



TÍTULO DE LA COMUNICACIÓN: The Role of Knowledge Infrastructures in Regional Innovation Systems: the Case of the Basque Country

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It is well recognized in the literature that innovation is not produced in isolation but as a consequence of interaction between firms and other agents embedded in a system. In that sense knowledge infrastructures play an important role in the system in both a narrow and broad conception of innovation systems (Lundvall, 1992; Nelson, 1993). Their role has been characterized in terms of functions by some authors as Edquist and Hommen (2008) but there is not a clear agreement in the literature about them. In addition, we could identify some type of organizations as knowledge infrastructure (i.e. mission oriented centres, government labs, RTOs) but the distinction about the functions and activities they traditionally performed is not clear anymore as for example public institutions are pushed to have closer links to industry (Sanz-Menendez and Cruz-Castro, 2006; OECD 2011). This paper explores the roles different types of actors are currently performing in a regional innovation system and illustrates it with a case:

The Basque Country. The Basque Country faces some challenges with respect to knowledge infrastructures as it has built a complex but powerful knowledge system and now it is the turn of maximizing its potential. This paper will identify the strengths and weaknesses of the Basque knowledge infrastructures in order to provide some policy recommendations.

PALABRAS CLAVE: *(máximo 6 palabras)*

Knowledge infrastructure, regional innovation systems, Basque Country.

1. Introduction

One of the main ideas developed by the innovation economy in the last decades is that innovation cannot be understood as a isolated action from one individual or firm but as a social process. In addition, due to the fast advance and the complex characteristics of knowledge it is very unlikely that one single organization has all the required knowledge to innovate. Therefore, the system in which the organization is embedded is very important, as it will shape its innovation capability.

In the 80's the importance of the systems to innovate was recognised and afterwards consolidated by the work of two scholars: Lundvall (1992) and Nelson (1993). The two approaches differ in their conception of the system and the actors that take part of it. Lundvall presents a wide approach in which the system is composed of organizations that conduct technological innovation based on R&D but also based on other types of knowledge resulting from doing, using and interacting processes. In contrast, Nelson only considers as part of the system R&D organizations, as his focus is only on technological innovation. Although we recognise that adopting a wide approach would be more appropriate for understanding some important elements of the innovation processes nowadays, as for example innovations in low tech sectors or in SMEs, in this paper we will focus on the restrictive conception of a regional innovation system as it will allow us to delimitate the type of knowledge infrastructures we will analyse and to understand a key part of the knowledge generated within a system (Niosi, 2010).

Apart from delimiting the actors to study, it is important to decide whether conduct an analysis following an institutional or a functional approach. On the one hand, Fisher (2001) defines an innovation system as a set of actors that interact in order to generate, disseminate and use new knowledge. On the other hand, Edquist and other scholars (Edquist, 2001; 2005; 2008; Edquist and Chaminade, 2006; Edquist and Hommen, 2008) have promoted the view that an innovation system is composed of all the factors that might affect the development, dissemination and use of innovations, which is the main system's function. Therefore, when analysing a system of innovation could be more important to analyse whether all the activities within a system are well developed or not rather than analysing the actors embedded in that system, as these actors might be performing the same activities and others might be avoided. However, taking into consideration that there is not an agreement in the literature about the functions that should be included in a certain system (Edquist and Hommen, 2008; Lundvall et al, 2009, Bergek et al., 2008; Chaminade, 2010), and that information and literature about

systems is normally organized by type of actor, this paper will follow a double approach. It will focus on the actors that generate and disseminate knowledge for innovations, what we called knowledge infrastructures, but also with a functional perspective, in order to understand the functions they perform within a system, following an integrated approach.

In addition, within the innovation systems approach, it is important to highlight that this paper will focus on a regional innovation system, which limits the scope of our analysis to the infrastructure that supports innovation in a region (Asheim and Gertler, 2005). Following Cooke (1996, 1998 and 2001) a regional innovation system is composed of two subsystems: the knowledge generation subsystem, which is composed of public and private labs, universities, etc.; and the knowledge application and exploitation subsystem, which includes firms, their clients, collaborators, competitors and suppliers. This paper will focus on the first subsystem although recognises that some firms' activities should be part of this subsystem too.

Therefore, the main of the paper is to understand the different role and functions that knowledge generating infrastructures are performing within Regional Innovation Systems and their characteristics. This understanding will enable us to analyse the system's efficiency and how can this efficiency be improved through public policies. For doing so, the paper is structured as follows. In section 2 we explore the concept of knowledge infrastructure and classify them into different categories. In section 3 we present and compare the different characteristics each type of infrastructure presents-including activities and functions-, according to the theoretical and empirical literature. Afterwards, we explore these characteristics through a case study in a Spanish region (the Basque Country) and finally we extract conclusions and policy recommendations.

2. Knowledge Infrastructures in a Regional Innovation System

There is not a clear definition of what a knowledge infrastructure is and which ones are included in that concept in the economic literature. There are some authors that consider them as organizations and institutions (Smith, 1997, 2002; Buret and Héraud, 2001) and others that highlight the collective cognitive capabilities. Following Smith (1997, 2005), we can define knowledge infrastructures as those composed of public and private organizations and institutions, which role is focused on generating, maintaining, distributing, managing and protecting knowledge and with certain characteristics (economies of scale, indivisibilities, multiple users and externalities). Smith (1997) also highlights the main functions these infrastructures perform: knowledge production and

diffusion; education, training and skills generation; standards, regulation and protection of technical activities; spin-offs generations and dissemination activities.

Among the organizations that fulfil these roles we only consider those organizations with legal form located in a region (Koschatzky and Héraud, 1996; Bureth and Héraud, 2001), in which knowledge generation and diffusion constitute a main activity.

Taking these issues into consideration different classifications of knowledge infrastructures can be found in the literature (Hamdouch and Moulaert, 2006; Smith, 1997; Koschatzky and Héraud, 1996; Bureth and Héraud, 2001). Focusing on those providing R&D services, we can highlight the followings:

- University
- Public Research Organizations
- Research Organisations (RTOs)
- Hybrid Centres as Centres of Competence and Cooperative Research Centres

Although there is quite a clear distinction between university and other organizations, the distinction among the different extra-university research organizations is not so obvious. OECD (2011) for example, defines as Public Research Organisations those organizations, centres and institutes that perform research with a certain level of *publicness*. Among this category four types can be distinguished: public research centres that operate in several fields and with a certain size (i.e. CNRS or CSIC); mission-oriented public centres conducting research in a certain field or sector; research technology organisations (RTOs); and Independent Research Centres, focused on a specific problems or topic (i.e. cooperative research centres and centres of excellence).

The first two categories can be grouped in the Public Research Organization, as they present similar characteristics, but the rest two of them (RTOs and hybrid organizations as Centres of Competence or Cooperative Research Centres) present singularities with respect to the previous category and it is therefore useful to analyse them in a separate way.

Therefore, in the following subsection we present the characteristics and features of these previously mentioned infrastructures.

2.1. Role of the Knowledge Infrastructures

As mentioned before, knowledge infrastructures have a core role within a Regional Innovation System as innovation is a result of an interacting and social process and knowledge necessary for that process is not embedded in a unique organization. Given that assumption, there are some standard and well accepted roles in both the theoretical and empirical literature of knowledge infrastructures; but the characteristics and features of each one may vary depending on the system we are analysing. Nevertheless, we explore in this section those established features for each type of organization within a Regional System.

Features, characteristics, and especially functions of every organization are a result of the traditional weight some of them have had over the history. Thus until XIX century university had only an educational role (Sotelo, 2008) that was spread to research activities in some countries as a result of the scientific specialization of some educational programmes (for example the beginning of PhD programmes), so universities began to conduct research, especially basic research (Godin, 1998). Although their role vary from country to country and from region to region, Public Research Organisations (PRO), by their part, were especially promoted after the Second World War to fill a gap in some mission oriented research, especially in military and civil applications (OECD, 2011). Since then, universities as well as public research organizations have conducted basic research but have also evolved towards applied research due to the need of being close to industry. In addition to that, some other types of institutions as RTOs began to conduct applied research adapted to the industrial needs in that time, although it was in the 80's and 90's when they had an important role in providing knowledge more focused on technological innovation than on science to firms (Teece, 2010), so filling a gap that university and PROs were not filling at that moment.

Nevertheless, in recent decades, the role of university and PROs has been discussed. According to Gibbons et al. (1994) there are two modes of knowledge production: Mode 1, in which research is conducted in traditional organizations without little connection to societal needs; and Mode 2, which constitutes a more cross-disciplinary research linked to societal needs and economic problems. Given the need of conducting a research oriented to problem solving issues, being closer to sectors and industries have become a must for these organizations. The need of increasing interactions with industry has been also developed by the Triple Helix model (Etzkowitz and Leydesdorff, 2000; Etzkowitz 2003 and 2007; Etzkowitz and Klofsten, 2005). The

main difference between the two models is the role they give to university. While in the Triple Helix Model university has a core role within the knowledge production system, Gibbons et al. consider university only as one part of that system, even a little one. Nevertheless, most of literature agree with the Triple Helix Model and recognizes the important role of university in the knowledge production and diffusion system over other type of agents. Moreover, most of the existing empirical models have given this core role to university. Finally, competence centres have been recently settled down as an intent not only to improve science-industry links but also to help universities modernise to meet changing circumstances (Arnold et al. 2004). Cooperative Research Centres are a specific formula to promote technology transfer from university (or in some cases other research institutions) to industry, in which both parties form part of the government board (Adams et al. 2001).

2.2. Charcateristics of the different Knowledge Infrastructures

In the following tables we provide a description of the current characteristics of each of the knowledge infrastructures. The aim of this section is not to provide a detailed description of each of them but to compare and highlight the main similarities and differences among them. This review is based on both a theoretical and empirical literature review. The characteristics we have studied revolve around the following issues:

- Governance and organizational issues (including funding)
- Main activities and functions and technology transfer issues
- Internationalization and markets
- Interactions among organizations in a Regional Innovation System

In Table 1 we can see the main characteristics of the different types of knowledge infrastructures in relation to governance and organizational issues.

First of all, we observe that legal form varies from one organization type to another. Whereas public institutions are mainly public organizations, we can find public and private RTOs (Eurolabs, 2002) and universities, which mainly follow humboldtian model of combination of research and education activities (Niosi, 2010).

More important than their legal form is the independency or autonomy of the organization. Thus we can distinguish between organizations with a certain degree of

autonomy in management independent of their legal form, such as RTOs or centres of competence and organizations very centralized although flexible in some aspects as public institutions. In fact, autonomy is one of the singular characteristic of RTOs (OECD, 2011; Gijsbers et al. 2005) even in the ones publicly owned in contrast to public institutions that were created to reach a governmental mission (Leijten, 2007) and therefore very conditioned to government. Nevertheless, autonomy in RTOs also depends on their internal organization being different in centralized institutions than in multi-centres. In university, even if they are de-centralized organizations in terms of management as the department is the important unit in this sense, they are very bureaucratic and regulated institutions in Europe.

On the contrary, when analysing the autonomy of the individual researcher the situation varies from the described above. Thus it is in RTOs where individual researchers have less autonomy in defining their research lines as the organization fixes them (OECD, 2011) than in universities, where the individual researcher has a greater autonomy (Foray and Lissoni, 2010).

Funding is one of the organizational characteristics that presents more singularities across the mentioned infrastructures. RTOs funding model is one of the most analysed topics in the literature of these centres (Arnold et al., 2007; Giral, 1999, Modrego et al., 2004, Fernández, 2010). Arnold et al. (2007) show the most sophisticated model in which 15% of funding comes from government and it is considered core funding, another 15% also comes from public funds but it is conditioned to government's objective and the rest 70% comes from industrial and competitively won public funding. Core funding can be established through individual negotiation or linked to the organizational performance, which is being the trend in the last years. This trend is also appearing in some other infrastructures as university, although courses fees (in private universities) and core funded non-conditioned to the institutional performance (in public universities) remain the main funding sources. Core public funding is also an important funding source for public institutions and centres of competence, although private funding is an increasing funding source, especially in later stages after the settlement of these centres.

Finally, human resources management and configuration also differs across the different infrastructures. While in university and public institutions people's background is mainly academic, in centres of competence and RTOs it is important to maintain an equilibrium between academic and industrial background. For example Arnold and Rush (1996) point out that personnel with industrial background in RTOs should be at

least one third of the total. Nevertheless, in Europe and Spain recruitment and personnel policies are directed to improve the academic background by increasing the number of PhDs in the organizations (Arnold et al., 2007; Astrom et al., 2008; Aeval, 2009). In these last type of infrastructures, personnel mobility is also a relevant issue as it helps to extend the contact networks and to maintain the centre updated (Arnold and Rush, 1996). Finally, salaries and the way they are established also differ across organizations. While in RTOs and centres of competence salary can be individually negotiated, in universities and public institutions it is established and regulated. Nevertheless, in RTOs salaries are lower than in industrial firms (Behlau, 2006) and they include other issues different to remuneration (Arnold et al., 2007; OECD, 2011). In addition, there is an increasing trend of linking salaries to individual performance in those organizations (Gijssbers et al., 2005; Arnold and Rush, 1996).

Table 1: Governance and organizational issues (including funding)

	RTO	University	Public Institutions	Centres of Competence
Legal form	Huge diversity of legal forms with predominance of public centres and private and non-profit organisations	Predominance of public universities following the same organizational model (Humboldt model)	Mainly public centres. Some hybrid forms are also appearing.	Mainly private and non-profit centres
Autonomy and flexibility of the organisation	Certain autonomy in management independent of the legal form, although there are difference between centralized centres and multi-centres	Bureaucratic and non-very flexible organizations. De-centralized organizations in terms of management. Very regulated organizations.	More flexible than universities. Centralized organizations in terms of management.	Certain autonomy in management although centralized organizations.
Autonomy of the individual researcher	Linked to the organization priorities and research lines. Centralized model	Individual researches establish their research lines. Decentralized model	Research agenda is a combination of the organizational and researchers priorities	Research agenda is a combination of the organizational and researchers priorities
Funding	Mix of public (both core and competitive) and private funding. Core	Mix of funding resources: core public funding (trend to be linked to their	Mix of funding sources although mainly public funding (core	Mix of funding sources: public (core) funding (principally) in early stages of

	public funding is conditioned to the organizational performance.	performance), competitive funding (mainly linked to research), course fees and private funding	and competitive). Trend to increase competitive funding and links to industry.	development and public (competitive) and private funding in later stages.
Human resources	Mix of people with academic and industrial background. Trend to give more importance of personal mobility. Trend to negotiate competitive salaries based on individual performance	People with academic background. Mainly civil servants and with low mobility. Salaries are highly structured, established and not very dispersed.	People with academic background. Mainly civil servants and with low mobility. Salaries are highly structured and established.	People with a mix of academic and industrial background. Trend to negotiate competitive salaries based on individual performance

Activities and functions of knowledge infrastructures are shown in Table 2, including the activities related to technology transfer issues. Among these activities we can distinguish activities related to education and training, which are the main university's function, and research activities, which can be divided into basic and applied research and are activities included in all the organizations' mission. Nevertheless, there are another set of activities as development and engineering or dissemination, public policies support etc, which are only conducted by RTOs; and technology transfer activities, which are increasing their importance in all types of organization due to the need of being closer to industry.

Although there is a vast literature about these activities in this section we will only provide an overall view of the current state of the art of the most important ones.

Education and training was the primarily university's function until XIX century. University studies can be divided into undergraduate, professional training and postgraduate although in Spain only graduate and postgraduate studies are included in the university mission. Quality of undergraduate studies in Europe are quite acceptable (Aghion et al., 2008) although in Spain there are some indicators that show inefficiencies in this system (duration of the degrees, maintenance of overcapacities in some fields, etc.). One of the weaknesses that can be found in current European universities is the focus on learning about contents instead of developing capabilities as

Lundvall et al. (2008) and Charles (2006) indicate. In addition, the concept of learning economy has gone beyond the knowledge economy, and in this context lifelong learning processes should be included in university's mission (Lundvall, 2008).

Research was included in university's activities in the XIX century, when research laboratories were created to develop basic research activities (Godin, 1998). After the Second World War, public laboratories were also expanded to conduct basic research around government missions. To fill the gap of research oriented to industry RTOs were promoted and created in the same countries (OECD, 2011). For that reason, research activities within these organizations are applied oriented. In fact, although RTOs carry out some activities that might be considered as basic research, these are oriented to acquire knowledge and capabilities necessary to conduct applied research and development activities directed to firms. In addition, RTOs carry out another range of activities as consultancy or policy support, which do not require a sophisticated knowledge generation and activities related to technology transfer issues to industry (licensing, spin-offs generation, etc.) (Arnold and Clark, 2010; Astrom et al.2008). These technology transfer issues are also currently part of the university mission, which is called the third mission. This third mission was actively promoted since the 70s and covers not only interactions and technology transfer to industry but also an important role for university as key facilitator for territorial development (Etzkowitz and Klofsten, 2005). This activity is also fundamental in centres of competence and cooperative research centres as they were precisely designed to foster technology transfer between university and industry (Adams et al., 2001). Finally, Public Institutions have technology transfer as one of their roles given the increasing need of being close to industry (OECD, 2011).

Table 2: Main activities and functions and technology transfer issues

	RTO	University	Public Institutions	Centres of Competence
Basic research	Focus on generating capacities in collaboration with universities. Specially in medium-big sized RTOs	Main activity in research: basic and precompetitive research	Main activity in research	An important activity for these centres linked to industrial needs.
Applied Research	This is the main function of RTOs which is developed by contracts and	Increasing activity as a result of a process of convergence	These institutions also conduct applied research	These institutions also conduct applied research

	individual projects with firms.	and need to be close to industry. Overlap with RTOs function		
Education and Training	Not a core activity for the organizations. Mainly focused on professional training	Core activity for the organization. Mainly focused on tertiary education.	Activity linked to the university but not within the organization (only in PhDs supervision)	Activity linked to the university but not within the organization (especially PhDs and postgraduate supervision)
Development and engineering	Some of the industry-related projects and solutions are closer to engineering than applied research.	It is not an activity included in their day-by-day.	Not a main activity	Not a main activity
Technology transfer by patenting, spin offs...	Important activity linked to industrial partners and projects	Activity in increasing importance. Linked to the Universities third mission	Activity in increasing importance due to the trend of being closer to industry.	Important activity linked to industrial partners and projects
Others: dissemination, consultancy, public policies support, standardization and certification, etc.)	One of the main functions of the RTOs is the connection and interaction with industry and other agents, which can be included under these activities.	Not a very important activity	Not a very important activity.	Not a very important activity.

Industry is precisely the main client of RTOs and Centres of Competences as their mission is to conduct research adapted to the industry needs. In university and public institutions the role of industry is increasing its importance but in the first case it is more appropriate to talk about society as the main client and government in the second case. With regards to industry, RTOs' clients are mainly big and medium sized companies (Astrom et al., 2008; Olazaran et al., 2009) even if their mission is also oriented to small ones. Another distinctive characteristic is that most of the organizational revenues in RTOs come from the same group of firms (Buesa et al. 2011). In addition, the geographical scope of these organizations, public institutions and centres of competence vary depending on the public administration which has promoted the centre, although we can highlight that in Spain most of RTOs are regional oriented (Modrego et al., 2004 and 2005). In the university case the orientation varies depending of the educational level. Whereas undergraduate students normally come from the region, there is a larger variety in postgraduate students from both national and international contexts. With regards to research a trend to internationalise the organizational activities can be seen in all the types of institutions. One of the reasons that underlie this internationalisation is the need of reaching new funding. In RTOs for example, apart from accessing to additional funding the literature also points out other reasons for internationalization (Arnold, Barker et al., 2010; Loikkanen et al., 2011, Berger and Hofer, 2011; OECD, 2011), which might be applied to other types of infrastructures. These are reducing costs (for example accessing to researchers with lower costs) and accessing to complementary knowledge, talent and resources in the knowledge frontier. There are different paths for internationalisation. Some of them are softer as researcher mobility and others imply higher resources investments as contract with foreign clients.

All of this is also dependent on the organizational specialization. While centres of competence and cooperative centres are specialized in a broad range of technological domains (Boekholt et al. 2010), RTOs can be specialized in one or various technology or market domains. Therefore a wide range of RTOs can be found from technology driven (technological vs. politechnological) to market driven (sectoral vs. multisectoral) (Arnold, Barker et al., 2010). With regard to public institutions their specialization can be different according to their mission. Thus we can find mission oriented centres that perform research in specific topics or sectors, public research centres that conduct basic research in several fields and other independent centres that perform basic research focus on problems or needs (OECD, 2011). Finally, among universities it is possible to find different organizational specialization both in education and research. In Europe it

is very common to find universities with a mix of activities in different fields and it is this lack of specialization what constitutes a weakness in the European university system (Aghion et al. 2008; Lambert and Butler, 2006).

Table 3: Internationalization and markets

	RTOs	University	Public Institutions	Centres of Competences
Type of client	Focus on firms, normally concentrated in a specific number of firms (especially medium and big companies)	Society in general (education) Increasing trend to work with firms in research activities	Mainly governments. Increasing trend to work with firms	Governments and industry
Specialization of their activities	Different types of specialization (sectoral vs technological and multisector vs politechnological)	Different types of specialization: focus on education (undergraduate, professional training, PhD) vs focus on research and focus on an specific knowledge field or multifield	Different types of specialization depending on the organization mission: sectoral, technological, etc...	Specialized in a technology or knowledge field.
Regional vs. National market	Mainly national although depending on the role of the Public Administration	Mainly regional although depending on the educational level (undergraduate -regional, postgraduate-national and international)	Variety depending on the Public Administration that promotes and funds the organisation	Variety depending on the Public Administration that promotes and funds the organisation
Internationalisation	Increasing trend. Need of size for internationalise activities	Mainly in terms of education (postgraduate) and research activities through competitive projects and publications	Increasing trend, especially through project partnerships and publications	Increasing trend, especially through project partnerships and publications

Finally, it is important to highlight the interactions among the different types of institutions we can find within a system. Apart from the interactions with industry, which is key in the case of RTOs and centres of competences, as we have mentioned previously, interactions among different agents is an important issue to analyse.

Centres of competence are themselves a type of institution that has been created to facilitate the interaction among different agents, although has specific focus on reinforcing university-industry links (Arnold et al., 2004; Adams et al., 2001). Interaction between individual researchers from different types of organization is a common way of interacting. In the case of public institutions which personnel come from the university this interaction is higher than in other organizations (OECD, 2011). University by its side although has to develop a third mission that implies a commitment with their region and society, in practice this has not been developed in Spain (Tarrach et al., 2011; Pérez and Serrano 2012), as they still lack of interactions with other organizations within the system. On the contrary, RTOs are by nature an interacting agent, constitute the main nodes in innovation networks and even foster relationships between agents (Basse et al., 2008; 2010). Special relationship is the one established between them and university, which can be built by different ways as personnel who teaches in the university, personnel doing their PhD, sharing facilities, hybrid centres as the competence centres, publishing in cooperation and projects in partnership (Behlau, 2006; Astrom et al., 2008; Arnold et al., 2004, 2007; Cruz-Castro et al., 2012). Nevertheless, from a system perspective interaction among different infrastructures is a key issue that has to be taken into account in order to facilitate knowledge creation and diffusion.

Table 4: Interactions between organizations in a Regional Innovation System

	RTOs	University	Public Institutions	Centres of Competences
Industry	Constant interaction with industry and firms as clients	Increasing importance in all their activities (education and research)	Increasing importance (core funding linked to industrial partnerships)	Constant interaction with industry and firms as clients. Industry are part from their board and even part of their personnel.
Other agents in the system: university, RTOs...	Interaction with University through different vias (personnel who teach, sharing	Increasing convergence with RTOs' activities. Need to increase interaction with	Little interactions with RTOs. Very connected to universities (some are	Conceived as an interacting agent with RTOs and universities.

	infrastructures, creating a hybrid institute, ...). Proactive agent.	other agents (reactive agent)	universities institutes)	
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In the next section we illustrate the situation of the different knowledge and R&D infrastructures in a concrete regional system in Spain: the Basque system.

3. The Basque Case: The Role of Different Infrastructures and how this Role can be Affected by Policy Making

The Basque Region is a region located in the North cost of Spain, in the South of Europe and close to Southwest France and one of the few European regions considered real Regional Innovation Systems (Cooke et al. 2000).

In the Basque Innovation System, the role of knowledge infrastructures have been conceived very different comparing to other regions and countries. While in most of the Spanish regions, following the model established in other countries, Science and Technology Policy was oriented towards university, in the Basque Country the orientation was directed to Technology Centres (RTOs) (Sanz-Menéndez and Cruz-Castro, 2005; Olazaran et al. 2004). In addition, the number and variety of knowledge actors in the region is one of the distinctive characteristics of the region. Especially remarkable is the important role of infrastructures conducting applied research and the low weight of public research institutions (OECD, 2011). To understand this complexity with regard to knowledge infrastructures it is necessary to explore some of the Basque Region main characteristics and specially its public policy trajectory. This analysis has been conducted through the study of documents and interviews with several key agents within the Basque System.

The Basque Region is a very industrialized region and Industrial Policy has played an important role within the regional economic development. Due to the industrial specialization, the Basque Government adapted its Science and Technology Policy to the industrial needs, promoting and funding a scientific and knowledge infrastructure linked to those needs.

In fact, in the 80's Science and Technology Policy in the Basque Country was focused on the creation and development of S&T infrastructure (Aranguren et al., 2012). During these years, greater efforts were concentrated in the creation of Technology Centres (RTOs) in order to foster technological development in firms. This Policy was

supported by the regional Department of Industry and produced an industrial bias in S&T Policy. In the 90's some regional efforts were directed to fill the scientific gap and reduce the industrial bias so Scientific Policy was strengthened but conceived separately from Technology Policy and even managed by a different regional department (the Science and Education Department). But still in these years the system remained biased to industrial and technology needs. In the early 2000's some other infrastructures were promoted by both Industry and Science and Education Departments as an attempt to correct the systemic unbalance between science and technology in the system (Cooperative Research Centres-CICs and Basque Excellence Research Centres-BERCs). Nevertheless, Science Policy still remains a field to reinforce, especially referring to the role of universities.

In summary, in the Basque Innovation System the following main knowledge infrastructures can be identified:

- Technology Centres (RTOs): They are the cornerstone of the Basque Innovation System. They have grouped in recent years into two corporations: Tecnalia and IK4. One of them is a formal merger of previous institutes and the other is an alliance in which the institutes still maintain their previous independence and legal form.
- Universities: In the Basque Country there are three universities: one large and public one, spread in all the regional territory (UPV); and two privates, one linked to a cooperative group and its industry and locally concentrated (University of Mondragon), and other present in two of the three regional provinces and socially and business oriented (University of Deusto).
- Public Institutions and Excellence Centres: In the Basque Country public institutions have had a very limited weight until the last decade in which Basque Excellence Centres have been constituted based on the existing critical mass in the Public University for improving the scientific and research foundations of the innovation system.
- Centres of Competence: In the last decade Cooperative Research Centres were fostered in order to support strategic sectors that either already exist in the region or are sectors or technologies that the government seeks to promote.

In the following tables we summarize the main features of these knowledge infrastructures in the Basque Region, in which we highlight the singularities with respect to the general features described in the previous section.

In Table 5 the main singularities with regards to governance and organizational issues of the knowledge and R&D infrastructures in the Basque Country can be found. Concretely, regarding the legal form we see that RTOs and Cooperative Centres are mainly private (non-profit) and although we find in the region a large public university, the weight of privates ones in the territory is higher than in other countries and regions. It also remarkable that Cooperative Research Centres were conceived as a mix of real and virtual organizations but real have a higher presence than virtual ones.

In terms of organizational autonomy and flexibility there are not many differences with respect to the general features described in the previous section, apart from the singularities in the two corporations of RTOs. In the merged RTO, centres are very centralized in opposition to the alliance of centres. They are all autonomous but dependent on their governance board, in which private and public organizations take part. With regards to universities it is remarkable that the public one is much more regulated than the privates and , as a result, less flexible in certain aspects. Another remarkable aspect is that in public institutions and cooperatives centres the autonomy of the individual researcher varies from one organization to another as it is linked to the organizational and management model.

Funding is an area in which we can find some of the principal singularities within the Basque Case. RTOs funding model is a mix model. It is composed of private and public funding. Private funding mainly comes from commercial contracts with firms while public funding refers to funding that comes from public administrations. This public funding can be core or competitive. Core funding in this case comes mainly for the regional government and it is conditioned to the centres' performance. It is lower than EU average and in addition it has a decreasing trend. Competitive public funding by its part is a must for these organizations to complete their funding model. Universities have a similar mixed model but in the public one the weight of core public funds (not so linked to performance) is much higher than in private ones in which course fees and private funding have a greater impact. Competitive public funding has also a role in this organizational funding model.

Human resources are another aspect in which we can find some singularities in the Basque case. In RTOs people background remains linked to industry, but more in educational terms than in experience. On the contrary, academic background is not as

present as in other European organizations but it is a fact in which we can see an increasing trend. In the other type of organizations, personnel with academic background are the predominant feature, even in cooperative centres, which would have to combine also this with industrial background. Salaries are in general lower than the EU average, although in Basque Excellence Centres (BERCs) can be individually negotiated so we can find differences from one to another researcher. Low mobility of researchers is also a singularity within the Basque Case, especially in RTOs, universities and public institutions excluding BERCs.

Table 5: Governance and organizational issues (including funding) in the Basque Country

	RTO	University	Public Institutions and Excellence Centres	Centres of Competence-CICs
Legal form	Mainly private centres (non-profit) around two big corporations (one has recently become a merger)	One big public university and two private ones with different characteristics. Privates ones have a higher weight comparing to other territories	Mix of public and private centres.	Private and non-profit. Mix of virtual and real centres (predominance of real ones).
Autonomy and flexibility of the organisation	Mainly centralized centres (especially the merger) autonomous and flexible although dependent on the public and private organizations that form part of their governance board. The alliance corporation is a decentralized model of independent institutes.	Bureaucratic and non-very flexible organizations. The public one is much more regulated than the privates ones.	Idem to general features	Idem to general features
Autonomy of the individual researcher	Idem to general features	Idem to general features	In some institutions the individual has his own	In some institutions the individual has his own

			research agenda and in others the model is very centralized	research agenda and in others the model is very centralized
Funding	Mix of public (both core and competitive) and private funding. Core public funding (mainly regional) is conditioned to the organizational performance. Trend of a decreasing public core funding, which is already lower than the EU average.	Mix of funding resources: core public funding, regional public funding linked to their performance (recently established and with a low weight), competitive funding (mainly linked to research), course fees and private funding	Idem to general features	Idem to general features
Human resources	Predominance of people with industrial educational background but not experience. Increasing importance of academic background. Low mobility of people. Salaries lower than in other European countries.	People with academic background. Mainly civil servants and with low mobility. Salaries are lower than the EU average.	People with academic background. Mainly civil servants and with low mobility and highly structured salaries in some Public Labs. On the contrary, in BERCs personnel have high mobility and salaries are individually negotiated.	High weight of people with academic background. Salaries are individually negotiated.

With regards to the activities and functions of these infrastructures in the Basque region and in comparison with the theoretical functions for these organizations we can highlight the following singularities (see Table 6). Concretely, we can highlight that RTOs in the Basque Country are close to the industry and conduct applied research and other activities, as technology transfer ones directed to the regional industry while basic

research is mainly conducted by international projects and core funding. They also include other type of activities directed to assess regional public administration. On the contrary, even though Cooperative Research Centres were supposed to conduct research oriented to industry they are still far for the industrial needs and basically carry out activities linked to basic and scientific research. In addition, university lacks specialization with regards to postgraduate studies, and is increasing the weight of technology transfer activities within its activities in the recent years.

Table 6: Main activities and functions and technology transfer issues

	RTO	University	Public Institutions	Centres of Competence-CICs
Basic research	Activity mainly carried out through international projects and core funding	Main activity funded basically by core (public) and competitive funding	Idem than general features	Main activity but not highly linked to industrial needs.
Applied Research	Idem than general features	Idem than general features	Idem than general features	Idem than general features
Development and engineering	Idem than general features	Idem than general features	Idem than general features	Idem than general features
Education and training	Idem than general features	Inefficiencies in undergraduate (public university). Lack of specialization in postgraduate studies.	Idem than general features	Idem than general features
Technology transfer (patenting, spin offs...)	Important activity especially focused on patenting with industrial partners and spin offs.	Activity in increasing importance in the last years.	Idem than general features	Not very developed and still far from industry
Others: dissemination, consultancy, public policies support, etc.)	Important activity in some centres, mainly linked to regional industry and government.	Idem than general features	Idem than general features	Not very developed and still far from industry

In Table 7 the main features with regard internationalization and markets of Basque knowledge infrastructures are highlighted.

RTO's clients can be basically divided into two: firms and public administration. It is remarkable that in the Basque case the main clients are regional and activities and projects are concentrated in a certain number of clients. Regional firms are also one of the main clients of Basque Universities, especially in the University of Mondragon, which is oriented to the Mondragon cooperatives. In education and training, concretely in undergraduate studies, students are mainly from the region and in postgraduate studies the scope is more international, with a high concentration of students from Latin America in PhD studies.

Universities are not very specialized in scientific or educational domains but a specialization in terms of their mission can be found in the Basque sector. Thus, between the two private ones we can distinguish between a university which is focused on the industry and close to it (University of Mondragon); and another which is more social oriented (University of Deusto). In the RTO's case, they are market driven organizations, that is to say, they are organized and oriented to certain sectors and markets. Nevertheless, they have evolved from a technology push model, as until the beginning of the XXI century they were politechnological centres. This specialization in technologies is the model followed by the Cooperative Research Centres that are not very close to the regional industry and they were created with a strategic mission regarding to the region and the firms located in it.

Finally, we can point out that RTO's in the Basque Country are highly internacionalised in terms of projects funded by competitive funding (i.e. Seventh Framework Programme of the European Commission) but not in terms of projects with private firms in other countries.

Table 7: Internationalizations and markets

	RTOs	University	Public Institutions	Centres of Competences-CICs
Type of client	Mix of firms (mainly regional firms-SMEs) and public administrations. Concentrated in a certain number of clients	Society in general (in education and training activities). In undergraduate studies the students are mainly from	Idem than general features	Not very closed to industry in some cases.

		the region and in postgraduate the scope is more international. Regional industries (especially in the case of the private university oriented to industry)		
Specialization	Mainly multisectoral (market driven). They have evolved from politechnological centres.	Not very specialized in scientific or educational domains but in terms of mission as they fulfill different goals (links to industry, business oriented, social oriented...)	Very scientific oriented	Specialized in scientific fields.
Regional vs. National market	Mainly based on regional clients but depending on the specific markets/ sector.	Main focus on regional market in undergraduate studies and international in postgraduate (Mainly, Latin-American students)	Main focus on regional market	Main focus on regional market
Internationalisation	High internationalized in competitive projects and low in industrial projects.	Specially in postgraduate studies	Idem than general features	Idem than general features

Lack or inefficient interactions between the different knowledge infrastructures in the Basque Innovation System is one of the system's unresolved matters. R&D and knowledge infrastructures have an interacting role with industry, especially RTOs and CICs. In this last case, in the Basque organizations industrial representatives are in the

government board but still lack of a systematic interaction with industry in the day-by-day activities. This interaction it is also an emerging feature in public institutions and in the Basque region.

Interactions among different types of agents also present some weaknesses. RTOs have little interaction with universities as they still remain not very proactive in establishing those links with other agents. In addition, public institutions and BERCs do not normally interact with RTOs but some of them have strong linkages with university and university groups as part of their personnel academic background comes from those groups. Nevertheless, it depends on the person who is managing the institution more than a general feature. The same situation can be observed in the CICs in which interaction with RTOs and university varies from one centre to another. However, in this case this could be considered as a very important weakness as they are centres precisely conceived to facilitate this interaction.

Table 8: Interactions between organizations in a Regional Innovation System

	RTOs	University	Public Institutions and BERCs	Centres of Competences-CICs
Industry	Idem than general features	Idem than general features	Increasing importance but still low orientation and interaction with industry	Industrial representatives are in the government board but still low orientation and interaction with industry
Other agents in the system: university, RTOs...	Low interaction with universities (mainly by competitive project partnerships) and increasing interactions with competence centres and others.	Idem than general features	Little interactions with RTOs. Connected to universities (some are universities institutes), although depending on each institute Manager.	Conceived as an interacting agent with RTOs and universities and this interaction depends of each institute Manager.

3.1. Challenges for optimizing the role of the different knowledge infrastructures in the region

From the main features analysed in this section and comparing them to the general situation described in section 2 we can extract some challenges that the Basque Country is currently facing in relation to its knowledge and R&D infrastructures.

First of all, the diversity and number of knowledge infrastructures requires a successful coordination and a systemic view of the roles and functions they are effectively carrying out. For that reason, it is important to move forward from the policy dichotomy of technology from one side, managed by the Industry Department and science from the other side, managed by the Science and Education Department.

Science and Technology Policy in the Basque Country had different stages and the focus on technology or science has always been conditioned to the gaps the system was showing in every moment. Nevertheless, there still remains a scientific gap in the system that has to be solved through the support of the organizations oriented to science (universities, BERCs and CICs) but also through the promotion of better interactions between them and the technology oriented infrastructures (RTOs). In addition, interactions between all the infrastructures and industry should be promoted and improved.

Another challenge these organizations are facing is the one related to funding. Core funding is following a decreasing path, not only because of the crisis effect in governmental budget restrictions but also because some of the organizations were highly funded in early stages of their life-cycle and they have to move towards a mixed funding model. In addition, competitive funding is everyday more competitive, both at regional/national and European level, so organizations face an important challenge of establishing partnerships at different levels based on excellence to reach that funding. Moreover, internationalisation of their activities is another challenge we can point out, not only with regards to competitive funding, but also in relation to private funding. The internationalisation gap is also visible in the human resources field, not only that talent attraction and retention should be improved but also personnel in these centres should have a higher international mobility. In addition, mobility towards and from industry is another gap that should be filled within the Basque system. That would reinforce the industrial orientation of some centres as RTOs and CICs.

Finally, it is remarkable that all the knowledge and R&D functions are covered within the system although technology transfer and dissemination activities towards industry is an important challenge that some of the infrastructures are facing as it has been a forgotten aspect for them in the last years (for example, university's focus has relied

more on education than on research and technology transfer issues, CICs are still far from industry...).

However, in overall terms, the Basque infrastructures system presents a very rich and complete system in terms of technology and scientific orientation and potentialities should be reinforced through an integrated and holistic coordination in order to not generate overlaps among infrastructures that might be affecting and generating inefficiencies in the system.

4. Conclusions and Policy Recommendations

Knowledge infrastructures play an important role in Regional Innovation Systems (RIS) as they form part of the knowledge generation subsystem and therefore constitute a key element for innovation. Innovation is nowadays conceived as a social process and in consequence an interactive process in which industry and other actors among which we can highlight knowledge infrastructures establish links and relationships. The nature of the R&D infrastructures may vary from one to another although in most of RIS we can distinguish between the following categories: university, public institutions, research and technology organizations (RTOs) and centres of competence. Each one has different characteristics and features as they are oriented to fulfil different roles within a system. Thus there are infrastructures more scientific oriented and other more industry oriented. In this paper we have analysed in detail the different features and roles of each type of infrastructure according to the literature and have compared them with an empirical case. From that comparison we can extract some relevant conclusions.

First of all, individual infrastructures might be failing in their role or function within a system, due to several reasons. They might be failing because of some organizational features are not well shaped (for example cooperative research centres low industry oriented, as they personal and management have a high academic background and they do not interact with industry) or because policy is not reinforcing some important aspects (for example high core regional funding for basic research might be diminishing the need to retort to European R&D programmes in Cooperative Centres). It is therefore fundamental to assess and evaluate the role of every individual infrastructure with respect to the goal and the mission they were created for, in order to correct any deviations from that mission.

Secondly, it is important to understand whether individual infrastructures are failing but the whole knowledge system is well performing. That is to say that even though some individual infrastructures might be not fulfilling their individual role some others are

doing it so the system is being efficient. For example, centres of competence have been fulfilling the role of basic research in the Basque Case even though that was the theoretical role of universities and public institutions as they were not complying with it. That situation has provoked two direct consequences. First of all it has highlighted the need of reinforcing the individual and failing infrastructures and a part of regional policy that has maybe stayed behind (Science Policy) and in addition has shown the need of coordinate knowledge infrastructures following a systemic and integrated view. That means, not only evaluating the individual infrastructures performance according to individual roles but also evaluation the knowledge subsystem performance, taking in account the overall functions they should be accomplishing.

Thirdly, knowledge infrastructures have to be adapted to the regional context and situation. In the case we see that the predominance of infrastructures that conduct applied research oriented to industry due to the industrial specialisation of the region.

Finally, it is also remarkable the role of public policies shaping the knowledge infrastructures subsystem as they direct from one to another direction depending on both the regional context and strategic decisions (for example, the decision of promoting the technological system instead of the science one). In addition, the path dependency character of public policies (Mytelka and Smith, 2002; Flanagan et al., 2011) makes that current decisions are affected from previous ones so current S&T policies will be affected by decisions taken in the past with respect to knowledge infrastructures too.

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