Is university-industry collaboration biased by sex criteria?

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Abstract

This paper studies the attitudes and decisions of research groups led by men or women towards the collaboration with firms in research and development joint projects. We worked with a sample of 420 research groups of eight regions of Spain, France and Portugal in a sequential process. First, we studied the interest of the research groups to collaborate and, then, if the final decision of collaborating with firms changed according to the sex criteria. The results show that women are worse positioned in the social networks of collaboration and commercialization with industry. Research groups led by men have around 10% higher probability of showing interest in R&D cooperation with firms. However, when men and women leaders of research groups have the same motivation to collaborate, they do not differ in their decision of collaborating. These results evidence different initial attitudes towards university-industry collaboration according to sex criteria.

Key words: university-industry collaboration; knowledge management; female researchers; technology transfer

Introduction

The study of the different motives driving University-Industry (U-I) collaboration have occupied to researchers for decades (Ferreira, Raposo & Fernandez, 2013). Previous studies evidence that those countries with a rich tradition of U-I collaboration maintain SMEs with higher absorptive capacity of innovation, more industry-oriented universities, and more supportive instruments of financing and commercializing the cooperation outcomes (Koschatzky & Stahlecker, 2010). The U-I collaboration forms a multi-polar network that facilitates the firms' innovation capacity to compete in the New Economy through alliances (Wright & Dana, 2003; Dana, Etemad, & Wright, 2008). In addition, when the inter-organizational collaboration maintains through time, the interdependences can create symbiotic relations that support the competitive advantage of the organizations involved (Etemad, Wright, & Dana, 2001). In this sense, U-I collaboration often leads to technology transfer and knowledge spillovers from research laboratories to productive sector (Ferreira, Dana & Ratten, 2017)

The collaboration between university research groups and firms involves systemic relations at three levels: (1) individual, because the decision to engage is primarily taken at the individual level (Bozeman, Fay, & Slade, 2013; Perkmann et al., 2013; Calvo Fernández-López, Rodeiro-Pazos & Rodríguez-Gulías, 2018; Fernández-López, Calvo Fernández-López & Rodeiro-Pazos, 2018), (2) organizational, because most researchers that collaborate with firms use the knowledge synergies and scientific equipment of their research group (Mansfield, 1998, Faulkner & Senker, 1995), and (3) institutional, because the collaboration is formally managed between the university and the firm, in order to fulfil the requirements of the legal framework of property rights and confidentiality of results (Arrow, 1962; Kremer, 1998).

Particularly, at the individual-level, the sex of the team members can condition their inter-personal relations, and, at last extent, the collaboration strategy between researchers and firms

(Bozeman & Corley, 2004; Azagra-Caro, 2007; Bozeman & Gaughan, 2011). Similarly, the sex of the research group leader can also influence the collaboration behaviour inside of the research team (Schein, 1975; Petty & Bruning, 1980; Brenner, Tomkiewicz, & Schein, 1989; Foster, 1994; Young & Hurlic, 2007), or in other words, at organizational and institutional levels.

Although there is a considerable amount of literature on U-I collaboration, some fundamental questions remain opened. Recently studies (Ferree & Zippel, 2015; Gill, 2014; Gill & Donaghue, 2016; Zippel, Ferree & Zimmermann, 2016) have examined knowledge production in higher education including a gender perspective. Nevertheless, there is little work on sex differences in attitudes towards U-I engagement in R&D. In addition, most of the studies devote attention to engagement in collaborative projects at the researcher (individual) level (Bozeman & Corley, 2004; Azagra-Caro, Archontakis, Gutiérrez-Gracia, & Fernández-de-Lucio, 2006; Azagra-Caro, 2007; Link, Siegel, & Bozeman, 2007; Bozeman & Gaughan, 2011), neglecting that engagement is the 'last and successful' step of a sequential process that previously requires the researcher's interest in collaborating. Moreover, both 'stages' of the collaboration process (i.e. interest and engagement) can be conditioned by the research group'strategy. Finally, the few studies on the issue usually lack of a theoretical framework for hypothesizing the relationship between sex and R&D collaboration.

This paper aims to fill these gaps in the literature on sex differences in U-I collaboration by studying the attitudes and decisions of research groups led by men or women towards the collaboration with firms in research and development joint projects. The objective of the paper is to analyse whether the sex of the research group leader influences the attitudes towards the U-I engagement in R&D. More specifically, adopting a social network approach we answer two questions: Are the research groups led by a woman more interested in collaborating with firms ('first stage' of the collaboration process)? and, among the research groups interested, are those led by a woman more likely to be engaged in formal collaboration ('second stage' of the collaboration process) than those led by a man?

This study makes several contributions. First, instead of considering the researcher as unit of analysis, as most of previous studies, we use the research group leader, in an individual-organizational approach. Second, unlike previous studies, we draw on the social network theoretical approach. Finally, we identify the U-I cooperation as a sequential process. To the best of our knowledge, no study focuses on sex gender differences in U-I collaboration has followed this approach. In so doing, we make not only methodological contributions, but also theoretical contributions; because the findings show that the sex gap differs along the U-I collaboration process. Therefore, the policies geared towards narrowing this gap should differ at each stage of the process.

We introduce the conceptual framework in Section 2. In Section 3, we present the methodological approach and the scope of the research. In Section 4, we reflect the outcomes of the econometric model and, finally, in Section 5 we conclude the study and propose some issues for practitioners and future research.

Theoretical framework

Over the last two decades, a stream of the literature on U-I collaboration began devoting attention to sex differences. Generally, the studies introduce sex as a control variable and lack of a theoretical framework for hypothesizing the relationship between sex and R&D collaboration. Some studies conclude that the sex of the researcher is a relevant variable that influences the inter-personal and inter-organizational relations, even in academia (Bozeman & Corley, 2004; Azagra-Caro et al.; 2006; Azagra-Caro, 2007; Link et al. 2007; Bozeman & Gaughan, 2011). Unlike these studies, we focus the analysis on the role played by the sex of researchers in U-I collaboration by adopting a social network approach. Under this approach, individuals are embedded in a complex network of interrelationships with other individuals.

This behaviour causes certain interdependence, that is, each party can rely on the other in an ongoing manner (Etemad et al., 2001). However, there is a gap research about the position of female researchers in the social networks of knowledge commercialization, and what factors explain this position.

Position of female researchers in the social networks of knowledge commercialization

Advancing into the social network approach, Meng (2016) suggests that women are worse positioned in the social networks of commercialization with industry than men, and therefore it reduces their innovation capacity (patenting). It could be partly due to the fact that the importance of work–life balance reduces women' opportunities for developing collaborative research projects and building career-related information networks, compared to men (Valian, 1999; Williams, 2000).

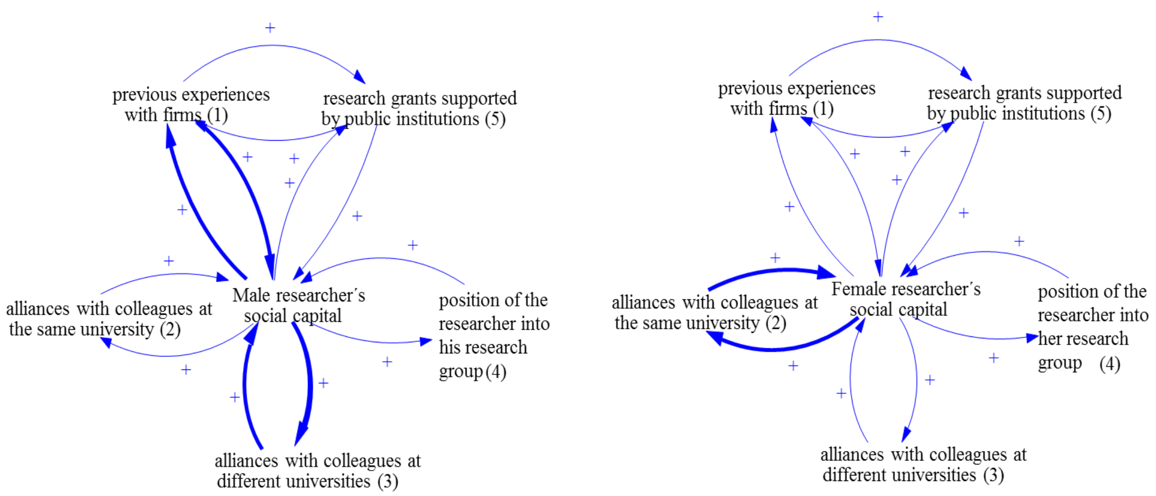
Van der Gaag and Snijders (2004) define the individual's social capital as the collection of resources owned by the members of an individual's personal social network, which may become available to the individual because of the history of these relationships. From this approach, the value of the research group leader is dependent on the value of his/her relationships, in terms of financial resources, talent attraction, use of scientific equipment or knowledge transfer, all of them coming from their professional relationships.

Drawing on the literature on U-I collaboration, the researcher´s social capital will be mainly conditioned by: (1) the previous experience in collaborative projects with firms (D´Este & Patel, 2007; D´Este & Perkman, 2011; Pinto, 2011; Petruzzelli, 2011), (2) the alliances with colleagues at the same university, (3) the alliances with colleagues at different universities (Gulbrandsen & Smeby, 2005; Meng, 2016), (4) the position of the researcher into his/her own research group (Gulbrandsen & Smeby, 2005), and (5) the support of public institutions through research grants (Bozeman & Gaughan, 2007). Although each one of these factors individually increases the stock of the researcher´s social capital, the interaction of some of them can have a balancing effect on the level of social capital (Figure 1).

Focusing on the sex criteria, Bozeman and Corley (2004) states that collaboration patterns vary between male and female researchers. The authors find that female researchers collaborate more with other females than male researchers in the same conditions do. Additionally, men show more international collaboration with colleagues at other universities (Fox & Mohapatra, 2007; Frehill & Zippel, 2010). Later on, based on a survey of 1,700 respondents of academic scientists of the U.S.A., Bozeman and Gaughan (2011) conclude that men and women also differ in their collaboration strategies, since men are more focused on the collaboration based on instrumentality and previous experiences than women are.

According to the previous arguments of the literature, Figure 1 highlights the most relevant loops of collaboration for male and female researchers. Male researchers build their networks on previous experiences with firms and alliances with colleagues at different universities, while women do it on alliances with colleagues at the same university. These sex differences in collaboration strategies may condition women's social networks and, then, their attitudes towards U-I engagement in R&D.

Figure 1: Loops of collaboration strategy for male and female researchers



Factors of sex differences in social networks of knowledge commercialization

Previous studies on U-I collaboration reveal that: 1) prior collaborative experiences and the resources transfer from industry to researchers have positive influence on researchers´ interest to collaborate with firms (Schartinger, Rammer, Fisher, & Fröhlich, 2002; Lee, 2000; D´Este & Patel, 2007; Nilsson, Rickne, & Bengtsson, 2010; D'Este & Perkmann, 2011; Petruzzelli, 2011; Pinto, 2011); 2) the scientific quality of university and department positively relates with industry collaboration (Schartinger et al., 2002; Bruno & Orsenigo, 2003; D´Este & Perkmann, 2007; D´Este & Patel, 2007; Pinto, 2011; Abramo, D´Angelo, & Di Costa, 2011); 3) the size of the research group also influences its collaboration propensity (Abramo et al., 2011; Bozeman & Gaughan, 2011; Pinto 2011); 4) most U-I engagements rise between knowledge-intensive industries and technical researchers (Lee, 1998; Meyer-Kramer & Smoch, 1998; Schartinger et al., 2002; Azagra-Caro et al., 2006; D'Este & Perkmann, 2011); and, 5) the amount of the public research budget negatively relates with the researchers´ interest in collaborating with firms (Gulbrandsen & Smeby, 2005; D'Este & Perkmann, 2011; Schuelke-Leech, 2013).

In this paper we argue that the aforementioned driving forces of U-I collaboration condition the loops of researchers' collaboration, eventually affecting the researchers' social networks of knowledge commercialization and their attitudes to R&D collaboration.

Regarding previous experience in collaborative projects (loop 1), there is evidence of that those researchers that have previously collaborated with firms are more prone to have future engagements (Schartinger et al., 2002; Pinto, 2011), and they increase their value as providers for the firms (Lee, 2000; D´Este & Patel, 2007; Nilsson et al., 2010; D'Este & Perkmann, 2011; Petruzzelli, 2011). Under this argument, the engagement of women with industry depends on the previous involvement of their peers (Giuliani, Morrison, Pietrobelli, & Rabelloti, 2010). At this point, most of research shows a lesser engagement of women compared to men because of their lesser experience (Boardman & Ponomriov, 2009).

Most of previous research claims that the scientific quality of the research group (related to loops 2 and 3) is positively related to R&D agreements with firms. Thus, researchers involved in R&D collaborations show a higher number of publications (D´Este & Patel, 2007). The empirical studies that include the sex variable to explain different scientific production between men and women in academia offer evidences of a lower scientific productivity of women compared to men (Blackburn, Bieber, Lawrence, & Trautvetter, 1991; Bailey, 1999; Sax, Hagedorn, Arredondo, & Dicrisi, 2002), although there are not conclusive evidences that being man or woman can explain a lower scientific productivity in same conditions (Xie & Shauman, 1998; Kotrlick, Bertlett, Higgings, & Williams, 2002). In this line of reasoning, Azagra-Caro et al. (2006) conclude that the engagement of female researchers in cooperation agreements with firms is lower than the engagement of men, which may be explained by a a higher focus of the former on teaching rather than on scientific production. This conclusion had been previously reinforced by other studies (Park, 1996; Bird, Litt, & Wang, 2004) that showed that male academics, on average, spend less time than women in teaching and more hours in research.

In contrast, Kremer (1998) provides arguments in favour of a negative relationship between the scientific quality of the research group and R&D collaboration. Given that most companies do not permit the publication of collaboration results through confidentiality clauses, researchers may be less motivated to collaborate with industry since the scientific production (mainly articles published in high-impact journals) is significantly related to their promotion at institutional-level.

The position of the researcher in the group (loop 4) is related to the both the size and the field of science of the research group. Thus, it is traditionally found that the higher the research group is, more prone the collaboration will be (Abramo et al., 2011; Pinto 2011). Since most of research considers the researcher as the unit of analysis, only few studies relate the sex of the leader and the size of the research group. Thus, Bozeman and Gaughan (2011) find that mentoring strategies of collaboration with internal and external actors (firms) are associated with a greater number of collaborators for both men and women, but only in the case of women, the mentoring strategy increases the number of collaborators.

The field of science of the research group is relevant since most U-I agreements happen in applied fields, engineering and technology (Lee, 1998; Meyer-Kramer & Smoch, 1998; Azagra-Caro et al., 2006, D'Este & Perkmann, 2011), and natural and life sciences (Schartinger et al., 2002). Similarly, Bozeman and Gaughan (2011) conclude that those researchers with more industrial interactions have also more collaborators. The empirical evidence shows that women are under-represented in the fields most active in technology transfer, so they have fewer opportunities to engage with industry (Bozeman & Corley, 2004; Azagra-Caro et al., 2006; Link et al., 2007).

Finally, the effect of the research budget (loop 5) on the attitudes towards R&D collaboration with firms is not so clear. Grants and contracts tend to increase the industrial engagement of university researchers (Meyer-Kramer & Smoch, 1998; Lee, 2000; Bozeman & Gaughan, 2007; Nilsson et al., 2010). However, in some occasions, if the researcher gets enough research budgets through public grants, it is likely that he or she is not so interested in collaborating with firms (Gulbrandsen & Smeby, 2005; D'Este & Perkmann, 2011; Schuelke-Leech, 2013).

To sum up, drawing on previous literature we argue that the aforementioned driving forces of U-I collaboration condition the researcher's social networks and, eventually, her or his attitudes towards R&D cooperation with firms. Moreover, R&D cooperation must be seen as a sequential process since the mentioned factors can play a different role at different stages of the process.

Methodology

The data and sample

As mentioned, the unit of analysis is the university research group. In this respect, we had access to information about university research groups in eight regions of the Southern Europe (Spain: Galicia, Vasque Country, Andalusia, Cantabria, Castille and Leon; France: Aquitannie, Centre; Portugal: Lisbon). The data for the empirical analysis were collected through a sequential process over the period 2011-2013. More specifically, in the first stage, 420 semi-structured interviews to research groups were conducted (306 in Spain, 86 in France and 28 in Portugal). During the interviews, research groups answered about their specific characteristics (size and budget) and scientific outcomes (publishing, patenting activity, innovation production and previous collaborations with firms). The survey also collected information about the interest of research groups to collaborate with firms in the R&D field.

At the same time, a sample of firms in the same regions was contacted in order to know their interest in collaborating with research groups, as well as their innovation demands. In particular, 439 semi-structured interviews were conducted (262 in Spain, 127 in France and 50 in Portugal).

In the second stage, those firms that had previously shown interest in collaborating with universities research groups were asked to describe in detail the innovative problems they faced (innovation demands).

In the third stage, research groups and firms previously interested in collaborating were put in touch. After several meetings, if a firm and a research group identified an innovative problem likely to solve working together, they signed one or more collaborative projects.

Definition of the variables

In order to analyse whether the sex of the research group leader influences the attitudes towards the U-I engagement in R&D, we considered cooperation as a sequential process. Therefore, we defined two dependent variables. The interest in collaborating with firms (the first stage of the cooperation process or necessary condition) was defined as a dummy variable coded as 1 if the group had shown interest in engaging in R&D cooperation with firms and 0 otherwise (D_INT). The decision to cooperate with firms (second and successful stage of the cooperation process) was defined as a dummy variable coded as 1 if the group signed one or more collaborative projects with firms and 0 otherwise (D_COOP).

The main independent variable was a dummy variable coded as 1 if the research group leader was a man and 0 otherwise (MEN). Additionally, drawing on the reviewed literature, we considered the following independent variables (Table 1).

We measured the size of the research group as the natural logarithm of the number of members in 2011 (LN_TOTAL). With regard to the field of science of the research group, there is no consensus on how some academic disciplines should be classified, even when OECD's Frascati Manual has classified research and experimental development (R&D) in the report Fields of Science and Technology 2007 (OCDE, 2007). In our sample we grouped five fields of science: Humanities and Arts (D_HUMART); Health and Welfare (D_HEALTHWEL); Science, Mathematics and Computing (D_SCMATH); Social Sciences, Business and Law (D_SSBL), and Engineering, Manufacturing and Construction (D_EMC). In this study, we considered the branch of knowledge that is taught and researched by each group at the departmental level as its field of science. Thus, we constructed five dummy variables coded as 1 for the referenced field of science and 0 otherwise. We omitted D_SCMATH variable to avoid perfect multicollinearity, therefore the field of science effects should be interpreted in relation to the field of Science, Mathematics and Computing.

In order to know the effect of a research group' budget on its attitudes towards R&D cooperation with firms, we used the natural logarithm of its research budget in 2011 (LN_BUDGET).

We measured the scientific quality of the research group by both the number of publications in Science Citation Index (LN_SCI) and the number of patents (LN_PATENT) over the period 2009-2011. We used a natural-log transformation in both cases.

Similarly, we measured the prior collaborative experience of the research group by two groups of variables. We used the natural logarithm of the number of collaborative projects signed between 2009 and 2011 (LN_AGREE). Given that some of these collaborative projects might have finished without any tangible result, we also used a set of dummy variables coded as 1 if the group had successfully helped a firm to introduce some type of innovation over the period 2009-2011, and 0 otherwise. More specifically, in order to test the effect of the different types of innovation, we defined four dummy variables to capture whether the group had jointly developed product innovation (D_IPROD), process innovation (D_IPROC), commercial innovation (D_ICOM) or organizational innovation (D_IORG).

Finally, we considered three country dummy variables (FRANCE, PORTUGAL and SPAIN). Each one we coded as 1 for the referenced country and 0 otherwise. We included these dummy variables to capture idiosyncratic cultural or institutional factors for each country. We omitted FRANCE dummy variable to avoid perfect multicollinearity, therefore the institutional country effects should be interpreted in relation to France.

Table 1. Questions regarding the interest of the research group to collaborate

Contributions of the research group to firms' innovation	
In the last three years (2009-2011), what kind of contributions has your research group developed for the firm´s innovation?	1. Contributions to product innovation
	2. Contributions to process innovation
	3. Contributions to commercial innovation
	4. Contributions to organizational innovations
Expectations for future collaborations	
In the next three years (2012-2014), is your research group available to do contributions for firms' innovations?	1. Description of "scientific and technological services"
	2. Description of "R&D projects
	3. Description of "tools for innovation management"
Is your research group interested in contacting with firms for participating in innovation agreements?	

Empirical results

Univariate results

The sample comprised 420 research groups: 94 led by women (22%) and 326 led by men (78%). Whereas 32% of the research groups led by men showed interest in collaborating with firms at the end of first stage of the process, 26% of the groups led by women did (Table 2). However, this difference disappeared at the second stage of the process, since 23% of the research groups interested in cooperating eventually signed collaborative projects with firms regardless the sex of the leader. As a result, 16% and 17% of the research groups respectively led by women and men ended cooperating with firms.

Table 2: Definitions of variables and predictions

Factor	Variables	Pred.	Definition
DEPENDENT VARIABLES	D_INT		Whether or not the group was interested in R&D cooperation with firms (1 or 0)
	D_COOP		Whether or not the group was definitively engaged in R&D cooperation with firms (1 or 0)
SEX	MEN	?	Whether or not the group was leaded by a man (1 or 0)
SIZE	LN_TOTAL	+	Natural logarithm of the number of members in 2011.
FIELD OF SCIENCE	D_HUMART D_HEALTHWEL D_SSBL D_EMC D_SCMATH (omitted)	?	Whether or not the group teaches and does research on Humanities and Arts/ Health and Welfare/ Science and Mathematics/ Social Sciences, Business and Law/ Engineering, Manufacturing and Construction (1 or 0)
RESEARCH BUGDET	LN_BUDGET	+	Natural logarithm of research budget in 2011
SCIENTIFIC QUALITY	LN_SCI	+	Natural logarithm of the number of publications in Science Citation Index over the period 2009-2011
	LN_PATENT	+	Natural logarithm of the number of patents over the period 2009-2011
EXPERIENCE	LN_AGREE	+	Natural logarithm of the number of collaborative projects signed between 2009 and 2011
	D_IPROD, D_IPROC, D_ICOM, D_IORG	+	Whether or not the group had jointly developed product/ process/ commercial/ organizational innovation in 2009-2011 period (1 or 0)
COUNTRY	PORTUGAL, SPAIN, FRANCE (omitted)	?	Whether or not research the group is French/ Portuguese/ Spanish (1 or 0)

As shown in Table 3, most of the research groups work on the fields of Engineering, Manufacturing and Construction (47%) and Health and Welfare (32%). The mean research budget in 2011 was €3 million. Although the average size of the groups is around 20 members, the 32% of the groups have 5 or less members. The mean values of the number of publications in Science Citation Index, patents and collaborative projects over the period 2009-2011 achieved 37 publications, 4 patents and 15 agreements. All these variables showed a high standard deviation. Regarding the types of jointly developed innovations, 13% of the sample research groups had helped to introduce product innovation (D_IPROD), 12% process innovation (D_PROC), 4% commercial innovation (D_COM) and 5% organizational innovation (D_ORG).

The country distribution was as follows: 73% of the sample research groups were Spanish, 20% were French and 7% were Portuguese.

Table 3: Number of the research groups interested and engaged in R&D collaboration with firms (by the sex of research group leader)

	Women			**Men**		
Total	94		22.38%	326		77.62%
	N		*% of total*	*N*		*% of total*
Non interested	30		32%	86		26%
Interested	**64**		**68%**	**240**		**74%**
	N	*% of interested*	*% of total*	*N*	*% of interested*	*% of total*
Engaged	*49*	*77%*		*184*	*77%*	
Non-engaged	*15*	*23%*	***15.96%***	*56*	*23%*	***17.18%***

Table 3 also shows the statistical significance of the differences of mean values between sub-samples. We did not find significant differences in the variables between groups led by men and women.

Multivariate results

We examined the attitudes towards R&D cooperation with firms by estimating regression models. Since we defined both dependent variables as binary variables, we applied a probit model. We proposed the following relationship:

$$Probability(Y_i = 1) = \phi(\beta_0 + \beta_1 Size_i + \beta_2 Men_i + Budget_i + \beta_3 Field_i + \beta_4 Budget_i + \beta_5 Quality_i + + \beta_6 Experience_i + \beta_7 Country_i)$$

The dependent variable (Y_i) quantifies the research group's probability of showing interest (D_INT) or collaborating (D_COOP) with firms, i is the index of research groups, and ϕ denotes the standard normal distribution function.

We estimated different empirical models (Table 4). While Model 1 includes LN_AGREE as a proxy for the experience of the research group, Model 2 considers whether the group had successfully helped a firm to introduce any type of innovation over the period 2009-2011. Although we used both types of variables as proxies for the experience of the research group, the second group actually reflects previous 'successful' collaborations. Model 3 simultaneously considers both measures. As Table 4 shows, a group of variables was significant in these three estimated models. Then, in order to test whether the effect of these variables differed depending on the sex of the leader of the research group, we re-run the Model 3 by interacting these significant variables with MEN variable (Models 4 to 8).

Table 4: Mean values of the variables by sub-samples

Variable	TOTAL	WOMEN	MEN	p-value
OBS	420	94	326	
D_INT	0.7238	0.6809	0.7362	0.2909
D_COOP	0.1690	0.1596	0.1718	0.7812
LN_TOTAL	2.1130	2.0369	2.2057	0.2577
MEN	0.7762			
D_HUMART	0.0095	0.0000	0.0123	0.2811
D_HEALTHWEL	0.3190	0.2766	0.3313	0.3168
D_SCMATH	0.1524	0.1596	0.1503	0.8259
D_SSBL	0.0405	0.0532	0.0368	0.4782
D_EMC	0.4714	0.5106	0.4601	0.6839
LN_BUDGET	6.4933	5.6851	6.7264	0.162
LN_SCI	1.4135	1.1847	1.4795	0.1117
LN_PATENT	0.2821	0.2412	0.2939	0.4825
LN_AGREE	0.8090	0.6915	0.8428	0.2507
D_IPROD	0.1310	0.1277	0.1319	0.9146
D_IPROC	0.1214	0.1170	0.1227	0.8821
D_ICOM	0.0405	0.0532	0.0368	0.4782
D_IORG	0.0548	0.0745	0.0491	0.3411
SPAIN	0.7286	0.6915	0.7393	0.3594
PORTUGAL	0.0667	0.1170	0.0521	0.0265
FRANCE	0.2047	0.1914	0.2085	0.7177

Notes: Table shows the p-values of significance tests (t test for continuous variables and Wilcoxon rank-sum (Mann-Whitney) test for discrete variables) for the differences of the mean values between the sub-samples.

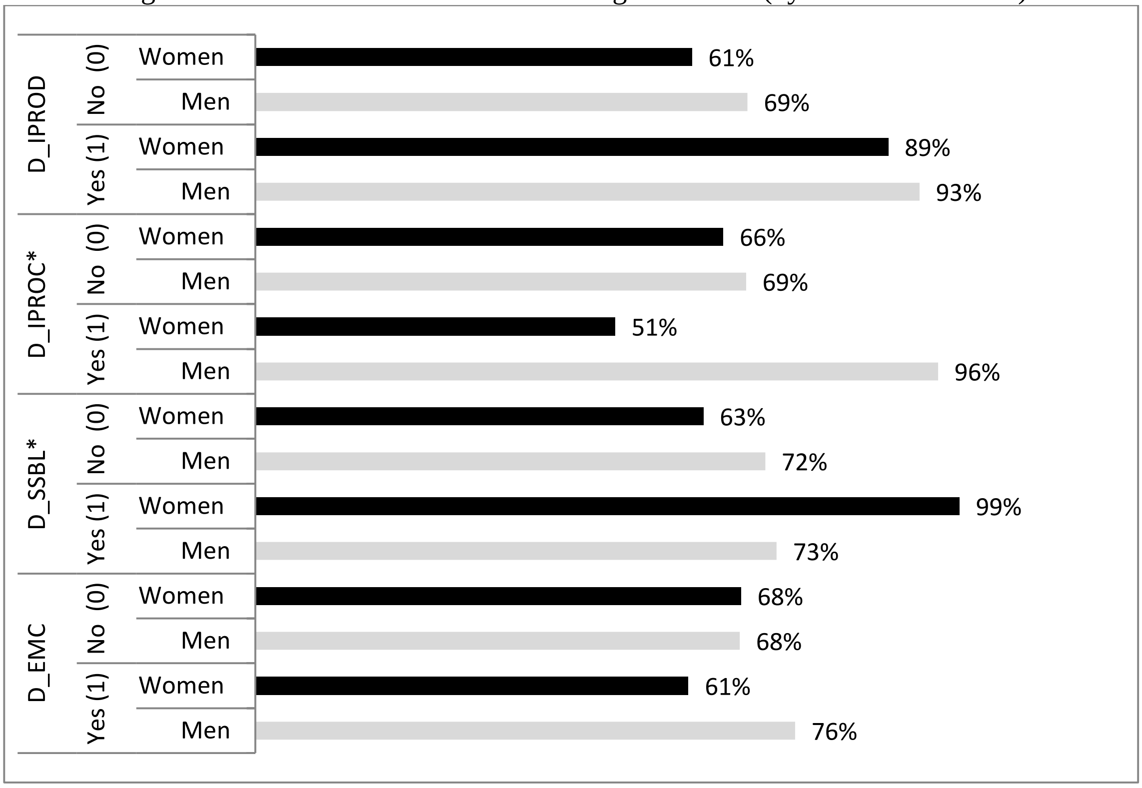
In Model 3, the results support that the research groups led by men are more likely to show interest in collaborating with firms; a group headed by men has around 10% higher probability of showing interest. As we mentioned, to explore more in-depth the role of the sex of research group leader, we additionally controlled for the interaction effects of the significant variables with MEN variable. Sex variable was significant in two of the estimated models (Models 5 and 7), suggesting again a positive relationship between male leaders and interest in R&D cooperation with firms.

More interesting was the significance of some interactions terms (i.e., MEND_IPROC and MEND_SSBL), suggesting that the effect of some variables on interest in collaborating with firms differs depending on the sex of the leader of the research group. Thus, the significant interaction effect of MEN and D_IPROC (Model 6) means that the positive effect of having successfully collaborated with a firm in process innovation is stronger for groups led by men than for groups led by women (Figure 2). This results supports those found by Bozeman and Gaughan (2011), who highlight that men are more focused on the collaboration based on instrumentality and previous experiences than women are.

Similarly, the significant interaction effect of MEN and D_SSBL (Model 7) suggests that the positive effect of leading a research group of the field of SSBL is stronger for groups led by women than it is for groups led by men (Figure 2). This finding partly differs from the conclusions of Corley and Gaughan (2005), Azagra-Caro et al. (2006) and Link et al. (2007), who state that women are lesser engaged with the industry because they are under-represented in the fields more active in technology transfer. In contrast, the estimate coefficient reveals that in the fields of science without a high technology level, women are more prone to collaborate with firms than men are.

Unlike linear models, in nonlinear models the magnitude of the interaction effect does not equal the marginal effect (Ai & Norton, 2003). For this reason, to test the robustness of the results we also computed the mean marginal effect and significance level of the interaction terms using Stata's *inteff* command (Norton, Wang, & Ai, 2004). The results supported the significance and sign of previous interaction terms (Figure 2)

Figure 2: Predicted interest in collaborating with firms (by interactions terms)



Note: * denotes significance of the interaction terms.

Other factors also explain the interest of research groups in R&D cooperation with firms. Thus, the field of science of the research group showed to be significant for the interest of the research group in engaging in R&D collaboration with firms. Particularly, those groups working on Social Sciences, Business, Law, Engineering, Manufacturing and Construction are more likely to be interested in engaging in cooperation with firms, compared to those that work on Science, Mathematics and Computing. These results are consistent with those of Lee (1998), Meyer-Kramer and Smoch (1998), Schartinger et al. (2002), Azagra-Caro et al. (2006), and D'Este and Perkmann (2011).

The research budget of the group positively relates to the interest in collaborating with firms. This result is consistent with those of Meyer-Kramer and Smoch (1998), Lee, (2000), Bozeman and Gaughan, (2007) and Nilsson et al., (2010).

The previous experience of the research group positively relates to the interest in future collaborations. It is worth noting that this significant relationship between experience and interest arises when the former is measured by what can be considered 'successful' previous collaborations, i.e. those ended in a jointly developed innovation with partners. Particularly, the relevant experiences that enhanced the research group' interest are those that resulted in product and process innovation as final outputs. This result is consistent with those of Schartinger et al. (2002), Lee (2000), D´Este and Patel (2007), Nilsson et al. (2010), D'Este and Perkmann (2011), Petruzzelli (2011), and Pinto (2011).

Finally, country also matters in attitudes towards R&D cooperation with firms. Thus, compared to the French research groups (omitted group), the Spanish groups were about 25%-28% less likely to be interested in collaborating with firms.

Since we consider cooperation as a sequential process, to analyse whether the sex of the research group leader influences the engagement in R&D cooperation with firms, we only took into account those groups which had shown interest in engaging in R&D cooperation with firms at the end of first stage of the analysis (304 research groups). Then, we re-run the previous estimated models for this sub-sample (interested groups) using D_COOP as dependent variable. We show these results in Table 5.

Table 5: Research groups' interest in R&D collaboration with firms (Average partial effects)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
LN_TOTAL	0.021	0.014	0.013	0.013	0.013	0.014	0.012	0.014
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
MEN	0.077	0.088	0.093^{+}	0.047	0.097^{+}	0.056	0.102^{+}	0.031
	(0.053)	(0.055)	(0.055)	(0.071)	(0.057)	(0.054)	(0.056)	(0.078)
D_HUMART	0.036	-0.088	-0.083	-0.07	-0.083	-0.075	-0.087	-0.074
	(0.185)	(0.253)	(0.250)	(0.247)	(0.250)	(0.243)	(0.249)	(0.248)
D_HEALTHWEL	0.068	0.08	0.074	0.075	0.075	0.071	0.074	0.073
	(0.060)	(0.062)	(0.062)	(0.062)	(0.062)	(0.062)	(0.062)	(0.062)
D_SSBL	0.241***	0.183*	0.178^{+}	0.184*	0.18^{+}	0.181*	0.311***	0.176^{+}
	(0.046)	(0.093)	(0.095)	(0.093)	(0.092)	(0.091)	(0.021)	(0.095)
D_EMC	0.133*	0.120*	0.118*	0.116+	0.118*	0.114^{+}	0.117*	0.031
	(0.057)	(0.060)	(0.059)	(0.060)	(0.059)	(0.059)	(0.059)	(0.103)
LN_BUDGET	0.010*	0.008^{+}	0.009*	0.003	0.009*	0.009*	0.009^{+}	0.009^{+}
	(0.004)	(0.004)	(0.004)	(0.008)	(0.004)	(0.004)	(0.004)	(0.004)
LN_SCI	0.009	0.005	0.011	0.011	0.011	0.009	0.011	0.011
	(0.019)	(0.019)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
LN_PATENT	-0.015	-0.062^{+}	-0.05	-0.05	-0.05	-0.048	-0.049	-0.049
	(0.035)	(0.036)	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)
LN_AGREE	-0.025		-0.029	-0.03	-0.029	-0.026	-0.029	-0.03
	(0.022)		(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
SPAIN	-0.251***	-0.284***	-0.280***	-0.282***	-0.280***	-0.276***	-0.279***	-0.279***
	(0.046)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.046)
PORTUGAL	0.164^{+}	0.043	0.079	0.080	0.078	0.183*	0.083	0.066
	(0.093)	(0.146)	(0.139)	(0.141)	(0.139)	(0.090)	(0.137)	(0.143)
D_IPROD		0.213***	0.209***	0.210***	0.236*	0.184**	0.214***	0.213***
		(0.054)	(0.055)	(0.056)	(0.097)	(0.060)	(0.054)	(0.054)
D_IPROC		0.155*	0.159*	0.158*	0.162*	-0.286	0.158*	0.154*
		(0.066)	(0.066)	(0.066)	(0.064)	(0.214)	(0.066)	(0.067)
D_ICOM		.	.	.	.	.	.	.
		.	.	.	.	.	.	.
D_IORG		.	.	.	.	.	.	.
		.	.	.	.	.	.	.
MENLN_BUDGET				0.008				
				(0.009)				
MEND_IPROD					(0.068)			
					(0.218)			
MEND_IPROC						0.328***		
						(0.042)		
MEND_SSBL							-0.687***	
							(0.022)	
MEND_EMC								0.111
								(0.097)
OBS.	420	389	389	389	389	389	389	389
Wald c^2(d.f.)	53.62*** (12)	63.47*** (13)	66.26*** (14)	65.87*** (15)	66.98*** (15)	69.77*** (15)	68.44*** (15)	66.29*** (15)
R^2 Mcfadden	0.12	0.14	0.15	0.15	0.15	0.16	0.15	0.15
Pseudolikelihood	-218.39	-202.91	-202.17	-201.71	-202.12	-198.23	-201.42	-201.55
Akaike criterion (d.f.)	462.78 (13)	433.82 (14)	434.34 (15)	435.42 (16)	428.47 (16)	436.28 (16)	434.83 (16)	435.10 (16)
Hosmer-Lemeshow c^2 (8 d.f.)	8.1	6.44	13.31	9.67	10.06	11.93	7.7	6.77

Notes: Table shows the average partial effects (APE). As noted by Tomás Bartus (2005), APEs provide a more realistic interpretation of the estimation results and more consistent estimates than marginal effects at the mean. The Stata *margeff* command was used to calculate the APEs. ***, **, *,$^{+}$ denote significance at the 0.001, 0.01, 0.05 and 0.10, respectively. Robust standard errors are in parentheses. d.f. denotes degrees of freedom.

Regarding the decision to cooperate with firms the sex of the research group leader showed not to be significant. Neither the main effect of sex variable, nor the interaction effects were significant. These results differ from those of Bozeman and Corley (2004), Azagra-Caro et al. (2006), Azagra-Caro (2007), Link et al. (2007), and Bozeman and Gaughan (2011). Our empirical evidence reveals that once a research group shows interest in R&D cooperation with firms, the final engagement is not dependent on the leader's sex.

In addition, the probabilities of signing a collaborative project are positively related to the scientific quality of the research group. This result is consistent with those of Schartinger et al. (2002), Bruno and Orsenigo (2003), D´Este and Perkmann (2007), D´Este and Patel (2007), Pinto (2011), and Abramo et al. (2011). Again, the country also matters; within the 'interested' research groups, the Spanish were around 15% more likely to definitively engage than the French.

Conclusions

This paper explores whether the sex of the research group leader affects the attitudes towards the U-I cooperation in R&D in eight regions of the Southern of Europe. By considering cooperation as a sequential process, the study analyses the determinants of both interest and engagement in R&D cooperation agreements with firms. It is precisely this sequential perspective that leads us to conclude that the sex gap differs along the U-I engagement in R&D. Then, we can point out several results relevant for decision-makers.

Thus, the study sample comprised 420 research groups: 94 led by women (22%) and 326 led by men (78%). These figures highlight the 'first barrier' for women in U-I relationships, i.e. achieving a leader position in the research group. They are also consistent with the conclusions of most of research that shows a lesser engagement of women compared to men because of their lesser seniority and status (Boardman & Ponomriov, 2009). According to European Commission (2016), in 2011 the 33% of the European researchers on all fields were women, therefore it could be expected that this percentage hold for the leaders of the research groups. However, in the study sample women continue under-represented at the head of research groups. Although it was not the objective of this study to analyse the reasons of this sex gap in the head of the research groups, academics and politicians should go further in this issue, since it is at this ‘stage’ of the U-I relationships where the highest differences in the proportion of men and women arise.

The results indicated that a research group led by men has around 10% higher probability of showing interest in R&D cooperation with firms. This figure points out the ‘second barrier’ for women in U-I cooperation, i.e. having interest in R&D cooperation, suggesting that women display a different strategic approach to their academic careers. Thus, cooperation in R&D with firms frequently requires meetings and trips, among other tasks, outside workplace. However, women usually prefer to work at home for reasons of family care largely than men, reducing in this way their stock of social capital. Given that the incentive system of public universities mostly considers the scientific production (papers published in high-impact journals) as the main indicator for the academics’ promotion, women frequently choose to focus on publications, which allow them to work at home, rather than on cooperation with firms. In any case, future research should benefit from analysing the underlying reasons for this lesser interest in research groups led by women.

Moreover, the results also showed that the effect of some variables on the interest in collaborating with firms differs depending on the sex of the research group leader. More specifically, the positive effect of leading a research group of the field of Social Science, Business, and Law is stronger for groups led by women than it is for groups led by men. This finding lead us to recommend observing these real experiences and promoting them as good practices for the remaining research groups led by women.

We did not find differences according to sex criteria in the 'third' stage of U-I relationship, i.e. engagement in R&D cooperation. This result indicated that, among the research groups interested in cooperation, the effectiveness in engaging in collaborative projects does not depend on the leader's sex. It also proves that motivated female leaders do not under-perform their male counterparts. These findings open the debate on when sex differences in R&D collaboration really appear. In other words, considering R&D collaboration with firms as a sequential process allows shedding light on sex differences at different stages of the process.

In sum, the results support those steaming from the network approach; women are worse positioned in the social networks of collaboration and commercialization with industry than men are. This situation will reduce their motivation to collaborate, because they will not expect successful outcomes of this effort. However, when men and women leaders of research groups have the same motivation to collaborate, the engagement with industry is not significant according to sex criteria. Finally, from our perspective, future research should focus on identifying policies and incentives systems that motivate female leaders to show interest in cooperation with firms and assessing the effectiveness of these mechanisms in promoting knowledge transfer in areas dominated by female researchers.

Finally, this paper also presents some limitations. In particular, previous research has shown that the size of the research group may exert significant influence on R&D cooperation but we could not get information about number of the group's members of funds received by groups.

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