three main pillars: Excellence Science, Industrial Leadership, and Societal Challenges, which are (i) health and demographic change, (ii) food security and sustainable agriculture, (iii) clean and efficient energy, (iv) green transport, (v) climate change and resource efficiency, (vi) inclusive and innovative societies, and (vii) security.

On the other hand, European publics became aware of the fact that research could be put, to a large extent, directly to the service of society, as demonstrated, e.g., by the EU response to the Mad Cow Disease (Bovine Spongiform Encephalopathy) of the late 1990s, which anticipated the focus of Horizon 2020 on societal challenges (Finnegan 2015). In this context, appeals were made for a stronger citizen involvement in research and innovation policies, thus promoting new models for a more responsible research and a better alignment of science with society. A step forward in this direction were the Lisbon Treaty –signed in 2007 and entered into force in 2009– and the Lund declaration of 2009, which called explicitly for an emphasis on societal challenges. In this 'science for society' model, society rather than scientists set the research priorities, and the value generated by research is in addressing societal challenges, instead of simply addressing market demand. These models are complementary and seek to benefit society, but in different ways. Within a science for society policy, scientists could well be

[7] The EU's 8th framework program (FP8 - Horizon 2020) had a budget of nearly €80 billion, 25% higher than its predecessor FP7.

[8] Another particularly relevant flagship initiative in the context of research, technology, and innovation was the *Digital Agenda for Europe*, which was launched with the aim of speeding up the roll-out of high-speed internet and reaping the benefits of a digital single market for households and firms.

encouraged to do independent curiosity-driven research on particular societal goals, whereas within a market-driven approach cooperation is encouraged between researchers, the private sector, and the government on priorities set by the market.

In the framework of the financial and economic crisis of the early 2010s, the PCTI 2020 was launched with a focus on the idea of a Research and Innovation Strategy for Smart Specialization (RIS3) that was being developed by the European Commission, as part of the Europe 2020 strategy, aiming at a smart, sustainable, and inclusive growth.

The PCTI 2020 was designed on the grounds of an efficient innovation system, which had been developed during the previous three decades (Aranguren *et al.* 2016), but now focusing (by following a RIS3 methodology) on a few areas of economic and strategic importance: advanced manufacturing, energy, and health. The goal was to integrate, in the framework of smart specialization, business and social demands (market pull), the existing capacities and progress in science and technology (technology push), as well as the opportunity niches that had been identified: (i) agri-food industry in the context of sustainability and the environment, (ii) territorial planning and urban regeneration, (iii) leisure, entertainment, and culture, and (iv) specific activities related to ecosystems like, e.g., water decontamination activities, the regeneration and recovery of contaminated soils and the monitoring of ecological risk. Additionally, the plan sought to improve the innovation system through the implementation of four strategic lines, two cross-cutting themes, and one horizontal axis. The strategic lines were: (i) promote science, technology, and innovation to respond to societal challenges, (ii) strengthen the industrial leadership in the framework of a public-private collaboration, (iii) raise the excellence levels of the country as a whole, and (iv) guarantee the development of new talent in science, technology, and innovation. The cross-cutting themes were: (i) internationalization and (ii) connectivity; and the horizontal axis was gender equality.

The PCTI 2020, as previous plans, was very much focused on the improvement of industrial competitiveness, in contrast to the European approach where the 'science with and for society' (SwfS) model was particularly encouraged; and with the advent of the COVID-19 pandemic the idea of research as something that could be put directly to the service of society was strengthened, as reflected in the latest European framework program Horizon Europe (for the period 2021-2027).

2.2. Strengthening the system connectivity for the triple transition

Another lesson learned from COVID-19, which was considered, at the beginning of the present decade, in the elaboration of the ongoing PCTI 2030, was the need to strengthen the connectivity of our innovation system to succesfully undertake a triple global transition towards a technological/digital, ecological/sustainable, and physically/socially healthy society with employment quality and better life.

The general strategy of the PCTI 2030 was established on the basis of four important references: (i) the Horizon Europe FP, as an instrument to reinforce a target-oriented innovation system, (ii) the Digital Europe Program, focused on bringing digital technology to businesses, citizens, and public administrations, (iii) the European Green Deal, aimed at converting Europe into the first climate-neutral continent, and (iv) the Basque *Berpiztu* program for the economic revival and employment. Also, the Euskadi Basque Country Multilevel 2030 Agenda covered the committment of the Basque Country to meet the 17 Sustainable Development Goals (SDG) of the United Nations[9].

[9] The SDGs that are closely related to the PCTI 2030 are: good health and well-being (3rd goal); gender equality (5th goal); affordable and clean energy (7th goal); decent work and economic growth (8th goal), industry, innovation, and infrastructure (9th goal), sustainable cities and communities (11th goal), and climate action (13th goal).

On the other hand, the PCTI 2030 deployed and adapted the RIS3 that had been implemented in the previous PCTI 2020, and this was done on the basis of three strategic pillars, which are: "Scientific Excellence", "Technological Leadership in Industry", and "Open Innovation", in addition to the "Tallent" pillar, which represents the core of the strategic architecture. Together with these pillars, four operational objectives were identified: "Focus on Results"[10], "Development of Innovation", "Internationalization", and "Promotion of talent and women researchers". The revised strategic priorities were "Smart Industry", "Cleaner Energies", and "Personalized Health", and the revised areas of opportunity were "Healthy Food", "Eco-innovation", "Sustainable Cities", and "Euskadi Creativa"[11].

Towards the end of the last decade, the smart specialization strategy launched in the framework of the PCTI 2020 got consolidated, but the social challenges and the actors of the civil society still remained far from being fully integrated (Aranguren *et al.* 2019). Hence, the PCTI 2030 represented an opportunity to mind the existing gap, by promoting the development of cross-cutting tractor-effect initiatives, such as healthy ageing, electric mobility, and circular economy, which (i) should be aligned with the so-called 'missions' of the Horizon Europe program and (ii) should allow facing the existing societal challenges. Those cross-cutting tractor-effect initiatives are expected to promote collaborative work among companies, universities, technology centers, research centers, and the public administration, with the aim of identifying tractor-effect projects with transformation potential. Existing capabilities would be concentrated around these projects, possibly with the participation in larger-scale European projects through the missions of Horizon Europe[12].

In the framework of the PCTI 2030, responsible for the deployment of the RIS3 are the so-called Steering Groups –created in 2015–, which are made up of stakeholders of the so-called *triple helix*: (i) companies, (ii) the RVCTI, and (iii) the Administration, not including social stakeholders[13]. The RVCTI includes universities, BERCs, CICs, technology centers, and health research centers, among others. This governance model makes it difficult, however, to deploy the PCTI 2030 along the lines of SwfS that the EU has been promoting since the launching, during the last decade, of the program Horizon 2020. In this framework, curiosity-driven and market-driven reasearch should be complemented with a kind of research driven by societal challenges, and here the priorities should be established not only by the *triple helix*, but also by social stakeholders, thus giving rise to the so-called *quadruple helix*.

The construction, during the last decades, of the Basque innovation system has been very much focused on (i) scientific and economic targets and (ii) the participation in the system of a number of agents that would play a role in achieving these goals, and this is in contrast with the last two EU framework programs Horizon 2020 and Horizon Europe, which go well beyond by (i) including scientific and economic targets as part of a broader social target and (ii) incorporating all kinds of social actors as part of the innovation system.

[10] The expected results are mainly of a socioeconomic (knowledge-intensive employment), scientific/technological (scientific publications and exports of high and medium-high technology products), or innovation (sale of new products) nature. They are not focused on SDGs like "affordable and clean energy", "good health and well-being", or "climate action".

[11] The aim here was to work on the building up of a so-called Basque District of Culture and Creativity, which would lead to Cultural and Creative industries. This sector would integrate two subsectors: the cultural subsector (performing arts, visual arts, audiovisuals, printed media, music, and cultural heritage) and the creative subsector (architecture, crafts, digital content, design, gastronomy, language industries, fashion, advertising and marketing, and video games).

[12] In the strategic priority "Personalized Health", the participation in one of the five missions of Horizon Europe is envisioned, which is the beating cancer plan.

[13] The so-called "social agents" are included in the PCTI 2030; but they are not integrated as part of the governance model, which only integrates the agents of the triple helix.

3. Responsible Research&Innovation and Open Science

With the introduction of 'Societal Challenges' as one of the three pillars and 'Science with and for Society' as one of the two specific objectives of the EU framework program Horizon 2020, the foundations were laid for the promotion of an open, responsible, integrated, and adaptive innovation system, which would later be reinforced within the latest framework program Horizon Europe. Here, we present a description of this model and the lessons we can learn in order to promote new capacities in the Basque innovation system that would favor the governance of a responsible research and innovation in the near future.

The aim of the H2020 specific objective 'Science with and for society' was to build an effective cooperation between science and society, to recruit new talent for science, and to pair scientific excellence with social awareness and responsibility. In this framework, the concept of responsible research and innovation (RRI) was developed, towards an open science and innovation system that tackles the societal challenges of our world and promotes a model of participatory research and innovation where all societal actors (researchers, citizens, policy makers, businesses, third-sector organizations, etc.) work together during the whole research and innovation process in order to better align processes and outcomes with the values, needs, and expectations of our society[14].

First of all, RRI postulates the open nature of innovation, in relation to the objectives of the innovation process, the adecuacy of the results obtained, and the principles and criteria on which this adecuacy is established by the societal actors (Eizagirre *et al.* 2017). RRI represents a guiding principle for an innovation system that is built on criteria of anticipation, reflexivity, inclusive deliberation, and responsiveness (Owen *et al*. 2013)[15]. In the framework of RRI, a continuous and open process of adaptive learning is emphasized, as in the so-called AREA (Anticipate, Reflect, Engage, and Act) promoted in 2013 by the Engineering and Physical Sciences Research Council of the United Kingdom (UK) and then followed in other European countries like, e.g., Norway and the Netherlands (Owen, 2014)[16]. RRI also calls for the responsibility of scientists to not only mantain the quality and integrity of the research process itself but to also align their research with societal values[17].

In the Horizon 2020 work program, RRI is articulated as a complex learning process adapted to the demands, values, and expectations of society and its citizens. The first element of the learning process is oriented towards the acquisition of capacities to promote an open science based on collaborative interaction practices. The science promoted by RRI integrates this collaborative open science into an anticipatory governance structure that makes it possible to identify the right impact of science and technology when facing major socio-environmental challenges. This takes us to the idea of *responsive* science as an open, networked, collaborative science that is responsive to societal challenges. Responsible science and innovation is at the core of Horizon 2020, and a responsive open science

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[14] In Horizon 2020, the very concept of innovation is conceptualized in a novel way by integrating in a single process: fundamental research, technology development, proofs of concept, pilot lines, technology transfer, social innovation, standardization, and venture capital.

[15] In the H2020 framework program, five key areas were identified for RRI: public participation, gender equality, open access, scientific education, and ethical guidance. Indeed, member states and regions, as well as various organizations, have commonly promoted actions governed by these key areas in order to promote responsible practices. Some of these practices had already been in place, so they represented "de facto RRI" (Randles *et al.* 2016). Here, we focus on the most novel aspects: the four learning criteria to guide a responsible research and innovation.

[16] Given the open nature of the RRI concept, the practices favored within this framework are particularly diverse, heterogeneous, and controversial (Davies and Horst 2015, Lukovics *et al.* 2017, Mei *et al.* 2020, Mejlgaard *et al.* 2018).
In this context, the AREA scheme led to the AIRR approach, which reflects responsibility as anticipation, inclusion, reflexivity, and responsiveness (Stilgoe *et al.* 2013).

[17] In the RRI framework, responsibility is the result of an evolution in the radicalization of the understanding of the relationship between science and society (Rodriguez *et al.* 2020).

represents an important element of the ongoing Horizon Europe[18]. In what follows, this programmatic correlation is inverted: we first introduce the main characteristics of a responsive open science, and we then move on to the idea of responsible research and innovation.

3.1. Responsive Science as an open collaborative science (OS)

The idea to promote responsible research and innovation was launched in 2012 by Gilles Laroche, head of the 'Science in Society' Work Program of the EU 7th Framework Program (FP7), on the basis that societal perceptions and the impact of technology were difficult, even impossible, to predict. Laroche stated that early societal intervention could enable the anticipation of positive and negative impacts. Thus, it seemed necessary to build a European RRI model, based on the principle of inclusiveness, that would allow anticipating the effects of innovation (Owen *et al*. 2012) and would ensure ethical co-responsibility. In the framework of a target-oriented responsible research and innovation, three distinct features can be identified (Owen *et al*. 2012): right impact, responsiveness, and ethical co-responsibility, which we describe below.

The notion of "right impact" is related to the identification of the goals of innovation in an ethical and inclusive way. Responsiveness calls for the integration and institutionalization of mechanisms of reflection, anticipation, and inclusive deliberation around the processes of research and innovation (Owen *et al*. 2012); and the idea of co-responsibility comes into place as far as research and innovation get oriented towards socially acceptable impacts and through procedures that allow anticipating potential impacts and reinforcing the ethical reflexivity of all kinds of societal actors. On the basis of these three features, RRI can be conceptualized as a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the ethical acceptability, sustainability, and societal desirability of the innovation process and its marketable products (von Schomberg 2013).

Hence, mutual responsiveness is the result of a collective deliberative process that requires, in turn, a collaborative approach to the concept of responsibility. It is precisely, according to Owen and collaborators (Owen *et al*. 2012), this exercise of reconceptualization of responsibility one of the greatest intellectual challenges for those wrestling with the concept of responsible innovation.

3.2. Responsive Science as anticipatory science (RRI)

The deliberative component of mutual responsiveness and RRI is open in nature, as it should not be constrained to, e.g., the ongoing development of science and technology. Indeed, this deliberative process could well incorporate other courses of action. The *anticipation* allows for a reflection on those courses of action, and decisions are made in the framework of an anticipatory governance.

Anticipatory governance is defined as a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible (Guston 2014). First of all, David Guston distinguishes anticipation from other related concepts such as expectation, prediction, or foresight to emphasize the fact that anticipation refers to the development of a series of capabilities allowing for a real-time evaluation of technological activity with a focus on the long term. More specifically, according to Guston, anticipation is not about divining the future but, instead, about practicing, rehearsing, or exercising a capacity in a logically, spatially, or temporally

[18] Open Innovation also represents one of the three pillars of the PCTI 2030.

prior way. Anticipation is about strengthening the capabilities of the governance model to respond to the challenge of responsible innovation. The virtue of an anticipatory governance lies in the development of complex assemblies that, based on the explicit exploration of multiple futures, allows us to build a co-responsibility of the present. Rabinow and Benett (Rabinow and Bennett 2009) argued that formal proceduralism might not be able to answer the ethical and political questions of whether or not a given course of action is good or bad, right or wrong, just or unjust; Guston argued, however, that it can, because it provides a different context where researchers and decision-makers have the opportunity to focus on the normative dimensions of their activity.

It is in this sense that the appeal to commitment is defined as a crucial capacity, along with foresight and integration, and it is in the framework of complex assemblies where each actor can be co-responsible of the present through a critical appropriation of possible futures. It is not social analysts who should have the capacity to judge between good and evil. On the contrary, it is about strengthening the reflective capacity of all actors from their particular position in the complex assembly of practices shaping innovation.

3.3. Open Science operazionalization: mission-driven research and innovation

The European framework programs Horizon 2020 and Horizon Europe have been paying particular attention to entangle science and society, not so much by enabling measures aimed at the scientific community *stricto sensu* but by seeking to modify the institutional architecture of the science ecosystem[19]. The ongoing dynamics are evolving towards a system of co-responsibility based on social collaboration between the academia and the social sectors. By engaging citizens in an inclusive innovation process, scientists and innovators can anticipate and respond to societal demands and expectations, thus making the social sectors co-responsible for the innovation process.

In the framework of the ongoing program Horizon Europe, a new instrument has been launched with the aim of delivering solutions to some of the greatest challenges facing our world by means of a mission-oriented research [Mazzucato 2018, Mazzucato *et al.* 2020], the missions being "cancer", "climate change", "healthy oceans", "climate-neutral cities", and "healthy soil and food"[20]. The involvement of stakeholders and citizens is a central element of the missions. Citizens are mobilized to be incorporated into the collective interaction with other actors of the quadruple helix, thus opening science and innovation to the development of sustainable and resilient practices.

Within the so-called missions, European regions are particularly relevant in the process of co-design and co-creation aimed at finding solutions to the problems identified by the quadruple helix. Indeed, regions are committed to promoting mission-oriented research, collaboratively contributing from the opportunities identified in the region to address the problems of the corresponding mission. The European Regions Research and Innovation Network (ERRIN) is a Brussels-based platform that gathers around 120 regional organizations from more than 20 European countries[21]. Some of the ERRIN regions have designed and applied their RIS3 within a mission-oriented prespective. The case of the Noord-Nederland region in the Netherlands[22] offers an eloquent example of the model's potential, although their alignment

[19] This new orientation is aimed not only at the identification of social challenges, but also at governance of the research and innovation ecosystem. In this context, 608 organizations have recently signed an agreement for an evaluation reform based on the maximization of the quality and impact of research through a qualitative judgment and a responsible use of quantitative indicators (CoARA 2022). CoARA (Coalition for Advancing Research Assessment) involves more than 350 organizations from 40 countries.
[20] In the PCTI 2030, there is an instrument (Transversal Driving Initiatives), which is claimed to be aligned with the *missions* of Horizon Europe.
[21] The delegation of the Basque Country to the EU is a member of ERRIN.
[22] The Noord-Nederland is a Dutch region consisting of the provinces of Groningen, Friesland, and Drenthe.

with the European mission-oriented strategy is not free of tensions between the Dutch region and the EU[23].

The main results achieved in the framework of the five Horizon-Europe missions were evaluated after two years of implementation. The evaluation report highlights two areas that require an improvement: (i) the need to strengthen collaboration between all key innovation players from across the quadruple helix and (ii) the need to improve the participation of stakeholders and citizens by promoting a dialogic communication model that subjects to public debate the demands, desires, lessons, progress, and results obtained.

A strong collaboration between the various areas of the quadruple helix and the involvement of the public from the various instances of political representation –from local instances to Member States– contribute to the strengthening of both responsive (OS) and responsible (RRI) science and innovation. The bottom-up structure of mission-oriented research founds the current strategy for a science and innovation that is more attentive to the demands, values, and expectations of our society.

4. Basque research and innovation from a RRI perspective

During the last four decades, Basque research and innovation has evolved from a system designed as a technological paradigm for the consolidation of the industry landscape to a true learning techno-social system that (i) adopts RRI as a framework for research and innovation and (ii) is focused on the resolution of all sorts of social problems.

On the other hand, the Basque research and innovation system has represented a genuine tool to strengthen its innovation power by focusing more on its integration into global value chains than on the shoring of the internal elements that compose it[24]. Indeed, in the most recent PCTIs it is emphasized the need to move towards the integration of the Basque research and innovation system into the ongoing European framework. This implies the adoption of strategies aimed at strengthening the resources and capabilities of the system (through the identification of areas and strategies of smart specialization) and, at the same time, supporting the connection of the actors of the system with more global areas of activity, particularly at the European level.

This connection asks for an effort to align with the new framework that is being built in the EU in order to face social challenges. This is a framework where a strong collaboration is expected between citizens and the actors of the so-called quadruple helix for a co-construction of open science from a mission-oriented research that is aimed at facing social challenges with an attitude of responsiveness and anticipation.

In this context, there are a few challenges that will require attention and debate in the near future, mostly related to the role played by fundamental (curiosity-driven) research and also the excellence criterion.

[23] These tensions are the result of different viewpoints on the role that research and innovation should play in a transition towards a science, technology, and innovation system that contributes to the development of the territory. The expectations of the EU and the regions –Noord-Nederland in this case– are often not the same when it comes to the understanding of the impact that research and governance have on the role that the actors (universities and research centers) should play in the corresponding innovation system. In spite of the complementary initiatives introduced by the European Commission, the public authorities in the region are targeting the contribution of the research system towards the innovation ecosystems specified in their own Smart Specialization Strategy, thus questionning the goal of a larger connectivity of the missions within the EU (Noord-Nederland 2021).

[24] This model was later proposed as a success example by one of its original driving forces (Azua 2015). This model was, however, oriented towards the interaction with industry rather than based on dynamics of knowledge generation (Porter 1990).

While the latest PCTIs seek to implement effective instruments for the production of an excellent science and innovation measured quantitatively in terms of high-impact publications and patents, Horizon Europe is giving more protagonism to the idea of excellence in terms of social commitment and responsibility, and, more specifically, social connectivity and the connection between projects and research agendas[25]. With this goal in mind, a real collaboration between all key innovation players from across the quadruple helix should be pursued, thus strengthening collaboration and improving participation. It is not clear, however, how this challenge could be realized in the framework of the ongoing PCTI.

5. Summary and conclusions

In summary, the Basque research and innovation system, which was launched in the 1980s soon after the approval of the Basque Devolution Act and has developed during the last four decades, has shown great promise as a dynamic and adaptive learning techno-social system. At this point, capitalizing on its strengths and addressing the existing challenges will be crucial for its continuous success in driving not only innovation and economic growth but also the well-being of our society.

Along the lines of the ongoing trends of European policies that are already being developed at a number of European countries, it is now time to analyze whether succesful Basque policies mainly oriented to economic growth need to be complemented with a more integral view of innovation that incorporates science, technology, and society as parts of a techno-social system that cannot possibly disentangle its components. Science communication in the Basque Country, as in many other countries around the world, is still based on the so-called deficit model (Miller 1983), which implies that communication should focus on improving the transfer of information from experts to non-experts. In this model, the general population is seen as the receiver of information and scientific knowledge, the information they receive having been prearranged following what the distributors believe to be in the public's interest (Wynne 2006). In the 'science with and for society model', however, there is a co-design and co-creation of knowledge enabling a true interaction between the actors of the quadruple helix and the citizens (Rubio 2019).

The development of science and technology should be subject to long-term country politics free from partisan litigation, a fact that should be aligned with the idea of citizen participation. In the ongoing framework programe Horizon Europe, special attention is paid to this issue, particularly in the context of mission-oriented research, with the aim of driving innovation towards general objectives to be deliberated among all societal actors. In this context, relevant contributions are collected from citizens by following the OS and RRI principles. Hence, an effort should be made in the Basque Country to explore the feasibility of these new policies and the potential impact of their application. This effort would necessarily require providing all societal actors (including policy makers) with the skills to acquire a capacity for deliberation on a research governance that should be oriented to solve existing and potential new challenges. This exercise might serve to align our policies with the objectives and missions of Horizon Europe and to offer a new input for the adaptation of future science, technology, and innovation strategic plans to the rapidly evolving challenges of science and technology.

[25] The commitment to OS, for example, would be assessed in terms of research behavior (e.g., early sharing of data and knowledge and, also, open collaboration) rather than in terms of quantitative indicators related to the quantity and impact of scientific publications; and the commitment to RRI would be assessed by the level of co-responsibility with the stakeholders and the citizens, as well as the quality of co-design and co-creation of the research agenda. An implementation of these guidelines can be found in the Impact Plan Approach of the Dutch Research Council (www.nwo.nl/en/impact-plan-approach), developed with the aim of increasing the chance of research social impact.

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