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Scientific output and transfer in nanosciences: a comparative analysis of the Basque Country, Finland and Sweden

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Abstract

Scientific progress is one of the pillars of competitive knowledge for countries and regions in today's globalized economy. The research in nanoscience and nanotechnology constitutes one of the most dynamic areas and a source of scientific progress and innovation. This study examines the relationship between scientific output in nanoscience and the required transfer of technology in the search for new applications. Three geographic areas are compared due to their similarities in regional size, economic terms and the strength of their respective innovation systems: the Basque Country (Spain), Uusimaa (Finland) and Sydsverige (Sweden).

The paper identifyies the relevant research groups in each geographical area and analyses their organizational routines. Quantitative as well as qualitative methods are used to interpret the information collected. A survey among representative members of key organizations in the three locations was conducted together with in-depth interviews with each group's leaders. The results obtained using the same procedure for each region are compared and conclusions are drawn which show that the makeup and institutionalisation of research groups greatly influence output and its transfer, in order to promote economic development based on innovation.

Keywords: nanoscience, scientific output, knowledge transfer, research group, innovation system.

1.-Introduction

In a rapidly changing globalized social and economic context, scientific progress is key to competitiveness and a major driver of technological change. Big organizational structures have become key players in this environment as providers of technology and scientific knowledge (Helfat, 1997; Okubo and Sjöberg, 2000; Borg, 2001; Beneito, 2003; Caloghirou et al., 2004). Scientific excellence is still a major driver for innovation, particularly in high technology fields (Carlsson, 2010). However, scientific output does not only lead to innovation or growth per se. Knowledge transfer activities are also required in order to disseminate (scientific) knowledge and make it applicable (Shane, 2002). In addition, the exploitation of scientific knowledge is also dependent on the knowledge bases of firms, their absorptive capacity and the innovation routines implemented in them. Depending on these factors, knowledge transfer may or not take place in a more or less fluid manner.

In this paper we will focus on nanoscience, as it is one of the most sensitive fields to knowledge transfer from scientific exploration to its further exploitation in business environments (Nikulainen and Palmberg, 2009). Scientific output in nanoscience catches the attention of both firms and policy-makers in charge of Science and Technology (S&T) policies. What makes nanotechnologies distinctive is the scale on which they operate and the physical properties metals adopt at this scale. Increasingly, new applications are being marketed in sectors such as clothing, automobiles, electronics, chemicals or medicine (Etxebarria et al., 2013). Due to the fast pace of the research currently being undertaken in this field (Etxebarria et al. 2102), it is expected that new radical innovations may be under development at present times.

The relationship between scientific output and knowledge transfer is a complex phenomenon that is necessary to analyse in detail due to the particularities of the disciplines from whom the transfer is to be made. From our point of view, the relationship between scientific output and knowledge transfer cannot be regarded as being homogeneous or used as a blueprint among scientific fields. For example, Wigren-Kristoferson et al. (2011) study the diffusion of academic knowledge in order to reach commercialization in several strong academic environments (e.g. medicine, physics, chemistry, social science, natural science, humanities and engineering).

However, the particularities of each of these fields are not addressed. It seems quite logical to wonder to what extent all the disciplines covered by their analysis are really comparable. In order to shed more light on the barriers and difficulties for knowledge transfer in high tech environments, we will focus on nanoscience as one of the scientific fields that more attention has brought and more expectations has created in the last decades as a discipline that may provide answers to some of the current gran challenges (e.g. energy, health, security, mobility).

In globally competitive environments firms face strong incentives to increase their scientific knowledge levels. In order to gain competitiveness they may opt for the internal generation of R&D, the external acquisition or the establishment of joint cooperation agreements with third parties (Cassiman and Veugelers, 2006). In this context, the organizational and strategic characteristics of the supply of scientific knowledge can have a strong influence on the effectiveness of the knowledge transfer and the difficulties or barriers found in it.

This study aims to contribute to a better understanding of the relationship between scientific output and knowledge transfer in nanoscience. In it we will focus on the research groups from big organizational structures located in three geographic areas, Uusimaa (Helsinki region in Finland), the Basque Country (Spain) and Sydsverige (southern region in Sweden). The reason for us to focus on these regions is due to their similar structural characteristics in terms of Science and Technology (S&T) policies, the existence of a comprehensive network of research capabilities, investment levels in R&D, industrial structure, international orientation of the economy, and income levels above the EU average among others. Quantitative and qualitative methods are used to interpret the information collected in the three locations. The results obtained using the same procedure for each region are compared and conclusions are drawn which show that the makeup and institutionalization of research groups greatly influence scientific output and its transfer.

The paper is distributed as follows. Section 2 describes the theoretical framework and the research questions addressed. In Section 3 the data gathering process and the methodology followed is declared. Following, the analysis of the data and the main results achieved are revealed. Finally the article closes by stating the main conclusions that can be derived from it in as well as by providing some policy recommendations for policy-makers involved in the articulation of S&T policies.

2.- Conceptual framework: knowledge transfer and scientific production

The term knowledge transfer refers to the knowledge exchange flows between the producers of scientific knowledge (e.g. universities, research organizations) and those in charge of exploiting it (i.e. firms in a broad sense). However, the exchange of knowledge is much more complex than a simple and unidirectional transfer between two organizations. In this sense, some scholars argue that it would be more appropriate to refer to the exchange of scientific and technical knowledge (Meyer-Krahmer and Schmoch, 1998; Bozeman, 2000).

The role played by academic environments in general and research groups in particular has evolved toward the provision of competences and skills related to research and scientific production (Etzkowitz, 1998). In this sense, scientific production is understood as the output of the research process in terms of journal publications, patents and spin-off companies.

The literature on university-industry cooperation reveals the complexity involved in these relations, as they are to be framed in the evolution of the economic and social system in which they are embedded.[1] University-industry relations are determined by institutions that regulate them, (policy) instruments for their promotion and rationales that justify and motivate them. In this paper we will analyse these relations from the perspective of an innovation system. According to the innovation systems literature, university-industry relations constitute a complex, dynamic and social phenomenon whose intensification is not only produced due to the new configuration of the relationship between science and innovation, but also to the evolution of the university and the surrounding socioeconomic environment. As a result, university-industry relations are subject to different interpretations depending on their origin, i.e. the academic community vs the exploitation subsystem and society in general.

As a matter of fact, these relations are approached from angles such as the agents involved in them (Etzkowitz and Leydesdorff, 2000), the instruments and mechanisms

[1] With the term "university-industry relations" we include all possible types of interactions between academia (i.e. universities, research organizations, other research environments, etc.) and the private sector, mainly represented by firms.

in place for their support and advancement (Bozeman, 2000; Siegel et al., 2003), the object involved in the transfer (Lee, 1996), or according to their influence on the quality of science and their consequences in economic terms (Callon, 1994; Cohen et al., 2002; Nelson, 2004). As a summary of the previous perspectives it can be concluded that: (i) the academic system in general and the universities in particular are providers of knowledge and technology; (ii) science becomes a major driver of technological change; (iii) there is a loss of control on academic research and risk of de-capitalizing universities (Blumenthal et al., 1996); (iv) conflicts between the interests of researchers and firms´ exist as to confidentiality agreements (Feller, 1997; Feller et al., 2002).

The paradigm of commercialization of scientific outputs is often understood as an unidirectional knowledge transfer, i.e. from academia (e.g. universities and research organizations) to private firms (Baba et al., 2009). This archetype might be found in industries such as biotechnology or pharmaceutical, which are among the few cases in which the advances of university labs have been absorbed and exploited by the private sector (Cohen et al., 2002). In contrast, in cases such as advanced materials private firms need to be aware of the needs of the users in order to develop their R&D projects (Maine and Garnsey, 2006). As long as cooperation between universities and industries in industries like advanced materials is bilateral, it becomes essential to promote an adequate coupling between scientific knowledge and the demands of users (Baba et al., 2009).

One of the reasons for the differences observed in the innovation patterns across industries is provided by the knowledge bases in which these are based. The classification of knowledge bases – analytic, synthetic and simbolic, by Asheim and Coenen (2005) becomes particularly useful not only in order to address the differences between innovation patterns in firms, but also to better comprehend the dynamics of the innovation systems in which these take place. In this sense, regional innovation systems (Cooke et al., 1997) evidence the effectiveness of hybrid structures that combine two or more types of rationality such as the production of science and rationality of the market.

From the point of view of public intervention, knowledge transfer and scientific production need necessarily be related through science policy, as the latter cannot be defined in a global and competitive socioeconomic context, without taking into consideration the influence of the exploration subsystem on innovation.[2] The relationship between (academic) scientific production and the private sector is thus sensitive to the model and instruments used by science policy, meaning this model results from the required negotiation among relevant stakeholders in the administration – university - business triangle (Etzkowitz, 1998).[3]

2.1.- Knowledge transfer and scientific production in nanoscience

The business world is also changing and in high-tech sectors firms adjust to the need to interact directly with scientific knowledge providers. This mutual dependence entails the increasing emergence of (academic) spin-offs.

In recent years we have witnessed the development of a scientific area that is opening the door to a new technological paradigm, and which is already introducing substantial changes in the productive sector of most economies: nanoscience. Most of the research in this field is being conducted at universities and public research centres. One of the factors that has most influenced the high scientific relevance of this scientific domain is the amount of public funds put into financing research projects (Shapira and Wang, 2009), with the expectation that these investments will turn into future commercial applications (Etxebarria et al., 2013).

Meyer (2001, 2006) has studied the role of the "inventors-authors" who publish and patent in this area. Besides the increasingly high number of scientific publications (and their citation scores), his results indicate that there is no evidence of a negative effect of technological development activities (i.e. patenting) on scientific production. What is more, high patenting activity tends to be tied to research groups and university labs of recognized prestige. Undoubtedly, these inventors-authors make an invaluable contribution to the development of nanoscience, despite they represent a minority among the researchers dedicated to this field of science.

These conclusions are also supported by Jiménez Sáez et al. (2011) and Wigren-Kristoferson et al. (2011). These scholars found that knowledge transfer is often regarded as an activity that promotes and deploys academic know-how to specific users

[2] These features are derived from the concept of articulation introduced by Rip and Nederhof (1986), which is used to assess the ability of an innovation system to establish a network of fluent and continuous knowledge flows among public research organizations and private companies (Jiménez-Sáez et al., 2011).
[3] To further explore the behavior of stakeholders, see Daake and William (2000), Mitchell et al. (1997), Mitchell and Agle (1997), or Clemens and Gallagher (2003).

or industry sectors. The literature suggests that the reasons why university researchers engage with industry are quite often related to strengthen their research rather than to exploit their knowledge. In this sense, the results suggest that the pure action (i.e. publishing) and academic dissemination of that scientific knowledge are complementary and self-reinforcing activities.

It can be concluded from here that scientific production in nanoscience and nanotechnology has certain relevant particularities (Shapira and Youtie, 2008; Munari and Toschi, 2011): (i) it catches the attention of research groups, firms and policy makers in charge of S&T policies; (ii) it can foster the prestige of the organization involved in that production, which can aid the acquisition of external funds; (iii) the internal and external organization of scientific production are of relevance for its further development and exploitation; (iv) a great deal of uncertainty exists due to the lack of knowledge as to the security in its exploitation, which makes practical results be expected in the very long run.

In this paper we will analyse the barriers (public) research organizations face when transferring the knowledge embedded in their scientific contributions to the industrial sector. In it we will focus on the organizational routines implemented in these organizations as this will allow us to observe the internal motivations (or lack of them) to engage in knowledge transfer as well as to conclude which are the main barriers for this purpose. Other rationales for this approach also include the fact that by getting in-depth knowledge of the (internal) organizational behavior of the units under analysis, we are able to characterize the orientation being given to the research conducted in them (i.e. basic, applied). In addition, we can also assess the orientation of the research groups towards the environment and the value they put into transfering knowledge to it. Finally, the analysis of the internal dynamics observed in the research groups in terms of structure, hierarchy, leadership, recruitment, etc. also offers us the possibility to better understand the philosophy being their scientific production and knowledge transfer activities.

Many national and regional governments have increasingly been investing in creating and forming nanotechnology clusters in their territories, not only to develop a comprehensive R&D-based exploration subsystem but also seeking for an effective access to the breakthroughs and application that may derive from this research base.

Accordingly, nanoscience is part of wider innovation system in which two main components play a crucial role, research groups (exploration) and firms (exploitation subsystem). However, as the literature shows, the transfer from research environments to the development of new applications is not that straightforward, and in many cases, not taking place. In this paper we will focus on the difficulties from the research side in order to reach these potential applications.

The research questions we will particularly address are the following:

- Does the context (i.e. innovation system) play a role on the effectiveness of knowledge transfer processes? In which direction?
- Does the transfer of scientific output in nanoscience depend on the type of organization the research group belongs to, so the groups located at universities face more difficulties to knowledge transfer than specialized S&T centres?

Accordingly, by focusing on the research groups placed in the big organizational structures, we aim at contributing to the study of the barriers research groups face in their knowledge transfer activitiees.

3.- Methodology and data

Three are the geographic areas covered in this paper: Uusimaa (Finland), the Basque Country (Spain) and Sydsverige (Sweden). The rationale for us to focus on these three regions lays in their similar structural characteristics. The three territories count with economies focused on the international scene, register income levels above the EU average and show intense collective organisation concerning social cohesion. As to their research orientation, the three regions show a similar pattern in the diversity of research areas covered. In a nutshell, it can be said that the three regions count with strong and comprehensive innovation systems (Asheim and Coenen, 2005; Cooke, 2005, 2011; Ache, 2011).

Table 1.- Main structural characteristics

	Uusimaa (Finland)	Basque Country (Spain)	Sydsverige (Sweden)
Population (2012)	1,549,058	2,128,397	1,405,912
GDP per capita (EU27=100) (2009)	189.79%	126.38%	114.045%

% population aged 25-64 with tertiary education (2012)	48.9%	46.2%	36.7%
Gross R&D investments (% of GDP) (2009)	3.83%	2.12%	4.73%
Business R&D investments (% of GDP) (2009)	2.64%	1.63%	3.51%
# Patent applications to the EPO per million population (2009)	308,156	51,576	263,354
People at risk of poverty or social exclusion (% population) (2011)	13.8%	16%	17.3%

Source: Eurostat (2013)

Our analysis is conducted at the micro-level. Our unit of analysis is the research group, not the whole organization it belongs to or the innovation system they are embedded in (Jiménez-Sáez et al., 2011), so more than one research group from the same research organizations are considered. Following Etxeberria et al. (2012), our first criteria for the selection of the population is that world-class research in nanoscience needs to be carried out. The three regions under study showed a comprehensive behavior as to advances in the nanoscience field. Then second, we focus on the performance of the most representative public research groups in the three territories, which are normally embedded in research and technology institutes and universities.[4]

In the Basque Country, the regional government created the Nanogune Cooperative Research Center (CIC-Nanogune), which aims at creating an effective framework of collaboration that strengthens interdisciplinary basic and applied world-class research in order to provide technology transfer and promote competitiveness of the Basque Industry in strategic areas.[5] Thus, it can be said that the CIC-Nanogune is binded both to scientific research and to the business environment. Besides this center, other research

[4] The reader may wonder why we only adopt a research perspective in order to study the relationship between the production of scientific output and the knowledge transfer between public research centres and firms. The reason is that the identification of the centres and the research groups within those centres was much more straightforward that the identification of nano firms due to the heterogeneity involved in this field (Porter and Youtie, 2009). It is also necessary to mention that if the large MNCs are excluded (Etxebarria et al., 2013) the amount of nano firms and spin-offs is still rather limited. In addition they are scattered all around the world, being many of them located far away from the regional contexts under study (Gomez-Uranga et al. 2011).

[5] http://www.nanogune.eu/en/about/description/ (last access March 2013).

groups in nanoscience are also located at the University of the Basque Country (UPV-EHU) and the network of technology centers that characterized the technologies policies of the Basque government in the previous decades.

Concerning the Nordic counterparts, both Uussimaa and Sydsverige embrace comprehensive research groups working on nanoscience. For example, Technical Research Centre of Finland’s (VTT) Micronova unit is located in Espoo, in the surroundings of Helsinki, which focuses on micro and nanoelectronics, photonics and nanofabrication among others.[6] Aalto University´s nanoscience research groups are also located close to the VTT premises. At Aalto, three main departments working on nanoscience can be identified: (i) the department of micro and nanoscience, which conducts research on microfabrication, electron physics, electronic circuit, or optoelectronics[7]; (ii) the low temperature lab, which is focused on nanophysics[8]; and (iii) the department of applied physics, which is dedicated to nanomagnetism and spintronics, nanomaterials and computational nanoscience.[9] In turn, Lund University (Sweden) hosts since about twenty years one of the most comprehensive research environments in nanoscience. Due to the multidisciplinary character of Lund University, the Nanometer Structure Consortium benefits from the combination of scientific competence in areas covering physics, electronics, materials science and life sciences on the nanoscale. As it is the case with Micronova at VTT, the Nanometer Structure Consortium also counts with a nanofabrication facility used by scientists and students as well as by R&D personnel from high-tech companies.[10]

The first step to the gathering of data was conducted through a survey to the nano research groups working in the three geographical areas (n= 54). 29 of these groups belong to the Basque Country while, 25 are located in the Nordic area. In the case of the Basque nano research groups, the respondents approach the total existing population, while in the Nordic case they embody a highly representative sample, incorporating the most representative nanoscience groups in the two regions (VTT and Aaalto in Uusimaa and the Lund Nanometer Consortium in Sydsverige).

[6] http://www.micronova.fi/research/ (last access March 2013).
[7] http://nano.aalto.fi/en/research/groups/ (last access March 2013).
[8] http://ltl.tkk.fi/wiki/LT (last access March 2013).
[9] http://physics.aalto.fi/groups/ (last access March 2013).
[10] http://www.nano.lth.se/ (last access March 2013).

The questionnaire was circulated by e-mail to the identified researchers in the three regions between 2010 and 2012. The questionnaire targeted those questions that could help us in the identification of the obstacles and barriers that researchers face when transferring their knowledge to the business sector. In addition, it also helped us to detect those cases in which the transfer of scientific knowledge was not among the goals of the research group.[11]

The questionnaire includes a set of questions and an extensive annex which provides the different possible dedications to nano research (see Appendix). 24 questions are included in the survey, which is divided into three chapters. The first chapter allows us to typify the researcher in this broad and interdisciplinary area. The second chapter deals with the degree of applicability of the conducted research and the degree to which the researcher is aware of its potential applicability. Lastly, the third section focuses on the barriers to knowledge transfer, which could be produced as a result of the orientation of the research group (questions 1 to 11), arising from the internal organization of the group and the institution it belongs to (questions 12-16) or due to the innovation system in which the group is embedded (questions 17-20). All these questions follow a response scheme based on a 1 to 5 Likert scale.

Accordingly, the share of research that is oriented towards potential applications, the type of organization (university department or specialized S&T centre), and the innovation system (i.e. the context) are taken as the main contextual variables that will be used to explain our main research goal, the way the knowledge transfer takes place and to what extent R&D groups in the nanoscience search for applicability of their own (basic) research results (see section 4.2).

In a second stage we proceeded to interview the principal investigators of the surveyed groups. This stage envisaged other type of structural characteristics of the research units such as their size, internal organizational procedures, structure and leadership, researcher recruitment, training and promotion or the degree of external relationships. Thus, the quantitative analysis is supplemented by qualitative interviews with leading scientists in these strong research environments. The dialogues consisted of a wider set of semi-structured interviews with the leading researchers of the previous research groups (n=21), 10 in the Basque Country and 11 in the Nordic regions. These lead

[11] The questionnaire was piloted at several research centers in the Basque country during 2010.

researchers are not only internationally recognized senior academics, but also act as main facilitators of the nanotechnology sector. The interviewees always received the standardized interview questions in advance. Despite this standardized protocol, interviews were open-ended. The interviews took place between January and May 2012. Each interview took on average about 90mins, and the agreement to consider the interviews anonymised was given to all scientists. The interviews were all transcribed based on the gathered information.

4.- Results

This section provides the main results of the statistical analysis of the data gathered through the survey to nanoscience research groups. This includes a descriptive analysis of the sampled population (section 4.1) and an ANOVA in order to identify the key determinants and obstacles to knowledge transfer (section 4.2), and a summary of the main conclusions obtained through the qualitative interviews (section 4.3).

4.1.- Descriptive analysis

The descriptive analysis is a result of analysing the questions included in chapters 1 and 2 in the survey (Appendix). These questions aim to identify whether the character of the research conducted at the research groups is oriented towards its (potential) applicability or if in contrast, research is of a fundamental character (see question 4).

54 responses were obtained through the survey. 53% proceed from research groups located in the Basque Country (n=29), 26.1% from Uusimaa (n=15) and 18% from Sydsverige (n=10). The university department level seems to be the main institutional character of these groups (76%), as compared to 24% of specialized S&T centers.

Table 2.- Share of the research with potential application

	n	%
0-20%	7	12.96
20-40%	12	22.22
40-60%	14	25.93
60-80%	12	22.22
80-100%	6	11.11

100%	3	5.55
Total	54	100,0

As regards the share of research that might have potential application, 61% of respondents indicated that this share is lower than 60%. However, it is noteworthy stating that only four researchers out of the total sample admitted they were not aware of the potential applications that could be derived from their own research. When the researchers were asked to indicate which could be the reasons for the fundamental or applied orientation of their work though, we only got a response rate of 44%.[12] The main reason these respondents put forward for explaining this unbalance is to be found in the research strategy adopted by the research group, rather than in the lack of applicable results of the conducted research. This reflects which the philosophy behind the targeted research groups is and how the nature of nano research may be primarily theoretical.

4.2.- Determinants of knowledge transfer

In this section we aim to analyse which are the main factors explaining the orientation towards knowledge transfer in the targeted population. In order to present the results achieved in this sense, Analysis of variance (ANOVA) is conducted in order to assess the relevance of the following determinants on knowledge transfer: (i) Geographic area: Basque or Nordic (Uusimaa and Sydsverige); (ii) University department or specialized S&T centre.[13] The following sections will respectively touch on each of these topics.[14]

4.2.1.- The relevance of the geographical location

Finally, this last ANOVA aims to investigate our third research question, which was related to the influence or role that the context (i.e. the innovation system) may play on the effectiveness of knowledge transfer processes.

[12] Etxebarria et al. (2013) point out that nano research is currently being driven to a high extent by the search of applications. From our point of view it is very significant that only 44% of the sample population does not provide an answer for the potential explanations of this lack of orientation towards the development of potential applications.

[13] The distinction between these two organizational settings intends to dichotomize the association to a classic and conventional organization (i.e. universities) from a more independent type of organization with more strategic capacity.

[14] We have not found any evidence indicating that the original strategic positioning of the research group (measured as a share of research with potential application) has any influence on their knowledge transfer activities.

Our results (see Table 5) indicate that the most significant difficulties related to knowledge transfer are those associated with: the protection of property rights, particularly regarding patents (Diff_IPR, p = .001), the lack of a critical mass of researchers working on nanotechnology (Lack_critic_res_mass, p= .001), lack of interest by governments about the potential economic benefits of nanoscience (Diff_lack_interest_gov, p = .000), a general lack of interest on research (Diff_lack_interest_res, p = .000), lack of firms related to the production of nanotechnologies in the closest environment (Diff_lack_firms, p = .000) and lack of users/customers of nanotechnologies in the closest environment (Diff_lack_users, p = .000).

The other significant factors that help explain these barriers to knowledge transfer to the regional innovation system are related to the orientation of the research group towards basic research (Basic_research, p = .042), difficulties derived from the lack of experience in the management and exploitation of research results (Diff_lack_tech_manag_reso, p = .050), the contradicting incentives offered to the research exploration subsystem (Diff_incent, p = .023) and the relatively weak position of universities as compared to other agents in the innovation system (Diff_univ, p = .035).

Table 5.- Geographical and institutional factors as barriers to knowledge transfer

Dependent variable: Geo

		Sum of squares	df	Mean square	F	p.
Basic_research**	Between groups Within groups TOTAL	4.833 58.000 62.833	1 52 53	4.833 1.115	4.333	**.042**
Diff_ident_app	Between groups Within groups TOTAL	1.946 59.388 61.333	1 52 53	1.946 1.142	1.704	0.198
Diff_lack_mang	Between groups Within groups TOTAL	1.533 85.448 86.981	1 52 53	1.533 1.643	.933	.339
Req_tech_not_avail	Between groups Within groups TOTAL	2.119 61.881 64.000	1 52 53	2.119 1.190	1.780	.188
Diff_IPR***	Between groups Within groups TOTAL	13.162 62.759 76.370	1 52 53	13.612 1.207	11.278	**.001**
Diff_cont_entrepr	Between groups Within groups TOTAL	4.484 77.608 82.093	1 52 53	4.484 1.492	3.005	.089
Firms_no_interest	Between groups Within groups TOTAL	2.884 86.450 89.333	1 52 53	2.884 1.662	1.735	.194
Diff_exploit_res	Between groups Within groups	.515 59.633	1 52	.515 1.147	.449	.506

	TOTAL	60.148	53			
Diff_int_exploit_res	Between groups Within groups TOTAL	.425 74.408 74.833	1 52 53	.425 1.431	.297	.588
Lack_critic_res_mass* **	Between groups Within groups TOTAL	15.500 59.926 75.426	1 52 53	15.500 1.152	13.450	**.001**
Diff_lack_tech_manag_reso*	Between groups Within groups TOTAL	3.727 48.199 51.926	1 52 53	3.727 .927	4.021	**.050**
Diff_lack_compt_KT	Between groups Within groups TOTAL	1.328 86.006 87.333	1 52 53	1.328 1.654	.803	.374
Diff_lack_interest_app	Between groups Within groups TOTAL	2.471 53.622 56.093	1 52 53	2.471 1.031	2.396	.128
Diff_incent*	Between groups Within groups TOTAL	7.783 73.550 81.333	1 52 53	7.783 1.414	5.503	**.023**
Diff_univ*	Between groups Within groups TOTAL	6.233 69.470 75.704	1 52 53	6.233 1.336	4.666	**.035**
Diff_lack_interest_gov* **	Between groups Within groups TOTAL	20.506 70.753 91.259	1 52 53	20.506 1.361	15.071	**.000**
Diff_lack_interest_res* **	Between groups Within groups TOTAL	20.920 67.172 88.093	1 52 53	20.920 1.292	16.195	**.000**
Diff_lack_firms* **	Between groups Within groups TOTAL	23.786 75.862 99.648	1 52 53	23.786 1.459	16.304	**.000**
Diff_lack_users* **	Between groups Within groups TOTAL	23.737 71.967 95.704	1 52 53	23.737 1.384	17.151	**.000**

a Computed using alpha = .05
b R square = .842 (Adjusted R square = .067)
c The variable “diff_acc_pub” has been removed from the analysis due to homoscedasticity in the Levene’s test.
*Correlation is significant at the 0.05 level; **correlation is significant at the 0.01; ***correlation is significant at the 0.001.

As it can be observed, these difficulties are not only related to the innovation system, but also to internal organizational aspects due to the institutional forms the research groups are embedded in. It is noteworthy indicating that the above determinants of the difficulties associated to knowledge transfer have a major impact on the research groups located in the Basque Country as compared to their Nordic counterparts. Accordingly, it can be concluded that organizational/institutional factors as well as those associated to the regional innovation system stimulate knowledge transfer to a higher extent in the Nordic area than in the Basque Country. Summing up, it can be concluded that the geographical location can be regarded as a significant determinant for knowledge transfer in nanoscience.

4.2.2.- The relevance of the type of organization

In this case, we conduct the same ANOVA in order to analyse our second research question, which wondered whether the transfer of knowledge was dependent on the type of organization the research group belongs to, so the groups located at universities face more difficulties to knowledge transfer than specialized S&T centres.

In this sense, our results indicate that there are indeed no significant differences between research groups located at universities and those located at specialized S&T centres. The only relevant factors explaining the difficulties to knowledge transfer would be the excessive orientation towards basic research (Basic_research, p = .010) and the lack of a clear interest in finding commercial applications to research results in these organizatios (either universities or specialized S&T centres) (Diff_lack_interest_app, p = .016).

In both cases, the research groups located at university departments seem to have more difficulties that those at specialized S&T centres, but as we have seen these differences are not particularly significant.

Table 4.- Type of organization as a barrier to knowledge transfer

Dependent variable: Org

		Sum of squares	df	Mean square	F	p.
Basic_research**	Between groups Within groups TOTAL	7.513 55.321 62.833	1 52 53	7.513 1.064	7.062	**.010**
Diff_ident_app	Between groups Within groups TOTAL	.005 61.328 61.333	1 52 53	.005 1.179	.004	.948
Diff_lack_mang	Between groups Within groups TOTAL	.509 86.473 86.981	1 52 53	.509 1.663	.306	.583
Req_tech_not_avail	Between groups Within groups TOTAL	.011 63.989 64.000	1 52 53	.011 1.231	.009	.924
Diff_IPR	Between groups Within groups TOTAL	.569 75.801 76.370	1 52 53	.569 1.458	.391	.535
Diff_acc_pub	Between groups Within groups TOTAL	1.101 45.936 47.037	1 52 53	1.101 .883	1.246	.269
Diff_cont_entrepr	Between groups Within groups TOTAL	1.376 80.717 82.093	1 52 53	1.376 1.552	.886	.351
Firms_no_interest	Between groups Within groups TOTAL	.245 89.088 89.333	1 52 53	.245 1.713	.143	.707
Diff_exploit_res	Between groups Within groups TOTAL	.017 60.131 60.148	1 52 53	.017 1.156	.015	.904
Diff_int_exploit_res	Between groups Within groups	.053 74.780	1 52	.053 1.438	.037	.849

	TOTAL	74.833	53			
Lack_critic_res_mass	Between groups Within groups TOTAL	4.991 70.435 75.426	1 52 53	4.991 1.355	3.684	.060
Diff_lack_tech_manag_reso	Between groups Within groups TOTAL	.027 51.899 51.926	1 52 53	.027 .998	.027	.869
Diff_lack_compt_KT	Between groups Within groups TOTAL	.662 86.672 87.333	1 52 53	.662 1.667	.397	.531
Diff_lack_interest_app*	Between groups Within groups TOTAL	5.984 50.109 56.093	1 52 53	5.984 .964	6.210	**.016**
Diff_incent	Between groups Within groups TOTAL	.020 81.313 81.333	1 52 53	.020 1.564	.013	.910
Diff_univ	Between groups Within groups TOTAL	.420 75.283 75.704	1 52 53	.420 1.448	.290	.592
Diff_lack_interest_gov	Between groups Within groups TOTAL	.468 90.792 91.259	1 52 53	.468 1.746	.268	.607
Diff_lack_interest_res	Between groups Within groups TOTAL	.288 87.805 88.093	1 52 53	.288 1.689	.170	.681
Diff_lack_firms	Between groups Within groups TOTAL	.856 98.792 99.648	1 52 53	.856 1.900	.451	.505
Diff_lack_users	Between groups Within groups TOTAL	2.570 93.133 95.704	1 52 53	2.570 1.791	1.435	.269

a Computed using alpha = .05
b R square = .345 (Adjusted R square = .008)
*Correlation is significant at the 0.05 level; **correlation is significant at the 0.01; ***correlation is significant at the 0.001.

4.3.- Qualitative assessment and complementarities with the empirical evidence

The previous quantitative analysis has been complemented with in-depth interviews with the principal investigators of the identified research groups. This qualitative assessment confirms some of the conclusions reached with the previous ANOVA, but also sheds light on other (non-measured) determinants that directly influence their knowledge transfer capabilities.

In a sense, all interviewees recognize that nanoscience is still emerging and hence its growth potential is still notorious. They also tend to acknowledge that the risks associated with its exploitation have yet to be discovered, which is associated to their still infant translation into applications. The nature of nano research is mostly regarded as being “theoretical”, “basic” and “fundamental”, and hence under requirements of excellence. As a result, researchers in the field do not show great concerns about the future application and further exploitation of their results, and thus, towards knowledge transfer. The perception that applications are expected in horizons of about 20 years' time, and with great uncertainties as to the possible ways these might materialize strengthens the above described vision of nano research. Consequently, the view of researchers in nanoscience is merely academic, where international competitiveness through publishing and gaining visibility in prestigious journals, and managing global networks with key researchers and centres constitute its main incentives (Fernandez-Ribas and Shapira, 2009). In view of that, the rationale for researchers to start a "relationship" with the applied side of science (and hence with knowledge transfer) is related to the potential benefits they may get in terms of basic research. In other words, the applied side is regarded as valuable as long as it contributes to the further strengthening of the "pure" science.

Our research findings confirm those from Wigren-Kristoferson et al (2011) who indicated that scientists prioritize their academic identities, even if they acknowledge that their (fundamental) research questions are very much driven by the needs of those corporations involved in the exploitation and commercialization of their R&D findings (Etxebarria et al., 2013).

As regards the context (i.e. the innovation system) most researchers consider that companies should behave as the "vehicles" or "catalyzers", enabling the knowledge transfer and its further application to goods or services. Firms are also expected to "pull" applications, but they are usually not geographically located close to the research environments. From our point of view this constitutes an important trade-off for policy-makers in STI domains (Kaufmann and Tödtling, 2001), as they might be funding research activities (exploration subsystem) in their home countries, while the business environment (exploitation subsystem) capable of benefitting from the "domestic" scientific output is located elsewhere.

5.- Conclusions and policy implications

This paper intends to make an approximation to the barriers associated to knowledge in nanoscience. We aim to contribute to a better understanding of the relationship between scientific output and knowledge transfer in nanoscience, analyzing the main barriers to knowledge transfer and to what extent R&D groups in the nanoscience search for applicability of their own (basic) research results.

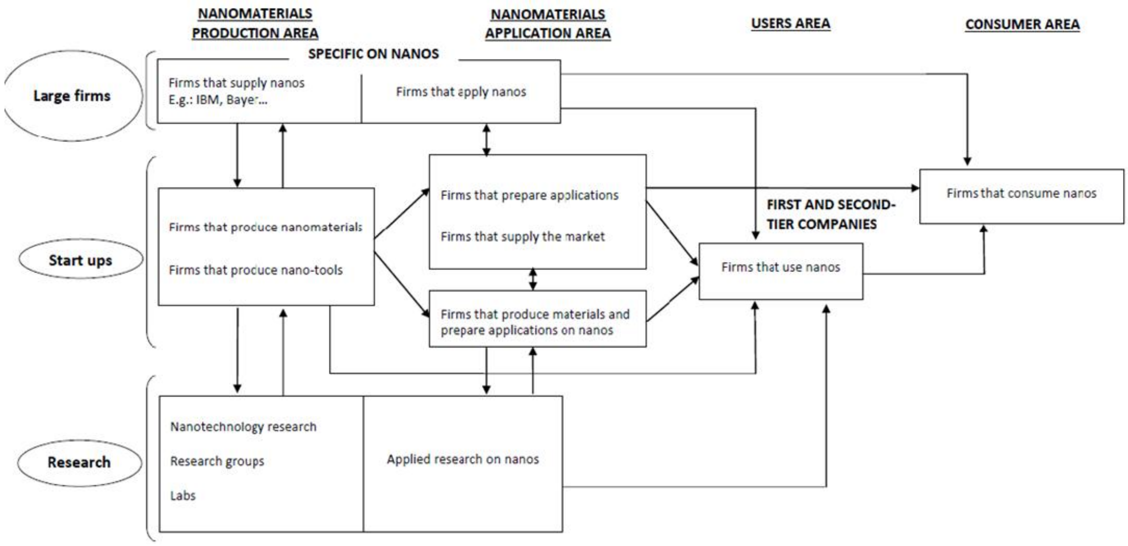
Our results indicate that the context (i.e. innovation system) plays a major role on the effectiveness of knowledge transfer processes, making them easier (Nordic case) or more difficult (Basque case). One of the reasons for this structural difficulties between the two geographical areas covered was pointed out by Gomez-Uranga et al. (2011) who already confirmed the few existing relationships between nano firms and venture capital companies in the Basque case. In turn, in the two Nordic regions (Uusimaa and Sydsverige) the critical mass of companies involved in the development of R&D-based advances in the nanofield is larger. However, in general terms it can be noticed that there is a lack of firms that consume nanotechnology and carry radical innovations in all the three regions.

We have observed that nanotechnology firms located in the three regions studied do not have the capacity (either because of their limited number – Nordic case, or because of the lack of relationships with academia – Basque case) to absorb and exploit the knowledge generated through research at universities and research centres (Shapira and Wang, 2009). There are several examples of big multinational firms working with universities and research institutes such as IBM, INTEL, L´Oreal, Nokia, or General Electric. However, firms with low R&D capacity are much less willing to work with universities, mostly due to financial constraints. Accordingly, as pointed out by Gomez-Uranga et al., (2011), there is still a strong imbalance between the scientific production in nanotechnology and its transfer to local firms.

As we have introduced in Section 4.3, we believe there is a trade-off for policy-makers in STI domains. When governments support the research capabilities of the innovation system, incur in systemic inefficiencies due to the lack of an industrial structure able to absorb and exploit this research potential. In turn, if the goal is to increase the economic efficiency of the system, the public sector can support the development of industrial policies oriented to increase the research base of the industrial structure or bring into the system global players, an opportunity that might also influence cutbacks in research budgets (Shapira et al.,2011).

A direct implication for science policy is the need to encourage more effective strategies and programmes that support the institutionalization of research groups; i.e. the transfer of scientific results and their absorption by the industrial stakeholders embedded in the innovation system. In addition, such a political action implies science policy necessarily be coordinated with a comprehensive and broad enough industrial policy able to generate a real demand for nanoscience and nanotechnology.

Figure 1: Outline of technology transfer in nanosciences



Source: (Gomez-Uranga et al., 2011: 8).

The first point to highlight is the fact that having a comprehensive scientific (exploration) subsystem is not sufficient for a regional system to reach a certain level of success in terms of innovation. As we have observed, the three regions count with a considerable scientific production (i.e. publications and patents) but still have insufficient competences on the firm side.

When researchers were asked about possible initiatives that could be undertaken in order to mitigate this trade-off (Carlsson, 2010), they pointed out several alternatives that regional policy-makers could take into consideration in order to avoid that the returns of local R&D (in terms of innovations, new applications and employment generation) may be created overseas. One strategy could be to consider firms in sectors where the application of nanotechnologies is clear as nano user firms (e.g. energy, automotive, medicine, clothing, environmental sciences, etc.). Another alternative could be based on attracting R&D centers from large multinational corporations that have high nanotechnology production and patenting, and could hence benefit from the scientific competences of the region. Other possibilities could be to acknowledge the knowledge transfer and the cooperation with the private sector as part of the academic career.

The consensus in the difficulties involved in knowledge transfer and the catalyzing role firms are expected to undertake seems to suggest the need to connect science, technology and innovation with industrial policies in a broader policy-mix. Such a systemic setting could create a more comprehensive and holistic research-transfer process, that may succeed to reduce the uncertainty of the academic career and provide the business community with better capabilities for innovation.

Our second research question intended to study whether knowledge transfer was dependent on the type of organization the research group belongs to. The information gathered with the interview indicates that the size of the group is key for its competitiveness both in terms of research and capabilities for cooperating with the private sector. This dependence of the knowledge transfer on the size of the research group is to a high extent due to the fact that: (i) smaller groups have access to a shorter number of available resources (human, financial and technological), with a direct influence on its propensity to transfer; (ii) the dependence of small groups on university structures oriented to transfer results (e.g. TTOs, foundations, science parks, etc.) is much larger; (iv) small groups are more subject to contradictory incentives (academic promotion is achieved through publications, which are dependent on external funding sources, often obtained from cooperation with private organizations).

In this sense, specialized S&T centres might be expected to have an advantage as compared to university departments. However, we have not found any evidence supporting this hypothesis. From the point of view of the internal organization of these research groups, the smaller ones are set up around a unique leader/founder, adopting a hierarchical and pyramidal structure. Larger groups are on the contrary structured into more complex organizational configurations, which behave closer to the business logic. This is what we call in the frame of this article degree of “institutionalization”.

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Appendix: Survey to researchers in nanoscience

Chapter 1: General questions

1.- Is your research focused in nanosciences or nanotechnologies?

2.- Which are the nanoparticles /nanomaterials / nanoinstruments or equipment used or those you make research about? (Please indicate them with an X in the Annex) nanoplasmnics

Chapter 2: Degree of applicability of the research

3.- Are you aware of the potential applications your research could have in nanotechnologies? Yes/No.

	0%	20%	40%	60%	80%	100%
4.- Approximately, which share of your research would have a potential application?						

In case the previous share do not apply to your research, it is due to:

a) The research strategy adopted by the research group I belong to

b) Lack of applicable results in our research

c) Lack of knowledge about the potential of applying our research results

Chapter 3: Obstacles and barriers in the knowledge transfer (Please assess your answers in a 1-5 scale)

	1	2	3	4	5
5.- My research areas are too oriented towards basic research					

(1) No focus on basic research.
(5) Totally focused on basic research

	1	2	3	4	5
6.- I have difficulties in identifying potentially commercial applications out of my research					
7.- I have difficulties derived from the lack of experience in the management and exploitation of my research results (e.g. how to create a spin-off company, with whom to develop the exploitation, finding the right partner, finding the sources of funds, etc.).					

(1) No difficulties at all
(5) Many difficulties

	1	2	3	4	5
8.- Do you think that the technologies needed in order to make your research results marketable are already available?					

(1) I think we already have the required technologies
(5) I think we DO NOT have the required technologies

	1	2	3	4	5
9.- I have problems associated with the protection of the property rights, particularly regarding patents (either due to lack of information or because the bureaucracy associated to them are too					

complex and costly)					

(1) No problem at all
(5) Many problems

	1	2	3	4	5
10.- I have difficulties to access the results produced by research groups all over the world, even those in my closest environment.					
11.- I have difficulties to contact potential entrepreneurs that might be interested in the commercial exploitation of my research results.					

(1) No difficulties at all
(5) Many difficulties

	1	2	3	4	5
12.- The companies in my closest environment do not have any interest in our research areas.					

(1) Companies have high interest
(5) Companies do not show any interest at all

	1	2	3	4	5
13.- The exploitation of my research results turns out to be impossible.					
14.- The global/international exploitation of my research results turns out to be impossible.					

(1) DO NOT agree – it is not impossible to exploit my results
(5) Totally agree – I find it impossible to exploit my results

	1	2	3	4	5
15.- Do you consider there is no critical mass on nanotechnology and nanosciences at universities?					

(1) DO NOT agree
(5) Totally agree

The following questions are related to the research environment your research group belongs to:

	1	2	3	4	5
16.- I believe there are problems related to the organization of universities and research organizations: there is a clear lack of technical and management resources.					

(1) No lack of resources
(5) Maximum lack of resources

	1	2	3	4	5
17.- I believe there are problems related to the organization of universities and research organizations: lack of competences and implication from the technology transfer offices.					

(1) The competences and degree of commitment of the technology transfer offices are very low
(5) The competences and degree of commitment of the technology transfer offices are acceptable

	1	2	3	4	5
18.- I believe there are problems related to the organization of universities and research organizations: there is no clear interest in finding commercial applications to our research results.					

(1) We DO NOT have an environment fostering the commercial applications of our research results
(5) We have an environment fostering the commercial applications of our research results

	1	2	3	4	5
19.- I believe there are problems related to the organization of universities and research organizations: the system offers contradicting incentives					

(1) DO NOT agree – there is no contradiction in the incentives provided by the system
(5) Totally agree – there are huge contradictions in the incentive system

	1	2	3	4	5
20.- Universities have a weak relative position as compared to other agents in the innovation system.					

(1) DO NOT agree – universities do not have a relative position
(5) Totally agree – universities have the weakest relative position

	1	2	3	4	5
21.- There is a lack of interest by the public governments about the potential economic benefits of our research areas.					
22.- There is a lack of interest on research.					
23.- There is a lack of firms related to the production of nanotechnologies in our closest environment.					
24.- There is a lack of users/customers of nanotechnologies in our closest environment.					

(1) DO NOT agree – there is no lack of interest/firms/customers
(5) Totally agree – there is a huge lack of interest/firms/customers