INTERACTIONS WITH NON-ACADEMIC ACTORS

SURVEY OF RESEARCHERS IN THE SPANISH PUBLIC RESEARCH SYSTEM

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SUMMARY

1. EXECUTIVE SUMMARY

Introduction and aims

This document presents the main descriptive results of a 2016 survey of researchers in the Spanish public research system. The questionnaire investigated researchers' involvements in knowledge production and interaction with non-academic actors. It focuses particularly on the following: scientist's individual characteristics; organisational factors; the knowledge exchange processes in which they are involved; the types of socio-economic actors with whom they interact; the activities enabling transmission of research results to final users; and the dissemination tools used, including social media networks.

Population and sample

The survey was administered to scientists in different academic disciplines, working in the Spanish public system. In the absence of an official public register, the reference population comprised authors with a Spanish institutional affiliation who had published at least one article in a scientific journal included in the Web of Science (WoS) database in the period 2012-2014. From a total population of 64,508 individuals, the final sample included 57,406 individuals, which resulted in 11,992 valid responses - a response rate of 21%, comparable to other similar studies.

Characteristics of the respondents

The sample is representative of the reference population with respect to WoS categorisations of scientific discipline and types of organisations within the Spanish system. Additionally, the proportions of women and men at different academic ranks are representative of the Spanish public scientific sector overall.

Orientation of the research and time distribution

The range of individuals surveyed in all scientific disciplines covers the applied to basic research spectrum, which reflects the different potential uses of their research. The highest numbers of applied researchers are found in medical sciences and the highest numbers of basic researchers in humanities. Across basic, basic-applied and applied sciences, the lowest percentage in any discipline is 9% (applied research in Humanities).

Most of the working time of respondents is spent on research (42%). This includes university lecturers, who devote 32% of their time to teaching related activities. The time spent on administration is three times more than the time spent interacting with social actors.

Motivations for scientific work

The main groups of motivations for engagement in scientific research are the academic challenges involved (considered fairly or very important by over 80% of respondents), followed by employment-based rewards (59%-78%), the prosocial nature of the contribution made by research (56%-70%) and prestige from professional and social recognition (38%-55%).

The relative importance assigned to rewards and prosocial motivation is higher for postdocs compared to upper academic ranks.

Uses of non-academic inputs

Over one-third of respondents (36%) reported that they fairly often or always incorporate non-academic information or ideas to design their research and define their research objectives. In the case of more basic research, this figure is 15%, while 23% of researchers fairly often or always take account of these sources when reformulating their research agendas.

The research team

The mean size of research teams is 6.3 individuals. Overall, 5% of researchers work alone, rising to 11% in the humanities. Regarding team interdisciplinarity, 37% work in single discipline teams and 40% work in teams that include researchers from three or more disciplines.

Three types of external interactions

In the three years preceding the survey (2013-2015), the researchers were involved in external interactions described as informal (80%), formal, based on a formal contract or agreement (63%), or related to commercialisation of research results (12%).

1. Informal interactions

In the case of interactions not related to an institutional agreement, 65% of respondents (76% in earth and environmental science) gave advice or responded to specific enquiries from social actors. Practical training (e.g., training sessions or demonstrations) was provided by 41% of researchers (61% in medical sciences); 44% incorporated non-academic actors in their teaching activities

(57% in social sciences) and 20% included non-academic actors in the design of their teaching curricula (30% in social sciences).

2. Formal interactions with a variety of actors

Formal interactions occur with a wide range of social actors (small and medium sized firms, large firms, government agencies, private non-profit institutions, hospitals, international associations, etc.). Companies are the most frequent formal interaction partners. There are some differences, depending on scientific discipline, regarding the types of non-academic actor with which researchers interacted during the time period examined.

The four most frequent types of formal interaction are consultancy (44%), contract research (43%), joint research (44%) and specialised training (36%).

3. Commercialisation

Half of the researchers surveyed declared that their scientific activity generated results with commercialisation potential and, in 2013-2015, 12% had participated at least once in some kind of commercialisation activity (licensing of intellectual or industrial property rights or business creation). Three per cent declared involvement in new company creation (spin-off or start-up) based on the results of their research and their individual knowhow.

Barriers associated to the interactions

The questionnaire asked about two kinds of barriers to interactions with social actors: cognitive barriers (affecting scientific autonomy and credibility) and institutional barriers (bureaucracy and administrative inflexibility, poor management capacity, lack of technical support, conflict or unrealistic expectations). Perceptions varied based on the respondent's experience in external interactions: those with no previous experience had a higher perception of cognitive barriers and less awareness of institutional barriers compared to those with experience of external interaction.

Institutional barriers are perceived as more important by researchers working in research centres compared to researchers working in hospitals and universities. Among institutional barriers, bureaucracy and lack of flexibility in management were considered a barrier to external interactions fairly often or always by 61% of researchers.

Results of the interactions

a) For research

Respondents considered the results of different types of external interactions occurring in the period 2013 to 2015 as fairly or very important for their research on a range between 34% and 47%. In particular external interactions were important for identifying new approaches and perspectives and possible ideas for research questions. Although there were no major differences by discipline, engineering fields led this positive perception.

b) For non-academic actors

Between 20% and 33% of those polled considered that the outcomes of interactions in which they engaged in the 2013-2015 period were fairly or very important for the non-academic actors with which they interacted, mainly in relation to the scientific validation of their ideas, options or proposals. This applies especially to social sciences and engineering researchers.

Activities for transmission to final users

On average, 22% of the respondents fairly often or always engaged in activities to transmit their research results directly to final users during their professional careers. Activities for transmission include: documents and specific products, discussion of implications, reports on specific aspects, presentations in non-technical language and demonstrations of how the results could be applied.

Dissemination tools

Twenty-two per cent of researchers use dissemination websites fairly or very often to disseminate the content or the results of their research and between 2% and 10% use other new tools (social media networks or blogs); 13% publish articles in the press fairly or very often.

Comparing disciplines, humanities researchers use both traditional (69%) and new (61%) tools to disseminate their research to non-academic actors. At the other end of the scale, researchers in mathematics and information technology use traditional dissemination tools less than researchers in other disciplines (42%), while physics and chemistry and medical sciences researchers use new tools to a smaller degree (37%).

The more senior the researcher the greater the preference for traditional tools. Use of new tools and, particularly, social media networks is favoured more by PhD students.

Contribution of social media networks

A higher percentage of respondents consider social media networks useful/positive for disseminating research and research results, and sharing information with non-academics, compared to those who see them as having a negative effect (such as prioritising visibility over content quality, reducing scientific credibility, or attracting external attacks). Among all disciplines, medical sciences researchers stand out in considering social media networks as contributing negatively.

Positive valuation of social media networks is highest among PhD students and decreases with seniority. However, within each academic rank, women provide more positive valuations compared to men. These differences do not apply to negative valuations.

2. INTRODUCTION AND OBJECTIVES

This report presents the main descriptive results of a survey of researchers in the Spanish public scientific system, administered as part of the EXTRA project. EXTRA - Scientific excellence and knowledge transfer: Two riding together? Organisational factors, individual antecedents and societal impact, was conducted by INGENIO (CSIC-UPV)[1] in 2015-2017 and was financed by the National Programme for Research, Development and Innovation Aimed at the Challenges of Society within the National Plan for Scientific and Technical Research 2013-2016 (project ref: CSO2013-48053-R).

EXTRA aimed to investigate the combinations of individual characteristics and institutional conditions associated with scientists conducting research with both scientific and societal impacts, based on the rationale that interaction with social actors in the non-academic sphere may be an important driver of scientific research and research results with both scientific impact and societal relevance. Existing evidence on scientific impact and the societal relevance of scientific research is mixed (Lee and Bozeman 2005; Hessels *et al*. 2009; Kitagawa 2009; Manjarrés-Henríquez *et al*. 2009; Rentocchini *et al*. 2014; Banal-Estañol *et al*. 2015). The project therefore set out to improve our understanding of the complementarities among the different dimensions of scientific work, by examining how the search for societal impact is incorporated in research work.

To achieve its objectives, EXTRA used mainly primary data generated by a large-scale survey of scientists working in the Spanish public research system. This report presents the results of the survey. It seeks to identify patterns of researcher interaction with the social setting and associated profiles.

The survey included questions on three interconnected aspects of scientists' involvement in the production of knowledge and their interactions with external non-academic actors:

- Scientists' individual antecedents leading to a predisposition for involvement in the exchange of knowledge with and transfer of knowledge to non-academic actors;
- Organisational factors affecting the processes of research and interactions - either formal, informal, or commercialisation activities, involving scientists and non-academic organisations; and
- External interaction processes: types of knowledge exchanged, forms of interaction and main interaction partners (direct beneficiaries of the social impact of scientific knowledge).

The report is structured as follows:

Section 3 provides a short summary of the survey methodology and the response rates. It describes sample selection and questionnaire design, final distribution and data processing.

Section 4 presents the main descriptive results of the survey, under the following sub-section headings:

4.1. Respondents' characteristics

4.2. External interactions

4.3. Dissemination of research

The structure of the questionnaire is provided in Appendix 1.

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3. METHODOLOGY

3.1. SURVEY POPULATION AND SAMPLE

The survey addressed researchers active in the Spanish public scientific system (universities, research centres and hospitals). In the absence of an official public register, the reference population was constituted by scientific authors with a Spanish institutional affiliation who published one or more articles in a scientific journal indexed in the WoS database during the period 2012-2014 inclusive.[2]

After eliminating duplicates the starting population included 64,508 individuals. Some email addresses were invalid (4,059) and some individuals were excluded (1,717), mainly on the grounds of affiliation to some other type of organisation (e.g., a private university, private non-profit institution, firm, etc.). The final questionnaire was sent by email to 58,752 individuals.

Table 1 presents information on the original sample (58,752 researchers)[3] and the final sample (57,406), which excluded responses from individuals no longer active in the Spanish public scientific system at the time of the survey. The total number of valid responses obtained was 11,992, equivalent to a response rate of 21%. This is similar to other comparable studies (Bekkers and Bodas Freitas 2008; Abreu and Grinevich 2013; Perkmann *et al*. 2013; Hughes *et al*. 2016).

Because the researchers were selected based on publication in journals indexed in the WoS, the sample is not fully representative of research activity in some areas. This is especially the case for the Humanities, where publications tend to be in the form of monographs or book chapters and where non-WoS indexed journals are often preferred (Giménez-Toledo *et al*. 2016)[4]. While our approach to constructing the survey sample allowed us to include multiple disciplines, the degree to which this sample might resemble a representative sample of Spanish public sector researchers will vary between disciplines.

Table 1. Sample, responses and response rate (N and %)

		Total (N)	%
Sample surveyed		58,752	
Responses received		16,711	28
Not target population *		1,346	8
Final sample		**57,406**	
Total responses **		15,365	27
Valid responses ***		**11,992**	**21**

* Responses excluded because these are researchers who were not active in the Spanish public research system at the time of the survey (e.g. unemployed, retired, emigrated, private centres).
** All responses obtained.
*** Answering all sections of the questionnaire (covers over 70% of all the questions in the questionnaire).

3.2. QUESTIONNAIRE

The questionnaire was built on an analytical framework (D'Este *et al*. 2018) based on an exhaustive review of the literature and discussion with various specialists in the field. Questionnaires used by the members of the research team in other previous projects (ICUE and IMPACTO)[5] and/or in other national contexts (D'Este and Patel 2007; Abreu and Grinevich, 2013). Standardised practices and accumulated knowledge were also taken into account.

In the process of designing the questionnaire, preliminary interviews were held with researchers from

2. WoS was used not to obtain an accurate estimate of the number of a researcher's publications, but to help identify research active academics (those who had published at least 1 article over the 3-year period) and allow transversal validity across all disciplines (Walsh and Lee 2015).

3. To give an idea of sample size, the Instituto Nacional de Estadística (INE) R&D statistics show that in 2014 Spain had 137,676 researchers working in the public administration centres (22.6%) and public universities (77.4%), which is the general group to which the questionnaire was addressed. Thus, the sample represents more than 40% of the population of researchers in the public sector in that year. Note, also, that these figures are submitted annually by each organisation to INE and include both researcher employees and trainee researchers, regardless of their scientific production.

4. The number of articles published by Spanish researchers in humanities included in WoS (Arts & Humanities Citation Index) has increased gradually since the 1980s (1,795 articles representing, on average, around 0.7% of the total), up to the 2005-2014 period (with 12,771 articles representing 5% of the total). Two factors affected this new trend: a change in the publication patterns of researchers in the area and an increase in coverage of Spanish journals in that area in the WoS from the first decade of the 21st century.

5. Celia Díaz-Catalán, Irene Ramos-Vielba (Principal Investigator) and Richard Woolley took part in ICUE ("Cooperación universidad-empresa en el sistema español de I+D: opiniones y experiencias de los grupos de investigación", 2010-2013, ref. CSO2009-07805). Elena Castro-Martínez and Pablo D'Este took part in IMPACTO ("El impacto socioeconómico de las actividades del CSIC: una estrategia de aproximación", 2009-2012), a project carried out by INGENIO (CSIC-UPV) and IESA-CSIC.

several different disciplines[6]. Half of these were in Science, Technology, Engineering and Mathematics (STEM) disciplines and half in Social Sciences and Humanities (SSH). During November 2015 to May 2016, a total of 16 interviews were conducted with researchers in public universities, public research centres and a university hospital[7]. Conversations with researchers, including nine men and seven women at different stages in their professional careers, provided a greater understanding of the diversity in scientific activities and interactions with the non-academic environment. The researchers contributed experience and individual perceptions about the most significant scientific and societal results achieved during their careers. The information obtained from these interviews led to adaptations of some survey questions and confirmed their relevance overall.

The survey was pre-tested, first during January and February 2016 and again in March 2016, with members of the project team and some external experts[8]. Based on their knowledge and experience of the study topic or administration of surveys, these individuals provided very helpful scientific and technical feedback. In the first pre-test, a common form was used to collect and check all the evaluations of difficulties related to completing the questionnaire[9]. After incorporating the improvements suggested, the second pre-test verified its practical operation and led to some further improvements.

Two pilot tests were conducted in May 2016[10] to confirm the suitability of the questionnaire for collecting the data required for the research. Two random samples of 300 individuals were selected for these pilot tests of the survey procedure using Qualtrics software. The first pilot helped to check the validity and operability of the questionnaire[11]. The second pilot test was addressed to individual researchers identified using WoS data. As no further changes were introduced after the second pilot test, the 82 responses obtained from the second pilot were integrated with the final results.

The final questionnaire was administered electronically in the period 14 June to 31 July 2016. The researchers were sent a link that allowed them to respond to the survey online. The email provided a brief description of the project and what participation involved. The estimated time for responding was around 20 minutes. Reminders were sent to non-respondents after two and four weeks.

The invitation to participate in the survey included guarantee of confidentiality and anonymisation of any responses that might allow identification of the participants. The information collected is protected by the Data Protection Act 15/1999. The results are presented in aggregate form only.

The next step was processing of the survey responses, including verification to avoid possible errors, comparison of valid answers and establishing specific categories and sub-categories to code the response options for open questions. Standardisation, processing and validation of the response data allow comparison, exploratory analysis and statistical treatment.

In what follows, we apply univariate and bivariate analyses to a selection of the descriptive results. For the bivariate analysis, for each question we selected one of the following variables for comparison: scientific discipline; type of organisation; academic rank; or research orientation.

6. IT engineering applied to the hospital sphere, psychology, molecular chemistry, economic theory, physics-nanotechnology, health economics, clinical psychiatrics, geography, optical telecommunications, molecular and cellular plant biology, history of medicine, fine arts- drawing- biomedicine-genetics, restoration of works of art and sociology.

7. The contribution of all the researchers interviewed was essential to the construction of the questionnaire.

8. Apart from the contributors to the project, two technical experts from the Centro de Investigaciones Sociológicas provided some highly useful detailed comments.

9. Note was taken of their views about: understanding the questions, the response categories, the labelling on the scales, the length of the questionnaire, the ease of providing the type of information requested and complementary factors such as the format.

10. Each pilot lasted 2 weeks, during which time reminder messages were sent.

11. A detailed analysis of the responses received from the first pilot resulted in some slight changes for the second pilot to facilitate compilation of information on the different types of interactions with non-academic actors.

4. MAIN RESULTS

4.1. RESPONDENT CHARACTERISTICS

4.1.1. Discipline, organisation, professional category, gender

Table 2 presents information on the final sample, total and valid responses and respective response rates, by discipline, based on WoS publication classifications, aggregated in nine categories[12]. We used the WoS discipline classification since this source was used in identifying the reference population for the study.

The response rate by discipline was relatively closely bound around the overall rate of 21% apart from Humanities researchers, who were slightly more likely to respond (29%). Although the sample was selected using WoS categories as the basis, the questionnaire also asked respondents to state their discipline (from a list of 51). Table 3 compares the distribution of respondents by discipline, according to WoS (based on their publications) and respondents' self-report. The subsequent analyses use the discipline self-reported by each respondent.

Regarding the type of organisation to which scientists are affiliated, Table 4 shows that most of the respondents (74%) are employed by a university, with 15% working in a research centre[13] (Appendix 2 provides percentages of responses for the final sample by type of organisation). The remainder work in hospitals (6%) or have multiple affiliations (5%) to two or more different types of organisations[14]. Although the *Instituto Nacional de Estadística* uses a different classification, it found similar proportions for universities and public administrations, 76% and 24% respectively. Table 4 shows that 53% of researchers with multiple affiliations work in medical sciences departments. These individuals are medical professionals who are affiliated to a university, but also work at a hospital.

12. We considered the WoS *subject categories, taking* account of their equivalents in the Spanish context. The approach used by Universidad de Granada in its case study of the Spanish university system (I-UGR Rankings) was adopted to identify correspondence between different international rankings per discipline categories and subcategories (Robinson-García *et al*. 2014). The final 9 category classification allowed identification of a relevant number of researchers in each scientific field.

13. The *research centres* category includes public research bodies (OPI) of Central State Administration created to conduct scientific and technical research activities (regulated by Act 14/2011, of 1 June on Science, Technology and Innovation), as well as other Spanish public research centres.

14. The *multiple affiliation* category groups researchers who work in more than one type of organisation (whether this is a university, research centre or hospital, or any combination of these three) but does not necessarily reflect all the researchers with affiliations to multiple organisations since there may be variations in how the respondents refer to their institution.

Table 2. Sample, responses and response rates by scientific discipline (N and %)

Scientific discipline	Valid responses (N)	Valid response rate (%)	Total responses (N)	Total response rate (%)	Final sample (N)
Chemistry and physics	1,966	23	2,428	29	8,443
Humanities	775	29	991	37	2,651
Earth and environmental sciences	1,174	23	1,460	29	5,102
Social sciences	1,222	22	1,532	28	5,476
Engineering	956	20	1,201	25	4,805
Biological sciences	1,656	23	2,043	28	7,270
Mathematics and computer science	919	19	1,195	24	4,958
Medical sciences	1,909	17	2,645	24	11,203
Not classified*	1,415	19	1,870	25	7,498
Total	**11,992**	**21**	**15,365**	**27**	**57,406**

* Not classified: this includes the researchers who had the same number of publications in two or more disciplines, in the period taken as a reference for the selection (2012 – 2014), for which reason these could not be assigned to any specific discipline with the information available in WoS.

Table 3. WOS responses and EXTRA survey by scientific discipline (N and %)

Scientific discipline	WoS 2012 - 2014		EXTRA Survey***	
	Valid responses (N)	Valid percentage (%)	Valid responses (N)	Valid percentage (%)
Chemistry and physics	1,966	16	1,795	15
Humanities	775	6	629	5
Earth and environmental sciences	1,174	10	1,151	9
Social sciences	1,222	10	2,145	18
Engineering	956	8	1,872	16
Biological sciences	1,656	14	1,434	12
Mathematics and computer science	919	8	1,474	12
Medical sciences	1,909	16	1,393	12
Not classified* / Multidisciplinary **	1,415*	12	99**	1
Total	**11,992**	**100**	**11,992**	**100**

* Not classified: this includes the researchers who had the same number of publications in two or more disciplines, in the period taken as a reference for the selection (2012-2014), for which reason these could not be assigned to any specific discipline with the information available in WoS.
** In the survey 99 individuals choose "multidisciplinary" as their discipline.
*** Classification based on respondents' self-report.

Table 4. Type of organisation by scientific discipline (N and %)

Scientific discipline	University	Research centre	Hospital	Multiple affiliation	Total
Chemistry and physics	1,298	440	7	49	1,794
Humanities	571	48	1	9	629
Earth and environmental sciences	695	414	3	37	1,149
Social sciences	1,977	99	22	38	2,136
Engineering	1,560	275	3	29	1,867
Biological sciences	876	399	89	67	1,431
Mathematics and computer science	1,388	63	2	20	1,473
Medical sciences	454	73	579	283	1,389
Multidisciplinary	66	23	6	1	96
Total (N)	**8,885**	**1,834**	**712**	**533**	**11,964**
Percentage (%)	**74**	**15**	**6**	**5**	**100**

Missing values: 28.

The questionnaire asked respondents to indicate their professional category at the time of the survey. Table 5 presents the responses by category, whether specific to a university, a public research centre, or for all the types of organisations in the study including hospitals in the case of clinical researchers. The categories capturing the highest numbers are associate professor/senior lecturer with 29%, followed by full professor (including professor emeritus) 15%, assistant professor/lecturer 14%, and postdoctoral research fellow (under contract for a project or some other programme) 10%.

The sample included 37% women and 63% men. According to INE, women represented 43% of university and public research centre researchers in 2015. The distribution of women and men by academic rank in the Spanish system (Puy Rodríguez 2015) appears similar to the distribution in our sample[15] (see Table 6). The survey sample shows a glass ceiling rate[16] of 1.79, slightly lower than in the academic year 2014-2015 in Spanish public universities (1.86) according to *Científicas en cifras 2015* (Puy Rodríguez 2015)[17].

15. The distribution in the Spanish system is similar at higher levels (21% women on level A and 42% on level B), but varies more at the other two levels (49% on level C and 55% on level D).

16. Puy Rodríguez (2015) describes the glass ceiling as a relative index that compares the proportions of women and men at levels A, B, and C compared to the proportions of women and men at position A.

17. Among the EU28, the 2013 glass ceiling mean rate was 1.75 (Puy Rodríguez, 2015: 22).

Table 5. Academic rank (N and %)

University	PRC*	University / PRC* / hospital	Total (N)	%
Full professor (and professor emeritus)			1,796	15
	Research professor		269	2
Associate professor / senior lecturer			3,444	29
	Scientific researcher		701	6
	Tenured scientist		560	5
Contracted associate professor / lecturer			1,644	14
Assistant professor			462	4
Tenured university school lecturer			58	0
		Contracted postdoctoral research fellow	930	8
		Postdoctoral programmes**	215	2
		PhD student	420	3
		Clinical researcher	391	3
		Support technician	332	3
Part-time (associate) lecturer			452	4
		Others	311	2
Total			**11,972**	100

* PRC = public research centre.
** Includes Ramón y Cajal, Juan de la Cierva and other postdoctoral programmes.
Missing values: 20.

Table 6. Women/men by academic rank (% and N)

Academic rank	Women (%)	Men (%)	Total (N)	%
Level A	20	80	2,065	17
Level B	39	61	6,418	54
Level C	43	57	1,636	14
Level D	40	60	420	3
Others	41	59	1,433	12
Total	**37**	**63**	**11,972**	**100**

Level A: Full professor/professor emeritus; research professor.
Level B: Associate professor / senior lecturer; scientific researcher; tenured scientist; contracted associate professor / lecturer; Ramón y Cajal postdoctoral programme.
Level C: Assistant professor; tenured university school lecturer; contracted postdoctoral research fellow; Juan de la Cierva postdoctoral programme.
Level D: PhD student.
Others: Clinical researcher; support technician; part-time associate lecturer; others.
Missing values: 20.

In summary, the valid responses to the survey of researchers in the Spanish public system appear representative of the target population extracted from the WoS in terms of scientific discipline. In addition, the overall profile of the respondents appears quite well-matched to available secondary data on researchers by type of public sector organisation, gender participation and gender distribution by academic rank.

4.1.2. Orientation of the research and time distribution

The survey respondents were asked to define the orientation of their research in terms of basic or applied research[18], with basic defined as research intended to further scientific knowledge and applied defined as research aimed at obtaining scientific knowledge to solve particular problems

18. The survey included a 0-100 percentage scale on which respondents could indicate percentages of basic and applied research – summing to 100.

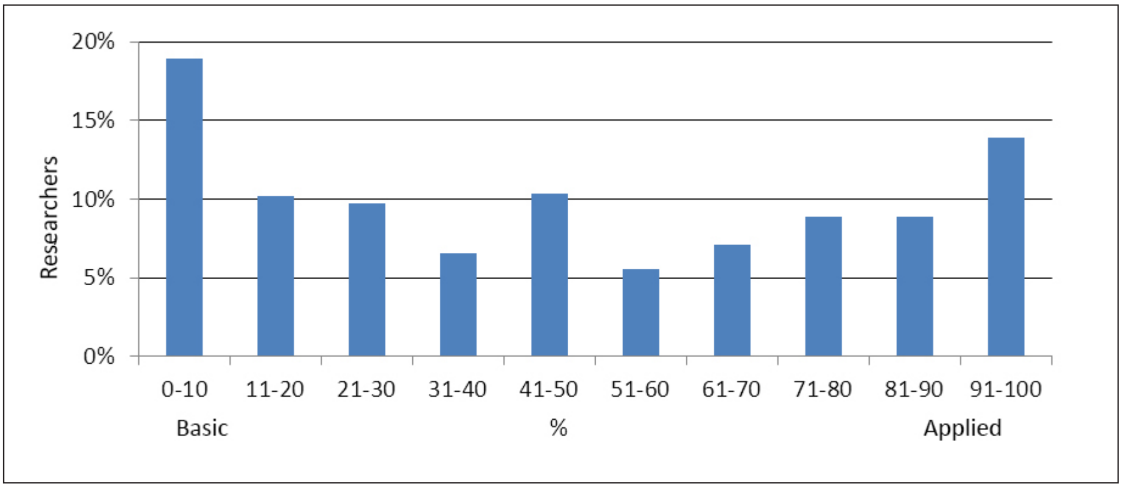
(OECD 2003). Previous work shows that research orientation affects the involvement of researchers in interactions and knowledge transfer activities (Abreu and Grinevich 2013).

Although a proportion of our respondents are at the extremes of the distribution (18% pure basic and 14% pure applied), each of the intervals along the continuum from basic to applied includes around 10% (Figure 1). This demonstrates the heterogeneity of research orientations among our respondents.

Based on these results, we established three categories by breaking down the sample in three groups of equal size (one third of the distribution each): basic research, applied research and intermediate between basic and applied. Figure 2 depicts their distribution according to the type of organisation of affiliation. In public research centres, basic research outweighs applied research; at universities levels of basic and applied research are similar, while in hospitals and among researchers affiliated to more than one institution, the research orientation is mainly applied. Recall that, according to Table 4, 53% of this last group work in the medical sciences.

Table 7 presents the distribution of research orientation by scientific discipline and highlights that humanities is linked strongly to basic research (68%), and medical sciences (58%) and engineering (50%) researchers to applied research. In general terms, in the other areas over 50% of respondents mainly performed either basic-applied or applied research.

Figure 1. Research orientation (%)



Average = 49, 29 / Standard deviation = 33,192 / N = 11.992.

Figure 2. Research orientation by type of organisation (%)

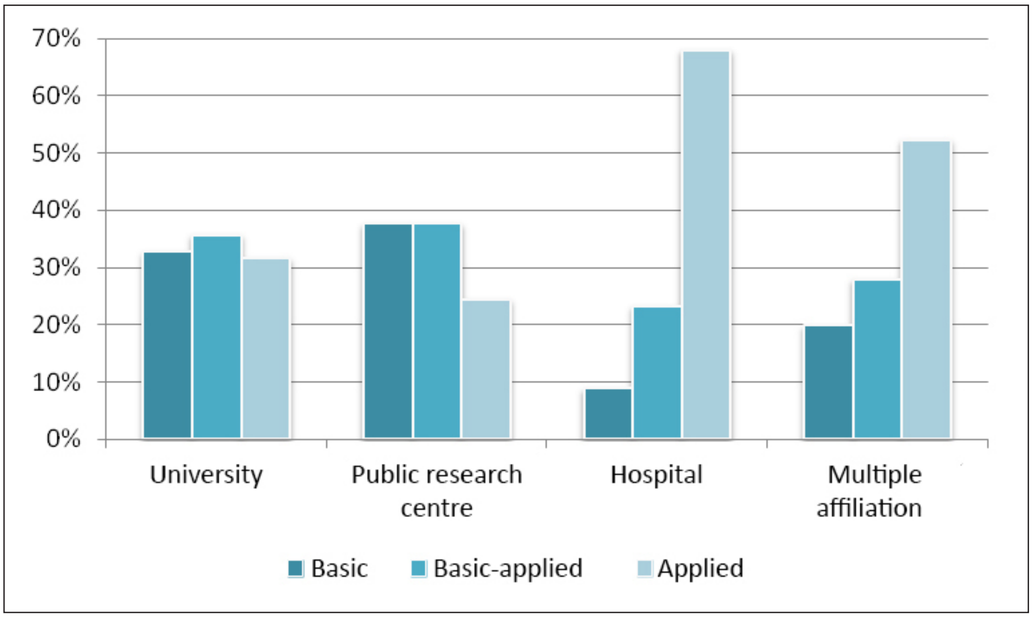


Table 7. Research orientation by scientific discipline (%)

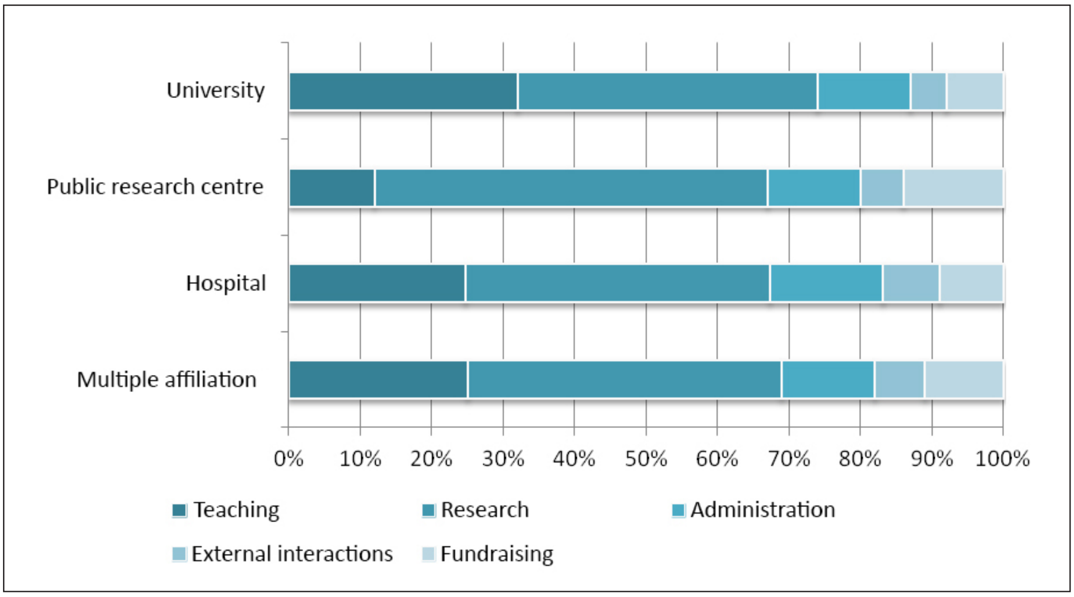
Scientific discipline	Basic	Basic-applied	Applied	Total (N)
Chemistry and physics	47	37	16	**1,795**
Humanities	68	23	9	**629**
Earth and environmental sciences	30	40	30	**1,151**
Social sciences	27	36	37	**2,145**
Engineering	12	38	50	**1,872**
Biological sciences	48	36	16	**1,434**
Mathematics and computer science	28	37	35	**1,474**
Medical sciences	16	26	58	**1,393**
Multidisciplinary	27	33	40	**99**
Total	**32**	**35**	**33**	**11,992**

Figure 3 shows the average time that respondents devote to different scientific activities. In all cases, most time is spent on research, including at universities. Note that this is not representative of all teaching staff working at a university; only those who had published at least one article included in the WoS during the period 2012-2014. Overall, respondents devote 28% of their time to teaching, 44% to research, 14% to administration, 5% to external interactions and 9% to fundraising. Researchers working in public research centres devote less time than the average to teaching (12%) and more to raising funding (14%). Administration accounts for 16% of hospital researchers' time. While researchers at universities devote a similar amount of time to interactions with non-academic actors as researchers at research centres, the latter are less oriented toward applied research than the former (see Figure 2). Analysis of the time distribution by type of organisation shows that there are statistically significant differences.

4.1.3. Motivations for scientific work

The survey asked about the importance of a number of motivations for carrying out scientific work. Table 8 displays the percentages of respondents who considered those motivations to be fairly or very important. They are grouped into four categories, based on a factor analysis, which confirms the findings in the literature on motivations (Lam 2011; D'Este *et al.* 2017). We see that the main moti-

Figure 3. Allocation of time to scientific activities, by type of organisation (%)



vations are related to scientific challenge, with prosocial motivations and rewards ranked next, and prestige from professional and social recognition ranked last.

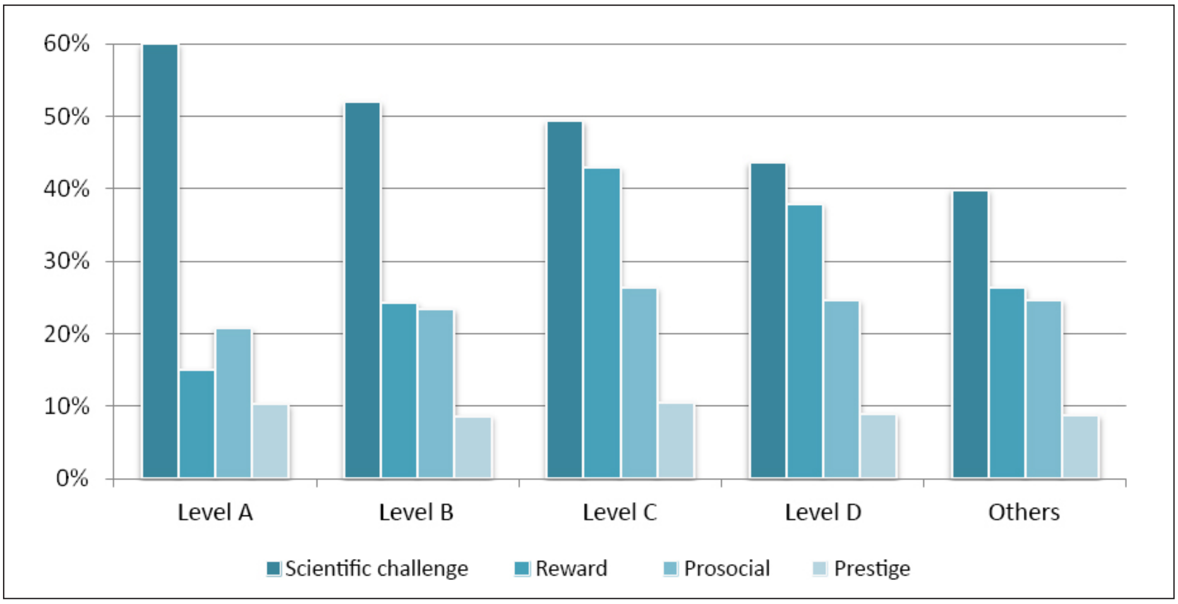
When we compare motivations to academic ranks (based on the aggregation in Table 6), some differences emerge (Figure 4). For respondents categorised as level A (full university professors and research professors), scientific challenge is the main motivation (fairly or very important for 60%), followed by prosocial motivations (fairly or very important for 21%) and reward and prestige (around 15% and 10% respectively). The main motivation for levels B, C, D and the group of *others* is also scientific challenge, although for a lower proportion than in the case of level A. In turn, the importance given to reward is higher in the case of levels C and D (43% and 38%, respectively). Prosocial type motivations are rather more important for the other levels (23% to 26%) than for level A.

Table 8. Motivations for scientific activity (%) (multiple response)

Type of motivation		Fairly / very important
Scientific challenge	The degree of personal satisfaction that I obtain from my academic and/ or research activities	94
	The intellectual challenge of better understanding the problems that I face as a researcher	91
	The degree of autonomy for undertaking my work	88
	My contribution to the furthering of knowledge in my discipline	80
Reward	Employment stability for doing my work	78
	The opportunities for improvement in my professional career	69
	My employment conditions (remuneration and salary complements, welfare benefits)	59
Prosocial	My contribution to solving social challenges or needs	70
	Generating answers useful for solving third parties' specific problems	68
	The potential positive impact of my research on non-academic actors	56
Prestige	The professional recognition of the academic community in my speciality	55
	The professional recognition among my working colleagues	47
	The social recognition obtained with my work	38

Total variance explained = 68.56%. Rotation method: Varimax with Kaiser normalisation.

Figure 4. Motivations for scientific activity by academic rank (%)



Hence, the most significant difference in motivations for scientific activity, when taking account of the four different stages in a professional scientific career, is scientific challenge, the importance of which increases with academic rank. Reward, in terms of improvements to working conditions, is highest among level C (postdoctoral) researchers and decreases in importance when these researchers achieve a stable work position (normally civil servant status). The levels of prosocial and prestige motivations are similar, regardless of academic status, with prestige being the least important among the four types of motivations.

If we consider motivations for scientific activity according to research orientation (basic, basic-applied or applied) (Figure 5), we find no great differences for reward and prestige. However, scientific challenge becomes the most significant motivation for basic research, in all cases. The level of prosocial motivation increases with an applied research orientation, and outweighs the motivation of reward in the case of researchers working in applied research.

4.1.4. Uses of non-academic inputs

Researchers may (or not) take account of social needs in their research work (Hessels and Van Lente 2008; Olmos-Peñuela *et al*. 2015). Table 9 presents the percentages of respondents who fairly often or always incorporate information or ideas from the non-academic environment in their scientific work: 36% of respondents do so when designing their research or defining research objectives, 35% when implementing their research projects and 23% when reformulating their research agendas. Thus, researchers seem to be fairly open to receiving inputs from outside academia throughout the different phases of the research process.

Figure 6 depicts the level of incorporation of ideas from the non-academic environment according to type of research (basic, basic-applied or applied). External ideas are more important in the case of more applied research. There are statistically significant differences in the distribution, but the patterns remain similar.

4.1.5. Research team: size and interdisciplinarity

The setting in which researchers perform their research tends to determine the research approach and results (Heinze *et al*. 2009). Note that the production of scientific knowledge by research teams has increased (Wuchty *et al*. 2007). The survey asked respondents to state the numbers of individuals in their research team. Table 10 shows the responses grouped by team size (individual, small, medium, large). The mean number of team members is 6.3 and the mode is 5. Working as an individual researcher applies to only 5% of respondents, while small teams (33%), medium (34%) and large teams (28%) have similar weights.

Figure 5. Motivations for scientific activity, by research orientation (%)

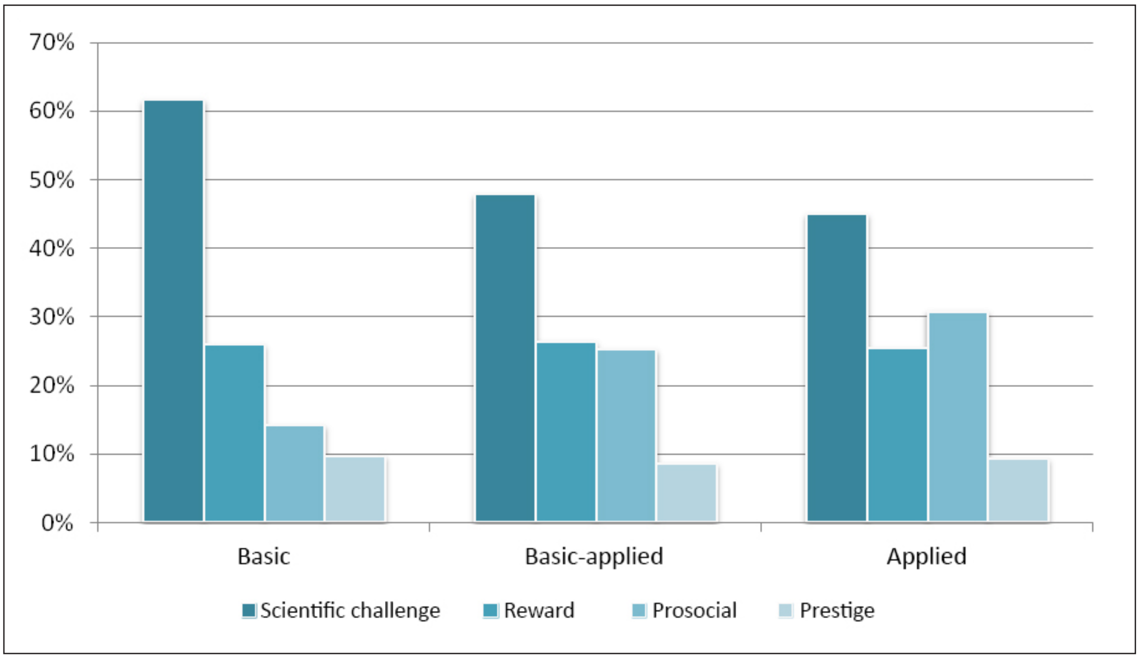


Table 9. Non-academic inputs into scientific activity (%)

	Fairly often / always
In the design of my research lines	36
In the definition of my research objectives	36
In the implementation of my research projects	35
In the dissemination of my research results	31
In the reformulation of my research agenda	23

Mean = 3. Standard deviation = 0.926 / N=11,948. Cronbach Alpha: 0.92.

Figure 6. Non-academic inputs into scientific activity, by research orientation (%)

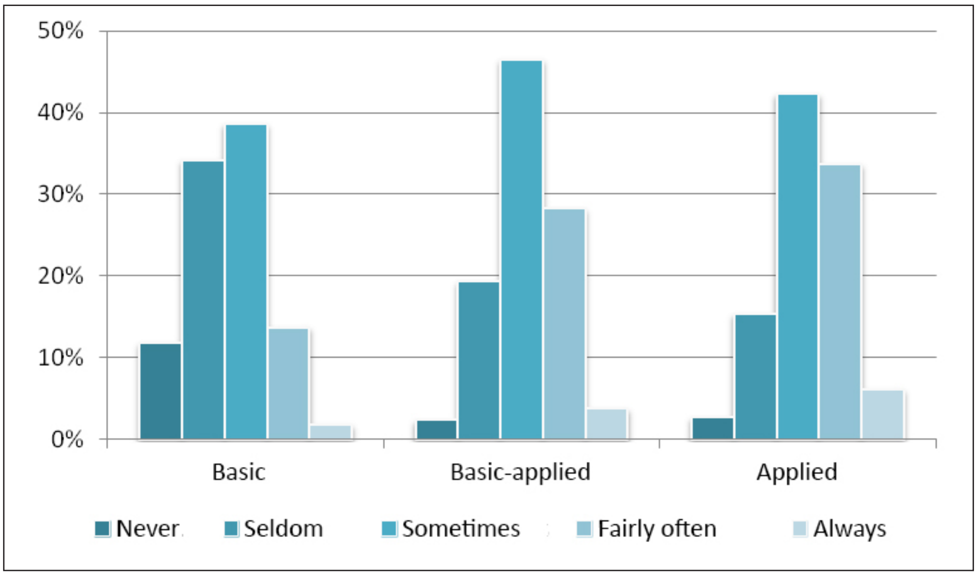


Table 10. Size of the research team (N and %)

Research team	No. of members	Total (N)	Valid percentage (%)
Individual	1	537	5
Small	From 2 to 4	3,981	33
Medium	From 5 to 7	4,086	34
Large	8 or more	3,315	28
Total		**11,919**	**100**

Missing values: 73.

Table 11 presents research team size in these four groups by discipline. From a comparative perspective, the highest percentages of individual researchers are in the humanities (11%) -an area where there is also the highest percentage of large teams (8 or more members)- and medical sciences (9%). Small teams (2-4 members) are more numerous among multidisciplinary researchers (46%) and social sciences researchers (36%), while medium sized teams (5-7 members) are common in chemistry and physics and biological sciences (37%). There are some statistically significant differences among disciplines.

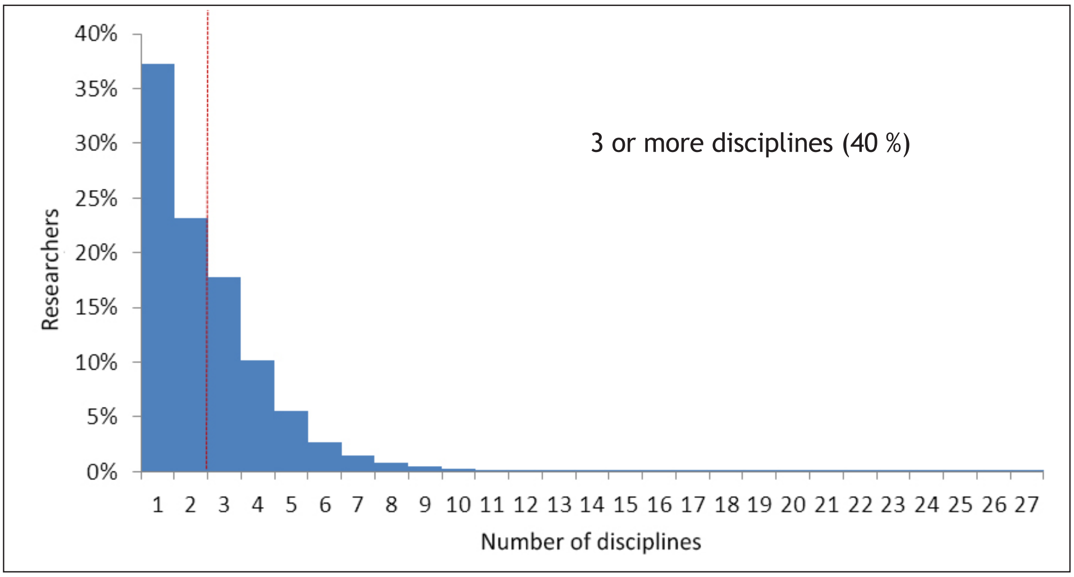
For the interdisciplinarity of research teams, the values obtained were: mean 2.50, median 2 and mode 1. Figure 7 shows that around 4,500 researchers (37%) work in teams of individuals from the same discipline – the most frequent situation among respondents. Around 40% of researchers work in teams whose members work in three or more disciplines.

Table 11. Size of the research team by scientific discipline (%)

Scientific discipline	Individual	Small	Medium	Large
Chemistry and physics	3	33	37	27
Humanities	11	21	35	33
Earth and environmental sciences	3	34	35	28
Social sciences	5	36	34	25
Engineering	4	32	33	31
Biological sciences	3	35	37	25
Mathematics and computer science	3	32	36	29
Medical sciences	9	35	29	27
Multidisciplinary	7	46	20	27
Total	**5**	**33**	**34**	**28**

Missing values: 73.

Figure 7. Disciplines of members of the research team (%)



Average =2,50 /Standard deviation =1,80 / N=11.902.

Table 12 presents the degree of interdisciplinarity in research teams according to type of organisation. Although there is a majority of teams that include researchers from one or two disciplines (60%), researchers working in public research centres or with multiple affiliations tend to work in teams whose members are from three or more disciplines. The differences between types of organisation are statistically significant.

4.2. EXTERNAL INTERACTIONS

4.2.1. Diversity of activities and non-academic actors

The literature on science-society interaction is extensive and covers aspects such as diversity of interaction mechanisms (Meyer-Krahmer and Schmoch 1998; Abreu *et al*. 2009; Dutrénit 2010; Landry *et al*. 2010; D'Este and Perkmann 2011; Ramos-Vielba and Fernández-Esquinas 2012; Perkmann *et al*. 2013) and social actors (Hughes and Kitson 2012).

The questionnaire asked respondents about their research related interactions with non-academic actors during 2013-2015, distinguishing among three major groups of activities found in the literature (Perkmann et al. 2013): a) informal activities, that is, not involving a contract or formal agreement; b) formal activities related to a formal contract or agreement; and c) activities related to the commercialisation of research results (see Box 1).

Table 12. Interdisciplinarity of the research team by type of organisation (%)

Research team	1-2 disciplines	3 or more disciplines	Total (N)
University	62	38	8,825
Public research centre	54	46	1,823
Hospital	68	32	697
Multiple affiliation	53	47	530
Total	**60**	**40**	**11,875**

Missing values: 117.

Box 1. Types of external interactions included in the questionnaire

Informales*	Formales	Commercialization**
1. Informal consultancy in response to specific inquiries 2. Informal training in response to specific requests (sessions, demonstrations) 3. Inclusion of non-academic actors in teaching activities 4. Inclusion of non-academic actors in design of teaching curriculum	1. Provision of technical or consultancy services 2. Contract research by non-academic actor 3. Joint research projects (with or without public support) 4. Providing specialized training 5. Temporary stays at a non-academic organisation 6. Hosting non-academic actors 7. Creative or cultural products (audiovisuals, artistic works) 8. Guidelines, protocols or norms 9. Renting, equipment or materials 10. Tests (e.g. proof of concept, prototypes)	1. Licensing intellectual property rights 2. Licensing of patents 3. Licensing of plant varieties and biological materials and others 4. Licensing of utility models 5. Licensing of knowhow (industrial secret) 6. Firm creation (spin-off or start-up): based on research results 7. Firm creation (spin-off or start-up): based on the researcher's knowhow

* Other non-bilateral informal interactions were also considered: participation in professional networks that are not exclusively academic (associations, mixed initiatives), presentations at conferences where non-academic actors participate, non-academic activities for the dissemination of knowledge (fairs, conferences, exhibitions), talks as a guest speaker in schools, museums or community organisations.
** The questionnaire also asked about the number of intellectual and industrial property titles (e.g. patents), obtained by respondents in the same period, as antecedents of subsequent commercial exploitations.

Table 13 presents responses by scientific discipline, distinguishing among three main types of external interactions. In the case of informal interactions, we chose activities implying a direct relationship with a social actor. The majority of respondents engage in informal activities - 80% of researchers in all areas, and 85% in the cases of social sciences and earth and environmental sciences researchers. Interaction for commercialisation of results involved only 12% of respondents overall, but 19% of engineering researchers.

Previous work on interactions between scientific researchers and non-academic actors (Molas-Gallart *et al*. 2015; Castro-Martínez *et al*. 2016) shows that interactions involve firms and other types of social agents with scientific knowledge and knowhow, for various activities. Box 2 shows the range of non-academic actors involved in the different types of formal interactions engaged in by respondents during 2013-2015.

Figure 8 depicts formal, informal and commercialisation interactions according to research orientation. The levels of formal interactions are similar for groups engaged in applied research (76%) and basic-applied research (68%); interactions for commercialisation are the same in both

Table 13. Types of external interactions in 2013-2015 by scientific discipline (% and N) (multiple response)

Scientific discipline	Informal	Formal	Commercialisation
Chemistry and physics	72	54	14
Humanities	82	42	12
Earth and environmental sciences	85	68	10
Social sciences	85	65	8
Engineering	84	75	19
Biological sciences	77	60	11
Mathematics and computer science	72	58	14
Medical sciences	84	67	10
Multidisciplinary	85	69	12
Total (%)	**80**	**63**	**12**
Total (N)	**11,458**	**11,050**	**11,960**

Box 2. Non-academic actors included in the questionnaire

1. Small and medium-sized firms (from 1 to 250 workers)
2. Large companies (more than 250 workers)
3. Government agencies*
4. Private non-profit institutions (foundations, NGOs)
5. Hospitals
6. Associations (e.g. professionals, citizens, users, patients)
7. International organizations (e.g. UNESCO, FAO, World Bank, EU)
8. Others (specify)**

* Government agency = only as direct contracting parties or external partners in research activities. Not in administrative management or competitive calls/tenders.
** This response was recoded and, as far as possible, assimilated to the preceding categories.

these cases (15%). The greatest difference between basic and applied research is for formal interactions (43% vs 76%).

4.2.2. Informal interactions

The literature emphasises informal activities, which are the most frequent and are often the precursor to formalised interactions as they induce mutual trust, which is a requirement for formal relations (Bonaccorsi and Piccaluga 1994; Amara et al. 2004; Link et al. 2007; Landry et al. 2010). Table 14 presents the results for the following activities: consultancy, practical training, and inclusion of non-academic actors in teaching activities and designing the teaching curriculum. The majority of respondents, in all areas of knowledge, engage in non-formalised consultancy activity and this is especially relevant to earth and environmental sciences, engineering and social sciences researchers (over 70%). Medical sciences researchers are conspicuous for providing specific practical training such as training sessions or demonstrations (61%). Participation of non-academic actors in curriculum design reached 20% overall, but was up to 30% in social sciences, which is the discipline with the highest number of external professionals involved in teaching activities (57%).

4.2.3. Formal interactions

The survey covered a diversity of formal interactions (based on a formal contract or agreement) linked to scientific work (see Box 1), undertaken during 2013-2015, with the non-academic actors presented in Box 2. It depicts seven different actors and

Figure 8. Types of external interactions according to research orientation (%)

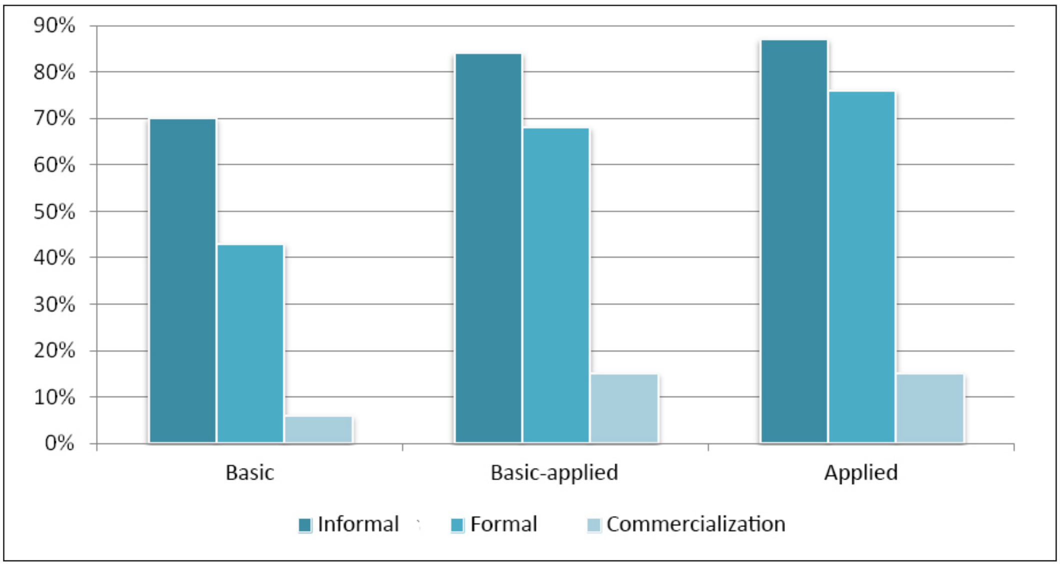


Table 14. Informal interactions in 2013-2015 by scientific discipline (N and %) (multiple response)

Scientific discipline	Informal consultancy	Informal training	Inclusion of non-academic actors in teaching activities	Inclusion of non-academic actors in design of teaching curriculum	Total (N)
Chemistry and physics	57	31	33	13	**1,724**
Humanities	61	41	51	21	**592**
Earth and environmental sciences	76	41	40	16	**1,106**
Social sciences	70	49	57	30	**2,056**
Engineering	73	37	46	20	**1,775**
Biological sciences	62	34	36	15	**1,367**
Mathematics and computer science	58	33	37	17	**1,400**
Medical sciences	63	61	54	24	**1,346**
Multidisciplinary	68	46	47	20	**92**
Total	65	41	44	20	**11,458**

Missing values: 534.

ten formal activities, and the frequency of the interactions that occurred (from 1 to 10 or more times) in the three year period (2013-2015). When that information is combined, we find that 63% of respondents were involved in some kind of formal interaction with a non-academic actor during the period analysed.

Table 15 presents details of the different types of non-academic formal interaction partners, by scientific discipline. The main interaction partners are firms (small, medium and large - 42%), although, overall, this type of actor is no more prevalent than the other actors jointly considered. The highest percentage of interactions with firms refers to engineering researchers (66%) and the lowest to humanities researchers (17%). Interactions with government agencies are fairly frequent in all scientific areas and, especially, earth and environmental sciences (40%) and social sciences (41%). Social sciences have the highest level of interactions with associations (21%) and international organisations (14%). As might be expected, medical sciences have a high level of interactions with hospitals (44%), although interactions with hospitals occur in all scientific disciplines.

Table 15. Formal interactions with non-academic actors in 2013-2015 by scientific discipline (N and %) (multiple response)

Scientific discipline	SME	Large company	Government agency*	Non-profit organisation	Hospital	Association	International organization	Total (N)
Chemistry and physics	35	23	17	8	7	5	7	**1,648**
Humanities	12	7	25	14	1	13	6	**558**
Earth and environmental sciences	35	23	40	15	2	13	14	**1,084**
Social sciences	20	13	41	26	9	21	14	**1,975**
Engineering	52	42	32	13	6	7	9	**1,768**
Biological sciences	30	19	23	14	16	8	7	**1,310**
Mathematics and computer science	37	30	25	11	11	7	8	**1,350**
Medical sciences	14	20	16	19	44	13	6	**1,268**
Multidisciplinary	22	18	25	21	18	13	8	**89**
Total	**31**	**24**	**28**	**15**	**12**	**11**	**9**	**11,050**

* Government agency = only as direct contracting parties or external partners in research activities. Not in administrative management or competitive calls/tenders.
Missing values: 942.

Table 16 presents rates of participation in different kinds of formal interactions by discipline. Overall, the first three (consultancy, contract research and joint research) are related to the highest percentage of respondents (around 44%), followed by training (36%). For exchanges of personnel (Table 16, columns 5 and 6) there are differences between scientific fields. For example, this type of interaction is below average in the humanities and above average in medical sciences. Among respondents, 19% of humanities researchers engaged in the generation of creative and cultural products (Table 16, column 7), which is associated to increased participation in efforts to foster a science culture (research dissemination, science exhibitions) (Olmos-Peñuela et al. 2014). Medical sciences shows high levels of engagement in the preparation of guidelines, protocols and norms (45%), renting, equipment and materials (23%) and testing and prototypes (28%).

4.2.4. Commercialisation

Half of the respondents declared that their research results had commercialisation potential and 12% had been involved in some kind of commercialisation activity at least once in the years 2013 to 2015.

References to applications for intellectual[19] and industrial[20] property rights are relevant to evaluate licences signed with social actors for commercial exploitation. Table 17 presents data on registrations, although there is not a one-to-one correspondence between application and licensing since rights obtained in previous years could have been licensed in the period considered.

Table 17 itemises the three commercialisation mechanisms investigated by discipline: intellectual property, industrial property and firm creation (spin-offs or start-ups). The results show that firm creation (based either on research results or researcher's knowhow) is the least frequent commercialisation type (3%), which is in line with the literature, and applies to highly business-oriented entities such as the Massachusetts Institute of Technology (Agrawal and Henderson 2002). Also, the larger proportion of applications for industrial property rights (19%) compared to licences obtained (6%), confirms the results in other reports on Spain (CRUE 2017) and international publications (Swamidass and Vulasa 2009), although, in any period, property rights granted in earlier years could be licensed, also to several organisations or for different uses (non-exclusive licences). We find similar differences between applications and exploitation in the case of intellectual property (7% registrations and 4% licences).

19. Registration of rights over digital content (computer programs, databases, web pages) and other creations (guides, questionnaires, records, etc.).

20. Obtaining patents, plant varieties or utility models.

Table 16. Formal interactions in 2013-2015 by scientific discipline (% and N) (multiple response)

Scientific discipline	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	Total (N)
Chemistry and physics	36	38	37	23	9	17	7	12	15	20	**1,636**
Humanities	28	20	23	26	9	9	19	16	8	5	**551**
Earth and environmental sciences	52	50	45	41	15	22	14	29	19	20	**1,077**
Social sciences	48	45	43	46	15	18	13	26	13	11	**1,960**
Engineering	54	57	54	36	14	20	10	20	22	35	**1,758**
Biological sciences	39	40	41	29	13	21	10	19	17	19	**1,292**
Mathematics and Information Technology	37	42	41	27	10	14	7	12	12	20	**1,342**
Medical sciences	42	39	54	53	22	31	15	45	23	28	**1,248**
Multidisciplinary	44	53	51	42	11	23	15	31	20	23	**88**
Total	**44**	**43**	**44**	**36**	**14**	**20**	**11**	**22**	**16**	**21**	**10,952**

Types of formal interactions:
1. Consultancy
2. Contract research
3. Joint research
4. Providing specialised training
5. Temporary stays at a non-academic organisation
6. Hosting non-academic actors
7. Creative or cultural products
8. Guidelines, protocols or norms
9. Renting, equipment or materials
10. Testing and prototypes

Missing values = 1,040.

Table 17. Registration* and commercialisation in 2013-2015 by scientific discipline (N and %) (multiple response)

Scientific discipline	Intellectual property		Industrial property		Firm creation		Total
	Registration**	Licence	Registration***	Licence	Results-based	Knowhow-based	(N)
Chemistry and physics	4	3	29	10	4	3	**1,788**
Humanities	6	10	1	0	1	1	**628**
Earth and environmental sciences	5	3	14	6	2	2	**1,149**
Social sciences	6	5	4	1	1	2	**2,133**
Engineering	11	4	36	11	5	4	**1,868**
Biological sciences	5	3	26	8	2	3	**1,429**
Mathematics and computer science	13	5	17	5	5	5	**1,474**
Medical sciences	7	5	17	5	2	2	**1,392**
Multidisciplinary	6	6	18	9	1	0	**99**
Total	7	4	19	6	3	3	**11,960**

Registration:
* Refers to the number of intellectual or industrial property rights obtained by the respondents in the same period, as the first step for later commercial exploitation.
** Registration of rights over digital contents (computer programs, databases, web pages) and other creations (guides, questionnaires, records, etc.) on other supports.
*** Obtaining patents, plant varieties or utility models.

4.2.5. Risks and barriers associated with external interactions

Regardless of interactions or not with a non-academic actor in the 2013-2015 period, respondents were asked to state whether, in their view, interactions with non-academic actors entailed any risk (see Table 18). The results of a factor analysis allow us to identify cognitive barriers composed of two main risk types related to scientific autonomy and scientific credibility (Ramos-Vielba *et al*. 2016). The former is more frequently considered a risk than the latter. In general, respondents with no experience of formal interactions (Table 18 column 1) perceived higher levels of both types of risk (fairly often or always) compared to those who had experience of formal interactions. The most notable differences, regardless of participation in formal interactions or not, were related to scientific credibility (changes to research focus, loss of scientific rigour).

Table 19 presents the perceptions of both kinds of risks, by discipline, for those who responded to the question on formal interactions. In general, chemistry and physics and engineering researchers have the highest perceptions of the existence of risks (fairly often or always) to scientific autonomy (23%), but we found no significant differences for risks associated with credibility. When comparing respondents with no experience of interacting with social actors and those with such experience, we found that the former group perceived a higher level of risk associated with cognitive barriers.

We asked how often researchers working at Spanish scientific institutions perceived certain institutional barriers when interacting with non-academic actors[21]: 40% fairly often or always perceive an institutional barrier. Bureaucracy and lack of flexibility are prominent barriers indicated by 61% of respondents who replied to both this question and the question about formal interactions. Table 20 shows that researchers with previous experience of formal interaction perceived greater institutional barriers compared to those with no experience of such interaction.

Thus, there are differences between researchers with and without previous experience of formal interactions. A higher proportion of the latter perceive cognitive barriers. However, experience of formal interaction increased perception of institutional barriers.

Regardless of participation in external interactions, if the responses for institutional barriers are distributed according to type of employing organisation, we find that researchers working in research centres have a higher perception of institutional barriers than those employed in other organisations (Figure 9). Among those indicating fairly often or always this type of barrier, the percentage of researchers from research centres is 50% compared to researchers working in a hospital (45%), those with multiple affiliations (40%) and those employed in a university (38%).

21. This response included the option *do not know*.

Table 18. Risks associated with external interactions (cognitive barriers), by experience of formal interactions (%)

		Fairly often / always		
		Formal interactions		
		No	Yes	Total*
Risk for scientific autonomy	Discrepancies connected with the time horizon of the research	37	35	36
	Difficulties in negotiation over intellectual property rights	23	21	22
	Conflict of interests between academic and non-academic actors	16	15	16
Risk for scientific credibility	Detrimental to research lines	17	12	14
	Drop in scientific rigour of research	16	11	13
	Detrimental to researchers' scientific careers	13	13	13
	Loss of prestige of the scientific activity	9	7	8

Total variance explained: 72.9%. Rotation method: Varimax with Kaiser normalisation.
* The total column refers to those who answered the question on the risks of external interactions (cognitive barriers) and the question on formal interactions. The number of missing values varies for each item, which is why the valid N varies from 10,573 to 10,764.

Table 19. Risks associated with external interactions (cognitive barriers), by experience of formal interactions and scientific discipline (% and N)

Scientific discipline	Fairly often / always					
	Risks for scientific autonomy			Risks for scientific credibility		
	Formal interactions			Formal interactions		
	No	Yes	Total	No	Yes	Total
Chemistry and physics	24	22	23	14	7	10
Humanities	14	11	12	13	8	11
Earth and environmental sciences	24	15	18	14	7	9
Social sciences	13	9	10	11	7	8
Engineering	25	22	23	13	10	10
Biological sciences	23	20	21	11	7	9
Mathematics computer science	20	23	22	11	11	11
Medical sciences	17	16	16	10	9	10
Multidisciplinary	15	21	19	14	9	10
Total (%)	**20**	**18**	**18**	**12**	**8**	**10**
Total (N)	**3,892**	**6,608**	**10,500**	**3,884**	**6,556**	**10,440**

Table 20. Risks associated with external interactions (institutional barriers), by experience of formal interactions (%)

	Fairly often / always		
	Formal interactions		
	No	Yes	Total*
Bureaucracy and lack of flexibility	55	65	61
Unclear administrative procedures for interaction with non-academic actors	34	41	38
Poor capacities (technical, negotiation, marketing) of the management staff	32	42	38
Conflicts from norms and regulations for financing of the research	32	41	38
Little reward for interactions with non-academic actors in the current evaluation system	28	39	35
Lack of support of technology transfer offices	26	33	30
Unrealistic expectations on the results of interaction with non-academic actors	26	30	29
Conflicts related to intellectual property rights	17	22	20

* The total column refers to those who answered the question on the risks of external interactions (institutional barriers) and the question on formal interactions. The number of missing values varies for each item, which is why the valid N range from 10,353 to 10,505.

4.2.6. Benefits of interactions for researchers and non-academic actors

Interactions with social actors are presumed useful for providing research questions, a real exploration context, resources or possible applications for research results (Levin *et al*. 2011).

Table 21 presents the percentages of respondents that indicated external interactions (formal, informal or commercialisation) during 2013 to 2015 as fairly or very important for their research. These are broken down into identification of new approaches and perspectives (47%), possible ideas for research questions (46%) and understanding problems faced by non-academic actors (45%). Other results obtained from external interactions are of a strategic or practical nature.

Figure 9. Risks associated with external interactions (institutional barriers), by type of organisation (%)

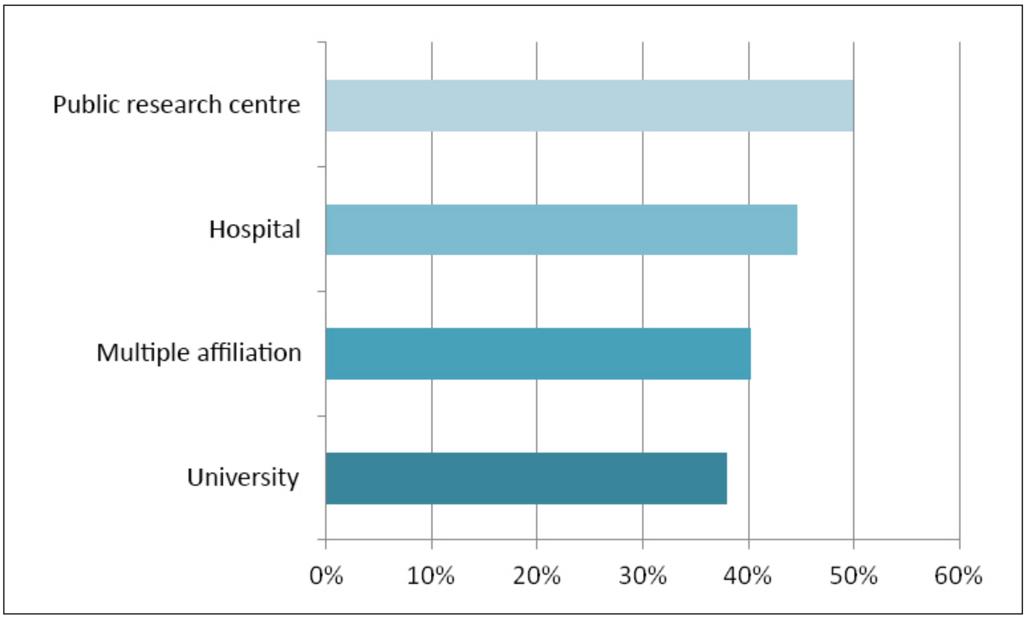


Table 21. Scientists' perceptions of the benefits of external interactions (%) (multiple response)

		Fairly / very important
1.	Identification of new approaches and perspectives	47
2.	Possible ideas for research questions	46
3.	Understanding problems faced by non-academic actors	45
4.	Identification of relevant sources of information for progressing in research	41
5.	Validation of ideas of scientific interest	41
6.	Specific responses to research problems	39
7.	Access to equipment, materials or financial resources	37
8.	Credibility and endorsement of external authority	36
9.	Social recognition of the research performed	34

Table 22 presents the first five results (stemming from external interactions during 2013-2015) considered by researchers to be fairly or very important for their research, again disaggregated by discipline. Respondents who regard themselves as multidisciplinary researchers are the most prominent in three of these five results. The most important outcome of external interactions (informal, formal or for commercialisation), in most disciplines except earth sciences and the environment, social sciences and engineering, is identification of new approaches and perspectives, and possible ideas for new research questions. In earth sciences and the environment, social sciences and engineering, the most important outcome is understanding non-academic actors' problems.

The questionnaire also asked respondents about which results had, in their opinion, stemmed from external interactions with non-academic actors. In the case of firms, new knowledge requirements are diverse, depending on firm sector, firm characteristics and firm strategy (Asheim and Coenen 2005). Therefore, it is not possible to identify one single potential application of the new knowledge acquired through external interactions.

Table 23 presents respondents' assessment (fairly or very important for the non-academic actor) of the different results from the external interactions in which they participated (informal, formal or commercialisation). Scientific validation of social actors' ideas, options or proposals were considered important for 33% of respondents, followed by a better understanding of the non-academic environment (30%). Previous work by CSIC (Valmaseda-Andia *et al*. 2015) found that most of the companies consult-

Table 22. Scientists' perceptions of the benefits of external interactions, by scientific discipline (%) (multiple response)

	Fairly / very important				
Scientific discipline	***1.***	***2.***	***3.***	***4.***	***5.***
Chemistry and physics	44	39	41	34	36
Humanities	49	45	38	45	40
Earth and environmental sciences	46	47	50	39	41
Social sciences	49	51	53	48	42
Engineering	51	46	54	44	45
Biological sciences	43	43	39	35	34
Mathematics and computer science	47	47	45	41	42
Medical sciences	47	49	34	38	42
Multidisciplinary	56	52	44	47	46
Total	**47**	**46**	**45**	**41**	**41**

Results for their research:
1. Identification of new approaches and perspectives
2. Possible ideas for research questions
3. Understanding problems faced by non-academic actors
4. Identification of relevant sources of information for progressing in research
5. Validation of ideas of scientific interest.

Table 23. Scientists' perceptions of the benefits of external interactions for non-academic actors (%) (multiple response)

		Fairly / very important
1.	Scientific validation of non-academic actors' ideas, options or proposals	33
2.	Better understanding of the non-academic environment	30
3.	Solving technical or organisational problems of non-academic actors	29
4.	Training of non-academic actors	28
5.	Development of new products or services or improvement of existing ones	27
6.	Support and legitimation of the activities undertaken by non-academic actors	26
7.	Identification of new opportunities for activity or business	24
8.	Strengthening the image, reputation or prestige	24
9.	Improvements in organisational practices or work procedures	21
10.	Extension of professional networks	20

ed considered the results of their interactions with the scientific sphere to be fairly or very beneficial, and highlighted, especially, increased firm prestige. However, this study found that researchers seem not to perceive the importance of their interactions for non-academic actors in the same way, which might suggest the need for feedback or follow-up mechanisms to check the real effects generated.

Table 24 presents data, by discipline, on the first five results of external interactions, ranked by respondents as fairly or very important for non-academic actors. Differences by scientific disciplines are low. In social sciences 41% indicated a better understanding of the non-academic environment and 37% ranked as important training and qualification of staff generated by the interactions. Engineering respondents stressed solutions to technical or organisational problems (39%) and development of new products or services or improvements of existing ones (39%). Multidisciplinary researchers perceived greater benefits for non-academic actors from the scientific validation of ideas, options or proposals (38%). Humanities researchers were less sure about the importance of solutions to problems (14%) and the development of new products or services (15%) related to their interactions.

Table 24. Scientists' perceptions of the benefits of external interactions for non-academic actors, by scientific discipline (%) (multiple response)

	Fairly / very important				
Scientific discipline	***1.***	***2.***	***3.***	***4.***	***5.***
Chemistry and physics	29	21	26	21	27
Humanities	26	27	14	24	15
Earth and environmental sciences	35	33	33	31	26
Social sciences	36	41	28	37	22
Engineering	36	33	39	29	39
Biological sciences	30	24	25	23	24
Mathematics and computer science	31	25	29	23	34
Medical sciences	34	26	24	31	23
Multidisciplinary	38	30	34	32	29
Total	**33**	**30**	**29**	**28**	**27**

Results for non-academic actors:
1. Scientific validation of non-academic actors' ideas, options or proposals
2. Better understanding of the non-academic environment
3. Solving technical or organisational problems of non-academic actors
4. Training of non-academic actors
5. Development of new products or services or improvement of existing ones

Thus, on the one hand, a larger proportion of respondents ranked the different results obtained from external interactions as fairly or very important for their research, compared to those who perceived their results as being fairly or very important for social actors. On the other hand, in both cases, for both researchers and non-academic actors, results with a strategic component seem to be valued more highly than more practical outcomes or outcomes related to prestige.

4.3. DISSEMINATION OF RESEARCH

4.3.1. Knowledge transmission practices

We considered the respondents' involvement in knowledge transmission practices (Landry and Amara 2009) that seek to ensure the results of their research reach final users. A total of 57% fairly often or always engaged in one of the knowledge transmission activities presented in Table 25 during their professional careers. Overall, 22% of respondents, on average, fairly often or always engage in knowledge transmission activities. These include preparation of documents and products intended for final users (ranked fairly often or always by 33%), sending research results directly to final users (30%) or discussing the implications of research results with users (30%).

If academic ranks are considered (Figure 10), we observe that the mean value for transmission activities ranked fairly often or always during the professional career in level A, is 25%; in the case of level D (PhD students) this drops to 16%. Therefore, there is no corresponding increase associated to the different academic ranks, given that the mean values are slightly higher for both the group of *others* (24%) and level C (23%), compared to level B (21%).

4.3.2. Dissemination tools

Table 26 presents the percentage of respondents who fairly or very often use different types of tools to communicate the content or results of their research to non-academic actors. The responses are grouped into new and traditional tools, based on a factor analysis. Use of websites has increased and exceeds use of traditional methods, such as press articles, which might, among other things, be linked to greater autonomy in managing the dissemination process and ability to reach a bigger audience more directly using digital media with no need for intermediaries. The use of (new and traditional) tools is still a minority situation among researchers; the mean for use of photo or video-sharing social media networks is 1.21 (1 never and 2 seldom) and 2 (seldom) for articles in the press or non-academic journals. Note, however, that use of dissemination tools is a relatively recent trend and the results of dissemination are not considered in performance evaluations. In the case of use of all kinds of social media networks, 70% of the respondents never use them, 28% seldom or sometimes use them and 2% use them fairly often or always.

Table 25. Transmission activities throughout their professional career (%) (multiple response)

	Fairly often / always
I have prepared documents and products intended for final users	33
I have sent research results directly to final users	30
I have discussed the implications of research results with final users	30
I have prepared reports on specific aspects for specific users	29
I have presented research results to users for their immediate use	28
I have presented research results in layman's terms	24
I have provided examples or demonstrations of how to use research results	23

Figure 10. Average value of transmission activities according to academic ranks (%)

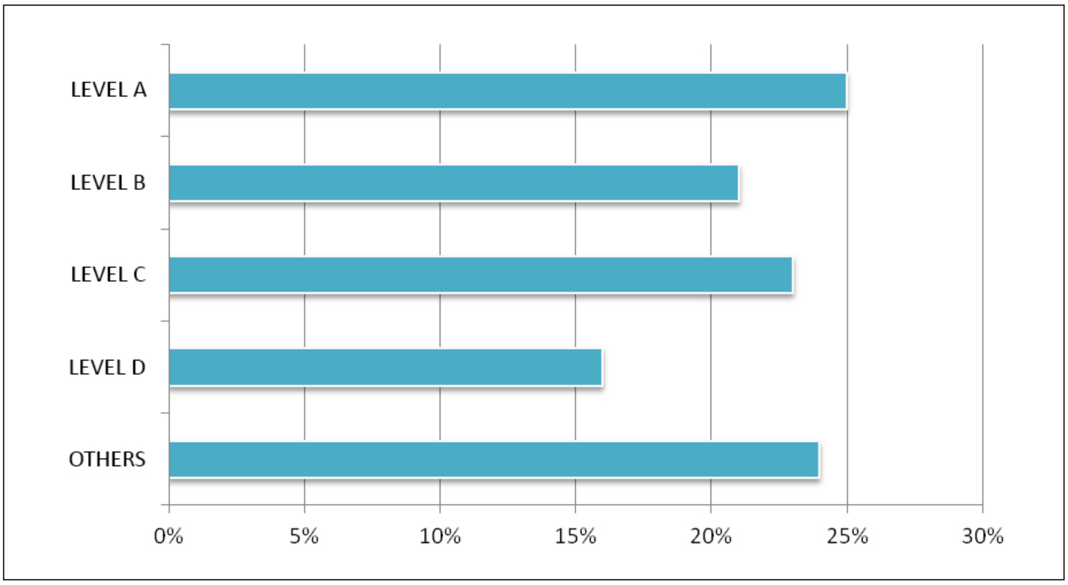


Table 26. Tools for communicating research content or results to non-academic actors (%)

		Fairly / very often
New	Dissemination web sites (personal web or others)	22
	General social media networks (Facebook, Google+, Hi5 or similar)	10
	Microblogging (Twitter, Tumblr or similar)	7
	Blogs	6
	Video-sharing social media networks (Youtube, Vimeo, TED Talks or similar)	4
	Photo-sharing social media networks (Instagram, Pinterest, Flickr or similar)	2
Traditional	Articles in the press or in non-academic journals	13
	Interviews given to the media	8
	Commented databases available in open source format	7
	Wikipedia	3
	Audio recordings (podcast)	2

Total variance explained = 52.3%. Rotation method: Varimax with Kaiser normalisation.

Table 27 shows that humanities researchers make the most use of both new and traditional tools. This group considers its contribution to culture as part of its vocation and new media have facilitated this (Olmos-Peñuela *et al*. 2014). Mathematics and information technology researchers use traditional tools to transfer the content or results of their research to non-academic actors less than the other disciplines. In the case of new tools, researchers in chemistry and physics and medical sciences make the least use of them for dissemination purposes.

Based on academic rank (Table 28), we observe that use of traditional tools for conveying the content or results of research to non-academic actors increases over the academic career, from levels D (40%) to A (64%). In the case of new tools, the reverse applies, with a greater presence among predoctoral (level D) (51%) and postdoctoral researchers (level C) (49%), dropping for levels B and A to 43%. For new tools, these differences are reflected in use of social media networks (Table 28 column 3), used by 40% in level D and 37% in level C, compared to 28% in B and 26% in A. For the *others* group, use of traditional tools is similar to level C (48%) and includes new tools and social media networks in particular, to a degree between levels C and B, but closer to level B.

4.3.3. Contribution of social media networks

Respondents were asked about the contribution made by academic researchers' use of social media networks to their scientific work and their links to the non-academic environment. These aspects are categorised as making a positive or a negative contribution (Lupton 2014), based on a factor analysis.

Table 27. Tools for communicating research content or results to non-academic actors by scientific discipline (%)

Scientific discipline	Traditional	New
Chemistry and physics	48	37
Humanities	69	61
Earth and environmental sciences	66	44
Social sciences	61	56
Engineering	43	39
Biological sciences	54	38
Mathematics and computer science	42	48
Medical sciences	51	37
Multidisciplinary	46	43
Total	**52**	**44**

Missing values: 528.

Table 28. Tools for communicating research content or results to non-academic actors by academic rank (% and N)

Professional category	Traditional	New	New: social media networks
Level A	64	43	26
Level B	52	43	28
Level C	48	49	37
Level D	40	51	40
Others	48	44	33
Total (%)	**52**	**44**	**30**
Total (N)	**11,189**	**11,183**	**11,326**

Table 29 presents the percentages of researchers with a (fairly or very high) perception that the positive contributions outweigh the negative ones. The positive contributions include for 54% the possibility of diffusing research content or results and sharing information with the non-academic world. For 42%, use of social network promotes outreach to the non-academic spheres. On the negative side, there is concern that an effect of incorporating social media networks might be to give priority to visibility to the detriment of the quality of the content being disclosed (37%), but there was little perception (9%) that social media networks are a threat to the scientific career.

Analysis of the contribution made by researchers' use of social media networks by scientific discipline (Table 30) shows that the largest percentage of those who value them positively are in humanities (54%) and social sciences (53%), while the highest percentages of negative valuations (25%) are in medical sciences.

If we compare positive valuations of the contribution of social media networks based on academic ranks (Table 31), we find they are higher for level D (55%) and drop as seniority increases (from C to A, except for the group of *others*). Within each academic level, women have a more positive evaluation than their male counterparts. In terms of negative evaluations, the highest values are in the *others* group (20%) and the lowest are in level C (13%). The differences between women and men do not follow any clearly identifiable pattern.

To summarise, on average, 22% of respondents declared fairly often or always engaging in some sort of activity to transmit their knowledge and findings to final users through *ad hoc* practices, during their professional careers. A minority regularly uses dissemination tools, and a larger proportion of them consider the contribution of using social media networks to be positive rather than negative.

Table 29. Contribution of the use of social media networks by researchers (%)

		Fairly / Very high
Positive	Diffusing research content or results outside the academic world	54
	Sharing information outside the academic world	54
	Furthering outreach to non-academic spheres	42
	Breaking down frontiers between personal and professional spheres	40
	Generating connections and networks with individuals or groups outside the academic world	34
	Receiving support outside the academic world	21
Negative	Prioritising visibility as opposed to content quality	37
	Reducing scientific credibility	21
	Becoming a target for external attacks	21
	Putting one's scientific career at risk	9

Variance explained = 64.4%. Rotation method: Varimax with Kaiser normalisation

Table 30. Contribution of use of social media networks by researchers by scientific discipline (%)

	Fairly / Very high	
Scientific discipline	**Positive**	**Negative**
Chemistry and physics	33	15
Humanities	54	19
Earth and environmental sciences	45	15
Social sciences	53	15
Engineering	32	16
Biological sciences	41	18
Mathematics and computer science	34	12
Medical sciences	47	25
Multidisciplinary	36	12
Total	**41**	**17**

Table 31. Contribution of use of social media networks by researchers by academic rank and gender (% and N)

	Positive			Negative		
Academic rank	**Women**	**Men**	**Total**	**Women**	**Men**	**Total**
Level A	35	29	30	16	18	18
Level B	44	36	39	17	16	16
Level C	58	47	52	12	13	13
Level D	66	48	55	18	15	16
Others	56	47	51	19	21	20
Total (%)	**48**	**37**	**41**	**16**	**17**	**17**
Total (N)	**3,925**	**6,925**	**10,850**	**3,925**	**6,964**	**10,889**

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APPENDICES

Appendix 1. Structure of the questionnaire

The questionnaire consists of 42 questions arranged in the following blocks:

A. Professional career (11 questions): doctorate: year, institution and area of knowledge in which this was obtained; current academic rank; year obtained, scientific discipline, type of institution; previous professional experience, directing positions held and number of *sexenios* obtained.

B. External interactions (9 questions): research orientation (basic/applied), types of non-academic actors they interacted with, type and number of formal interactions, type and frequency of informal interactions, type and number of commercialisation activities performed; importance of results of interactions; barriers associated to interactions.

C. Research activities (6 questions): motivations, time distribution (teaching, research, administration, knowledge transfer, dissemination, fundraising); skills, uses of non-academic inputs, international academic activities, self-efficacy.

D. Academic work environment (5 questions): team size, disciplines, importance granted by their institution to different scientific activities, opinion on their institutions’ supporting services of their institution to interactions with the non-academic world, institutional obstacles for the interaction.

E. Dissemination of research (5 questions): transmission activities, tools, use and contribution of social media networks.

F. Profile of the respondent (4 questions): age, nationality, gender.

G. Observations (2 questions): interest in receiving the results of the study, free comments on the questionnaire.

Appendix 2. Responses by type of organization

Type of organisation	Survey	% by final sample	Final sample
University	9,939	21 %	47,120
Research centre	1,400	24 %	5,929
Hospital	653	15 %	4,282
Total	**11,992**	**21 %**	**57,406***

*Missing values: 75.

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