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Gender diversity, R&D teams and patents: An application to Spanish firms

Mercedes Teruel (*), Agustí Segarra-Blasco (*)

Abstract

Previous results show that gender diversity increases the probability that firms invest in R&D and engage in innovation. This paper explores the relationship between gender diversity of R&D departments and their capacity to patent. Based on the Spanish Community Innovation Survey between 2004 and 2014, we apply a two-step procedure in order to control for endogeneity. Although gender diversity affects OEPM patents negatively, its impact is non-significant for patents with international coverage (EPO, USPTO, or PCT). A relevant result is the fact that the generation of patents is positively affected by the diversity of categories in the R&D labs. Our results highlight that, gender diversity of R&D teams does not play a relevant impact on the capacity of the firm to register patents. However, the diversity according to the professional role in R&D teams exerts a positive influence. In sum, the key question is not the gender diversity per se but the gender diversity jointly with the professional status.

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1. Introduction

Achieving the goals of Horizon 2020 implies to push the technological frontier by developing new knowledge and maximizing the potentiality of employees' skills. In this context, a special interest exists in increasing the presence of women in the Science and Technology System under the premise that when R&D teams are more gender-diverse, their productivity increases in terms of new knowledge and patent registrations. The patent system may be a channel in order to achieve these goals. On the one hand, the main aim of the patent system is to foster innovation and exploit the market value of a firm's knowledge. On the other hand, this system may be a channel to attract women to science and technological careers. As a result, a broader-based patent system conducive to female participation might better fulfil both goals and generate additional contributions from women in those technological sectors that rely upon patents (Burk, 2011).

The analysis of gender diversity and innovation is particularly interesting in Spain. In the last decades, Spain has considerably improved gender opportunities, although is still to be done in terms of wage equality, participation in managerial positions and presence in political life (World Economic Forum, 2016).The growing presence of women in the Spanish labour market has raised awareness regarding the effect of gender diversity on firm performance and especially the potential of Spanish innovation-based firms. This has increased the interest of researchers when analysing the effects of gender diversity in the entire workforce (Romero-Martínez et al., 2017; Teruel and Segarra, 2017) and in R&D teams (Díaz-García et al., 2013; Fernández-Sastre, 2015) on innovation output. Despite the recent advances in the labour market, the gender gap is still remarkable in R&D activities.

In this vein, the role of gender on innovation has gained a wider interest among researchers (Alsos et al., 2013). The majority of these works analyse the effect of gender diversity in corporate boards with respect to firm performance (Campbell and Mínguez-Vera, 2008), as well as the effect on firm strategies (Adams and Ferreira, 2009), and the relationship between workforce diversity and firm performance (Dwyer et al., 2003), in addition to innovation return at a company level (Østergaard et al., 2011). However, there is still much to discover in terms of the role of gender composition on innovation. While a more gender diverse R&D team has been shown to improve a firm's creativeness and its capacity to solve problems, other authors such as Lanjouw and Schankerman (2004) have found that research productivity at a firm level is inversely related to patent quality.

However, there is scarce evidence of the relationship between gender diversity in the workforce and the capacity to reinforce the Science and Technology System. Hence, we will therefore analyse the different impacts that gender diversity of R&D teams may have on different types of patents. This paper seeks to calibrate the impact of gender diversity in R&D teams on the innovation-based returns of innovative firms. We have measured the link between gender diversity in R&D teams and R&D returns in terms of patents. Our analysis focuses on R&D teams for different reasons. Firstly, intramural R&D teams provide a fair measure of a firm's interest in generating new knowledge and with respect to patent registration. Secondly, the link between inputs (researchers) and outputs (patents) are clear and direct.

At an empirical level, we have used a firm-level database drawn from the Spanish Technological Innovation Panel (hereafter PITEC) between 2004 and 2014. The data has been gathered following the Oslo Manual guidelines (OECD, 1997, 2005) and, as such, it may be considered as a Community Innovation Survey (CIS) dataset. Our empirical work is based on detailed panel data that consists of 4,085 Spanish manufacturing and service innovative firms. Gender diversity and the capacity to develop new patents may be affected by common elements of unobservable heterogeneity. For instance, firms that are more creative have a greater capacity to develop innovations, yet they also have a greater capacity when it comes to attracting more creative people. We have therefore used a two-step procedure where a control for endogeneity has been applied.

Our results show that gender diversity in R&D teams is not such a relevant factor in order to foster a firm's capacity to patent. This dimension shows a dual effect. First, it negatively affects a firms' capacity to register a patent with the Spanish patent office. Second, the gender composition of R&D departments does not affect the generation of more complex patents (EPO, USPTO and PCT patents). This dual effect not only emphasizes the different nature of the knowledge protected under Spanish coverage or those patents with a more internationalized coverage, it also stresses the different capacity of firms to register patents. Our results have also been confirmed by the percentage of female researchers. Finally, our results highlight the importance of the diversity of categories inside R&D teams. It therefore seems that the roles undertaken inside the R&D team appear to play a more important role in the generation of patents, rather than gender diversity.

The main contribution of this paper is to show evidence on the impact of more gender-diverse R&D teams and the capacity of firms to generate different types of patents. Our work helps to show evidence on the diverse impact of gender composition in R&D teams with respect to the generation of patents. Furthermore, we have also presented evidence on the difference between quantity and intensity. Finally, we have considered the impact of gender diversity on patent quality in terms of territorial coverage.

The structure of the paper is as follows. Section 2 outlines the literature related to gender diversity and innovation, especially the generation of patents. Section 3 presents the database used in addition to several descriptive statistics. Section 4 outlines the econometric methodology and variables applied. Section 5 details the effects and results of gender diversity and the generation of patents. Conclusions are drawn in Section 6.

2. Literature Review

Gender Diversity and Innovation

The concept of diversity is multidimensional and related to individual attributes, which include gender, ethnicity, education, language, and age, among others. These individual attributes reflect the content and the structure of diversity and they determine the composition and the interaction among individuals who belong to a group. The link between diversity and firm performance is not simple. Interactions between group diversity and productivity are in fact complex and dynamic, as the skills involved are complementary and knowledge spillovers may occur among heterogeneous individuals. These interactions have an impact on the learning process, the decision-making process and the creativity of the group.

In this paper we have interpreted gender diversity as a degree of heterogeneity in terms of sex. The growing presence of women in the Spanish labour market must affect firm performance, especially Spanish innovation-based firms. This paper specifically analyses a particular feature of diversity in terms of the presence of men and women in the R&D teams of Spanish firms. As mentioned above, the effects of increased gender diversity in the total workforce on firm performance has attracted the interest of researchers and policy makers. In general terms, the critical research question is if the gender composition of the teams affects individual and group performance at firm level (Marinova et al., 2016)[1].

Despite the growing amount of literature regarding the determinants of innovation at a firm level, few scholars have paid attention to the link between gender diversity and innovation[2]. In fact, this process has been considered as a "gender-neutral" phenomenon (Kvidal and Ljunggren, 2012). However, gender composition must affect firm performance (Milliken and Martinsm, 1996; Scott et al., 2011; Kim and Starks, 2016), as employees have to interact and solve problems. Authors such as Blake and Hanson (2005) and Alsos et al. (2013) have questioned the idea that innovation is a gender-neutral phenomenon and have invited the scientific community to reconceptualise innovation.

From a theoretical perspective, gender diversity increases creativity and innovation, as it leads to a greater diversity in terms of skills and abilities (Lazear, 1999; Baer et al., 2013). This argument is in line with Cumming and Oldham (1997), and with Bharadwaj and Menon (2000), who point out that team creativity is crucial for innovation at company level. Furthermore, a more gender-diverse environment may indicate a more open organizational culture, which may well be more conducive to encouraging innovation (Martins and Terblanchem 2003). These differences may consequently affect interaction and learning capacities and eventually affect innovation capacity (Laursen and Salter, 2006).

[1] In the early 90s, the research on this topic offered positive results on the effects of gender diversity on firm performance in terms of profits, growth or innovation returns. Despite the fact that some authors argued that gender diversity can act as a driver for a firm's competitive advantage (Cox and Blake, 1991), later empirical research has encountered ambiguous results, which confirm that diversity can have both positive and negative impacts on firm performance.

[2] Alsos et al. (2013) have reviewed the main literature that takes into account the relationship between innovation and gender in different fields. These authors point out that literature of this type is scarce in business, especially in the field of economics.

Gender diversity however may produce negative impacts. Firstly, it increases the time required to make decisions. As a result, firm performance may decrease in sectors that require rapid responses to market events (Carter et al. 2003; Smith et al. 2006). Secondly, gender diversity may also decrease group solidity, as it makes it harder to communicate clearly and openly, and conflicts increase within a group due to the existence of stereotypical gender roles (Kravitz 2003). Thirdly, gender diversity may increase wage discrimination and reduce employee satisfaction (Roberge and van Dick, 2010). Finally, those diverse work environments created by gender diversity require managers to possess specific leadership skills and talents (Bassett-Jones, 2005)[3].

With respect to empirical evidence on innovation, Østergaard et al. (2011) found that educational diversity and gender diversity positively affect the likelihood of innovation in Danish firms. However, they also found that there is no relationship between innovation and ethnic diversity. Furthermore, using data from French firms, Galia and Zenou (2012) found that the percentage of women on a management board positively affects the likelihood of a firm carrying out product, organizational and marketing innovations. Similarly, Torchia et al. (2011) showed that gender diversity on corporate boards positively affects organizational innovation. For a group of developing countries in South Asia, the Middle East and Africa, Ritter-Hayashi et al. (2016) using a sample from the World Bank Enterprise Survey, found that gender diversity has a direct, positive effect on firm innovation capacity.

In Spain, the empirical literature has found a positive impact. In a sample of Spanish firms, Díaz-García et al. (2013) observed that gender diversity is positively related to radical innovations but it does not encourage incremental innovations. More recently, Teruel and Segarra (2017) analyse the impact of gender diversity on the probability of developing product, process, marketing and organizational innovations. Positive impacts were revealed, however impact is highly sensitive to the firm size. Finally, Romero-Martínez et al. (2017) observe the impact of gender diversity and the education level of R&D researchers on product innovation. These authors find that gender diversity and the education level of R&D workers positively affects product innovation. However, the influence of gender diversity and education level is only

[3] At theoretical level, Roberge and van Dick (2010) have designed a model that shows that heterogeneous teams reduce intra-group cohesiveness, which may lead to conflicts. They argue that individual and group characteristics may counterbalance such negative effects.

significant when their influence is considered separately, while no significant impact was encountered when both variables were taken into account together.

Ambiguous results have given rise to different explanations. Marinova et al. (2016) find a curvilinear relationship between workforce gender composition and firm performance, and show that different proportions in terms of workforce gender diversity produce different effects on firm performance. Furthermore, Teruel and Segarra (2017) find that the differing capacity of firms with respect to benefitting from gender diversity is dependent on firm size. Their results show that small firms are not able to reap the benefits of gender diversity, as their size polarizes gender diversity distribution. This means that small firms exhibit more moderate levels of gender diversity and as a result, they are not able to take advantage of the positive effects of gender diversity on innovation. All in all, different explanations may explain the ambiguous relationship of gender diversity on innovation.

If however we consider the different impacts that homogeneous and heterogeneous groups may have on a firm's capacity to innovate, differences exist between departments. Homogeneity appears to be beneficial for groups with more routine tasks, while heterogeneity produces benefits for groups with more complex and interdependent tasks. In comparison with total company workforce, R&D teams are more closely linked to the generation of knowledge. R&D groups deal with creative tasks and interdependent work structures, and as such within the R&D sector one would expect gender diversity to lead to more positive effects (Cordero et al., 1996)

If we focus on the gender composition of R&D teams, few scholars have analysed its impact on R&D productivity and on innovation at a firm level. Among them, Turner (2009) shows how the composition of R&D teams improves firm innovation capacity. This work, however, has several methodological limitations, since the user data has been taken from only four firms. As far as we are aware, Díaz-García et al. (2013) and Fernandez-Sastre (2015) are the only works that analyse the impact of gender diversity of R&D teams on the likelihood of innovation. Both works use the PITEC database and their findings are based on Spanish innovative firms. Díaz-García et al. (2013) found a positive relationship between gender diversity in R&D teams and the probability of carrying out radical innovation, while Fernandez-Sastre (2015) analysed the impact of gender diversity in R&D teams on products, services, process and organizational innovations for Spanish manufacturing firms between 2008 and 2011. His results show that gender composition affects all types of innovation, particularly those concerning products and organization strategies.

The Influence of Gender Diversity on a Firm's Capacity to Patent

The generation of patents as a process with which to protect knowledge is rather characteristic of highly R&D-intensive firms that possess R&D departments. The protection of this knowledge is crucial for certain firms and industries in order to ensure their survival, given the shorter life cycles of their products. The performance of a firm R&D team is crucial in order to achieve these goals. And one key question is how to manage an R&D team, despite firm dynamics and complexities (Thamhain, 2003).

Side by side with these internal challenges, is the greater concern of increasing the presence of female researchers in general, in the scientific and technological sector. However, as Burk (2011) points out, the lack of women in R&D departments may be due to two different factors. Firstly, the low number of women interested in studying STEM and, secondly, there may be other reasons that may impede the employment of women in STEM-related jobs.

In the first case, there are common factors affecting the decision of women to follow STEM studies and develop a STEM career. Consequently, the fewer patents generated by women may be the result of the lower number of women engaged in technological innovation, which will result in fewer women to generate patents. In the second case, there are different factors affecting the decision to follow a career in a R&D department. In other words, the patent system may be gendered or biased against women (Burk, 2011).

The existence of a patent system encourages new ideas, new knowledge, and innovation. However, if this process accounts for only certain types of knowledge it may cause the system to either completely overlook other types of knowledge that could be profitable (Burk, 2011). Hence, in terms of gender diversity the problem not only involves the exclusion of women from full participation in the patent system but also the exclusion of knowledge that has been historically associated the social role of that particular sex.

In this sense, three different dimensions of knowledge that women may contribute to in the development of new patents can be outlined: technological practice, scientific knowledge and situated knowledge. Firstly, arguments exist that women are less affected by the dominant societal paradigm and they may have a more unique view of the world (technological practice). Secondly, several other arguments are noteworthy, and which state that science excludes knowledge or ways of understanding that have been assigned to individuals who fulfil a specific, subordinated social role (scientific knowledge). Thirdly, other arguments state that assumptions on which scientific knowledge is based may be also biased (situated knowledge).

In fact, the relationship between gender diversity and the generation of patents is scarce and even puzzling. On the one hand, Cordero et al. (1996) find that the presence of women in R&D departments does not significantly affect the patents generated by female researchers, yet the capacity of men to generate patents in R&D laboratories is positively affected by the percentage of male researchers in the laboratory. Interestingly, the job satisfaction of female researchers was found to be positively affected by the presence of women in the laboratory. The interpretation for these findings is that perhaps men do not generate working conditions that are favourable to women. On the other hand, Cady and Valentine (1999) find that gender diversity is negative, when related to the quantity of ideas generated. The authors point out that this may be the result of the intrinsically low presence of women. Furthermore, women may be less likely to participate in projects that will develop patents, as women in R&D laboratories are usually less likely to have a PhD, and employees with PhDs are more likely to participate in innovative projects that will lead to the generation of patents (Cordero et al., 1996).

As there are differences with respect to employees' skills and knowledge according to gender, gender composition in an R&D department will have an impact on the capacity to develop these patents. Gender composition may in fact positively affect those tasks that require creative (Polzer et al., 2009) or complex work (Wegge et al., 2008). Furthermore, gender diversity increases creativity and improves problem solving, given that a more diverse working group possesses a wider range of perspectives (Morrison, 1992; Robinson and Dechant, 1997; Latimer, 1998). These characteristics are necessary in order to foster the development of new knowledge. Hence, our main hypothesis is that a more gender-diverse R&D team will have a positive impact on the generation of patents.

3. Data and Methodology

3.1. Database

Our database belongs to PITEC (Panel de Innovación Tecnológica), which is the result of collaboration between the Spanish National Statistics Institute and the Foundation for Technological Innovation (COTEC). It contains data from a panel of more than 12,000 firms, compiled between 2003 and 2014 and it includes a large number of variables related to innovation and economic activity[4]. PITEC has several advantages. First, it compiles the Spanish CIS questionnaire R&D activities at firm level following the Oslo Manual guidelines (OECD, 1997, 2005). This allows us to use widely-accepted innovation indicators and variables. Secondly, it uses panel data and so these firms are tracked over time.

Although PITEC has a time period available from 2003 to 2014, we have observed the period from 2004 to 2014 due to data restrictions (the information concerning the number of patents starts in 2005). During this period, the sample contains a larger number of firms. We applied two filters in order to obtain the final sample. Firstly, we used only those firms that had provided complete information during the selected period. Secondly, we excluded firms with any employment-related problems (such as companies in sectors of high seasonality). Our final sample contains 40,032 observations belonging to 4,085 firms.

We must remark that the Spanish Community Innovation Survey (PITEC) asks to the firm if during the last two years it has applied for a patent to protect its inventions or its technological innovations. Table 1 describes the mean tests with respect to the capacity of these firms to generate patents (see Table A-2 and A-3 for descriptive statistics and correlations, respectively). Hence, we are not measuring the stock of knowledge, but the flow of knowledge. We have

[4] A more detailed description can be found on the Spanish Foundation for Science and Technology (FECYT) website.

classified these firms depending on whether they have an R&D department or not. We have observed that firms with an R&D department show significant differences in the mean test. Firms with an R&D department have a higher capacity to register patents, regardless the type of patent applied for. Secondly, we observed that the most common type of patents are Spanish patents (OEPM), while the less common type of patents are those that are registered in the United States Patent and Trademark Office (USPTO). It would therefore appear that firms with an R&D department have a greater capacity to generate patents and consequently, we may expect that these firms possess certain characteristics that differentiate them from those firms without R&D departments.

Table 1. Mean of number of applied patents according with the Blau Index. Period 2005-2014

	Number of patents		Prob (T<t)=Mean test (H0:)
	Firms with R&D department	Firms without R&D department	
All patents	1.0183	0.0724	0.0000
OEPM	0.5360	0.0517	0.0000
EPO	0.2858	0.0135	0.0000
USPTO	0.1405	0.0032	0.0000
PCT	0.2108	0.0072	0.0000
Observations	23,932	16,100	

Source: own elaboration from PITEC

OEPM: Spanish Office of Patents and Brands. EPO: European Patent Office. USPTO: United States Patent and Trademark Office. PCT: Patent Cooperation Treaty

Note: The values indicate the number of patents applied by the firm and not the percentage of firms.

We must remark that from the total sample of observations, 60.7% of firms stated that they possess R&D departments. From the total number of firms that register patents, 12.9% have an R&D department. As such, we have attempted to correct for selectivity bias and the lag between patent registration and R&D, and the lag between capacity and patent. An important issue here is the fact that many firms do not have an R&D department and this may bias our results based on firms that do. We have attempted to correct for this sample bias using a Heckman (1976) procedure (see Section 4).

As we observe in Table 1, the majority of patents have a Spanish coverage. Table 2 shows the distribution of the observations according to whether the firms have or have not registered a patent in the OEPM and if they have also registered patents with international coverage. First, a large share of firms with R&D departments do not register patents, while the larger proportion of firms register patents in the OEPM.

Second, there is a large percentage of firms that have registered a patent with international coverage and also with the EPO. The share of firms that adopt a strategy of registering patents with only an international coverage is lower. It can therefore be seen that the strategy of registering patents is different.

Table 2. Percentage of firms according with the geographical coverage of the patent (national / international). Firms with R&D departments. Period 2005-2014

	International coverage					
	EPO		USPTO		PCT	
	NO	YES	NO	YES	NO	YES
OEPM NO	84.24%	2.33%	85.72%	0.85%	84.38%	2.19%
YES	9.45%	3.97%	11.31%	2.11%	10.69%	2.74%

Source: own elaboration from PITEC
OEPM: Spanish Office of Patents and Brands. EPO: European Patent Office. USPTO: United States Patent and Trademark Office. PCT: Patent Cooperation Treaty

Table 3 reports the gender composition of R&D departments with respect to whether the department has applied for a patent. Table 3 shows that the gender composition is rather similar between firms with R&D departments that generate patents and those that do not register patents. However, if we observe the patent types, firms that protect their know-how less (with protection coverage at a national level only) have a lower mean percentage of women in their R&D departments.

Table 3. Mean percentage of women in the R&D department according with the types of patents. Period 2004-2014

	Women in the R&D department (%)	Blau Index	Observations
No patents	26.46	0.2352	19,235
All patents	27.82	0.2701	4,697
OEPM	26.56	0.26282	3,527
EPO	30.10	0.2853	1,657
USPTO	32.71	0.3067	779
PCT	32.45	0.3026	1,296

Source: own elaboration from PITEC

However, before analysing the incidence of gender diversity in the production of patents, we may be interested in analysing whether those firms that are protecting their intellectual property in the OEPM office and simultaneously in other international offices show a greater capacity to generate new knowledge. The main motivation is that the returns of R&D investments for innovative firms strongly depend on their ability to develop complementary appropriability strategies (Teece, 1986). Taking into account that innovative firms usually register patents in different agencies, we have analysed the complementarities between patenting at Spanish levels and international levels using the theory of supermodularity[5]. We have assumed that a firm can protect its knowledge in the Spanish patent office, A_1, and with other coverage (*EPO*, *USPTO*, *PCT*), A_2. A firm can adopt two binary decisions in relation to each activity, these being $A_i = 1$ when a firm performs the activity and $A_i = 0$ otherwise. The function $\Pi(A_1, A_2)$ is supermodular and A_1 and A_2 are complementary only if,

$$\Pi(1,1) - \Pi(0,1) \geq \Pi(1,0) - \Pi(0,0)$$

In other words, the complementarity test measures how the production of new knowledge is affected when a firm adds an activity to another one that it is already being carried out, and compares this to a situation where a firm adopts an activity in isolation. Thus, supermodularity leads to a formalisation of synergies and system effects.

Table 4
Test for complementarity between the production of patents

	χ^2	**Probability**
All patents	68.17	0.000
EPO patents	15.24	0.000
USPTO patents	65.05	0.000
PCT patents	29.37	0.000

Note: we test the following equation: - OEPMonly - OTHERSonly+ OEPMandOTHERS = 0

Table 4 shows the complementarity test classified according to the capacity to produce all types of patents, the Spanish patents, USPTO patents and PCT patents. Our results show that firms tend to develop a strategy of protecting their knowledge in different patent offices.

[5] The mathematical concept of supermodularity formalizes the idea of complementarity, see Milgrom and Roberts (1995).

3.2. Explanatory Variables

Gender diversity is estimated through the Blau Index (Blau, 1977), which has been commonly used to measure demographic heterogeneity. Although there are other options for measuring diversity (see Harrison and Klein, 2007), the Blau Index is preferred, in comparison to other measurement methods[6].

The formulation of the Blau Index is as follow:

$$B = \left[1 - \sum_{i=1}^{N} p_i^2\right]$$

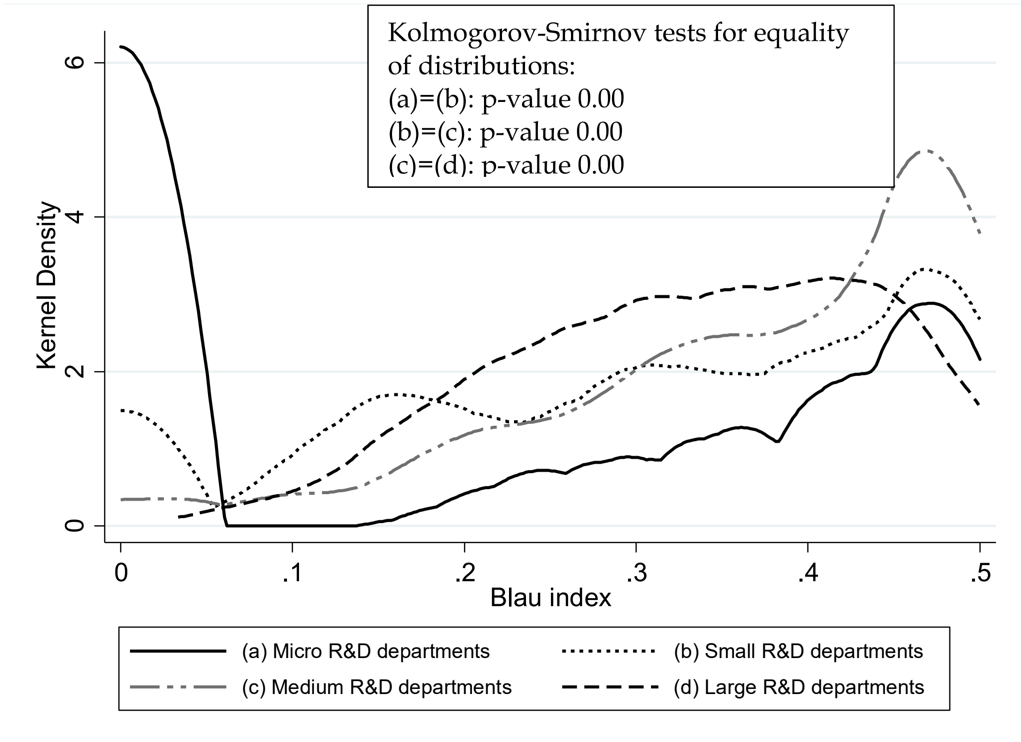
where B is the value of the Blau Index, and p_i is the proportion of members in the i^{th} of the N categories. In our case, N=2, due to the fact that we have only two categories: men or women. The value of our index ranges from 0 to 0.5, where 0 equals single-sex teams and 0.5 equals egalitarian teams[7].

Figure 1 shows the distribution of the Blau Index, which has been classified according to four different size of the R&D department. The results show that micro R&D departments (those with less than 10 researchers) obtain a bimodal distribution which is concentrated among the lowest values, while for larger R&D departments there is a mode in the intermediate values (around 0.4 in the Blau Index for the whole company).

[6] The Shannon-Weaver Entropy Index is expressed in logarithm and it cannot be calculated when a category is not represented.

[7] A weakness with respect to this index is that it does not consider the number of employees, giving the value 0.5 to 2-member teams composed of one woman and one man, while also giving the same index value to bigger teams e.g. a 50-member team of 25 women and 25 men. We argue that the effort and impact of having a diverse workforce must differ between smaller and larger firms and that smaller firms may show a larger sensitivity to this index.

Figure 1. Kernel densities of the Blau Index in R&D departments. 2004-2014

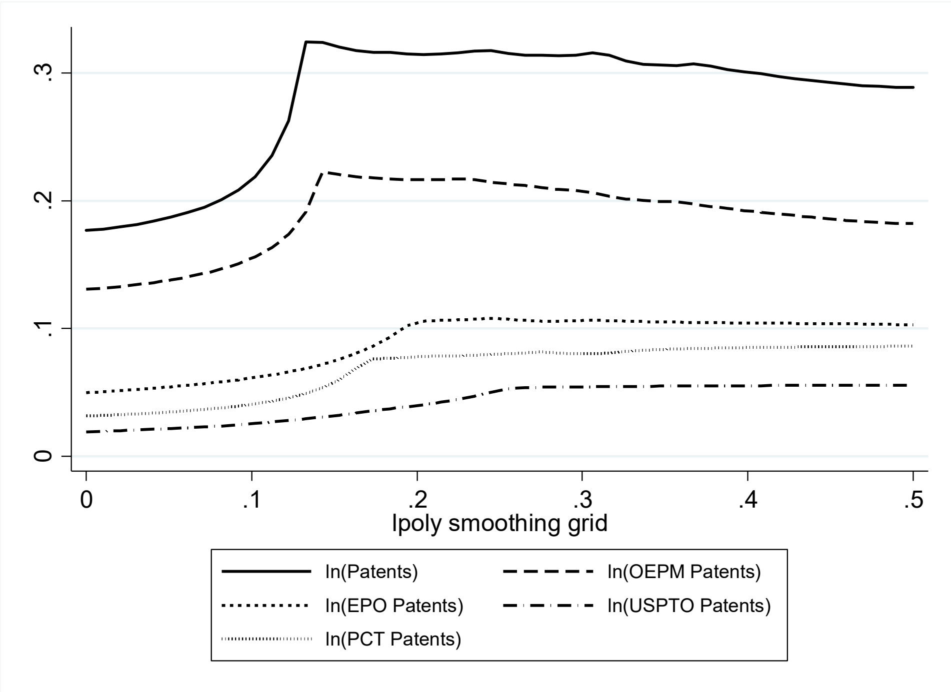


Note 1: Micro R&D departments have < 10 researchers; Small R&D departments have between 10 and 49 researchers, Medium R&D departments have between 40 and 249 employees, and Large R&D departments have more than 250 researchers.
Note2: The curves are obtained using a normal density smoother with a bandwidth of 0.5.
Source: own elaboration

As we have seen in Figure 1, the Blau Index shows different distributions according to the size of the R&D department. Similarly, we may suspect that the number of patents is highly different depending on the Blau Index. We used kernel-weighted local polynomial smoothing techniques to obtain non-parametric estimates of the dependence of patent numbers on the Blau index (Figure 2).

Figure 2 plots the link between gender diversity and the number of patents. The figure shows it to be an inverted U-shape. In general, an increase in the Blau Index has a greater impact on the number of patents registered. The graph displays a global maximum at a Blau Index of approximately 0.15 and shows decreasing performance levels that initiate from this point. At this point, once the firm surpasses this value, the relationship is still positive, but the impact shows a slight negative slope. This pattern is similar for the patents in the Spanish Office of Patents and Brands (*OEPM patents*), while the relationship is much smoother with respect to the number of patents in the European Office of Patents (*EPO patents*), the US Patents and Trademark Office (*USPTO patents*) and other Patent Cooperation Treaties (*PCT patents*).

Figure 2. Local polynomial smooth estimation of the Blau index in R&D departments on ln(number of patents). 2004-2014



Source: own elaboration
OEPM: Spanish Office of Patents and Marks. EPO: European Office of Patents. USPTO: US Patents and Trademark Office. PCT: Treats of cooperation of patents

4. Econometric Model Specification

In order to estimate an R&D team's capacity to generate patents, we have used an innovation production function in which a firm's innovation output depends on the gender diversity of the R&D department (*gender*). We distinguished between firms that have an R&D department and those that do not. Firstly, firm "i" may have an R&D department in period "t". Secondly, the firm will have a certain capacity to generate patents.

Equation (1) considers the probability that a firm decides to have an R&D department:

$$y_{1i,t} = \begin{cases} 1 \quad if \quad y^{*}_{1i,t} = f\left(X_{1i,t-1}\beta_1 + \gamma_{1,t} + \varepsilon_{1i,t}\right) \succ 0 \\ 0 \quad otherwise \end{cases} \quad \textbf{(1)}$$

where $y_{1i,t}$ is a dummy variable that indicates whether a firm decides to have an R&D department or not. We defined a latent dependent variable $y^{*}_{1i,t}$, a set of explanatory variables $X_{i,t-1}$, and a vector of coefficients to be estimated, β_1 , $\gamma_{1,t}$ is a time-fixed effect and error terms $\varepsilon_{1i,t}$ is a random error. Firm "i" has an R&D department if $y^{*}_{1i,t}$ is positive.

From Equation (1), we have obtained the Mills ratio in order to control for selection bias in our main equation (Equation (2)). As Table (1) shows, firms with R&D departments, and those without them have a different propensity to generate patents. Hence, sample selection may arise if firms with R&D departments are not homogeneous in comparison with the total number of firms. In this case, the error terms in both equations may contain several commonly-omitted variables, and therefore the residuals of both equations may not equal zero. Firstly, firms which may possess internal knowledge may decide to establish their own R&D departments in order to protect this knowledge. Secondly, firms with enough financial resources may decide to set up their own R&D departments. Therefore, firms with R&D departments may be better placed with regard to the generation of patents. Empirically, the estimation of coefficients $\beta_{2\cdot}$ yields inconsistent estimates if a sample selection exists. Hence, we apply a Heckman equation to estimate both equations.

Equation (2) estimates the capacity of a firm to generate patents, taking into account the sample selection:

$$y_{2i,t} = \beta_{20} + Z_{i,t-1}\beta_{21} + \beta_{22}gender_{i,t-1} + \gamma_{2t} + \varphi_{i,t} + \varepsilon_{2i,t} \qquad (2)$$

where $y_{2i,t}$ is the number of patents generated by firm "i" in period "t". The regressor of interest, $gender_{i,t-1}$, is defined as the Blau Index and $Z_{i,t-1}$ is a vector of relevant controls, $\gamma_{2,t}$ is a time-fixed effect and $\varepsilon_{2i,t}$ is random error. Finally, $\beta_{2\cdot}$ are the coefficients to be estimated and $\varphi_{i,t}$ corresponds to the Mills ratio.

Equation (1) includes as control variables ($X_{i,t-1}$) firm age, firm size, and as other explanatory variables, the so-called exclusion restrictions, to reduce collinearity between the inverse Mills ratio and the control variables of Equation (2). With this purpose we included the capital labour intensity of the firm in addition to sectoral dummies.

Additionally, Equation (2) includes other explanatory variables ($Z_{i,t-1}$) that affect the capacity of the R&D team to generate patents.[8] First, we introduce variables related to firm characteristics such as size (measured in employees) and age. We also include a set of explanatory variables captures the environment in which the company operates, such as a dummy identifying if the firm exports, a dummy identifying if a firm belongs to a group, a dummy identifying if the firm is a parent establishment and dummies identifying high-tech manufacturing, KIS and non-KIS firms. Furthermore, we include industrial characteristics such as the R&D intensity (internal and external R&D investment) and the R&D cooperation. Additionally, we introduced a set of characteristics regarding the R&D team, such as the gender diversity, the number of researchers, the educational and category diversity of the research team. Finally, we must remark that we have included the lagged value of our dependent variable in order to control for the persistent capacity of some companies to register patents. Table A.1 defines all the explanatory variables[9].

Furthermore, the link between patent registration and R&D work has a considerable lag that cannot be ignored (Hall et al., 1986). Hence, all the explanatory variables are in lags, in order to avoid double causality and to attempt to take into account the lagged impact between the R&D work and the generation of patents. Lagged values may help also to control for problems of endogeneity.

However, past levels of gender diversity may still be likely to be correlated with the current capacity to generate patents, as a firm may decide to modify the gender composition of their R&D team in order to reinforce their capacity to generate knowledge. The estimate is potentially affected by a reverse causality bias. It has been argued that gender diversity may be considered a determinant of knowledge generation. However, a firm's knowledge may affect the behaviour of researchers that work in a particular company. Firms that develop internal knowledge may attract better researchers, regardless of their gender

[8] Given our database, we cannot introduce other relevant explanatory variables, such as the number of citations of the patent, etc.

[9] See Table A.2 for a statistical description of the explanatory variables and Table A.3 for the Pearson correlations.

composition. Hence, in order to control the endogeneity problem we adopted an instrumental variable approach and controlling the potential endogeneity. We apply an exponential (Poisson) regression with endogenous regressor through a two-step generalized method of moments. The two-step GMM obtains parameter estimates based on the initial weight matrix, computes a new weight matrix based on those estimates, and then it reestimates the parameters based on that weight matrix.

As instruments, in addition to our explanatory variables, we include the sectoral value of gender diversity an also three dummies according the variable has introduced organizational innovations. Organizational innovations provide an environment to the firm which may promote the labour productivity of employees in R&D departments and any other department, while they do not directly contribute to the capacity to generate patents. A dummy was specifically included to identify if the firm had introduced: i) new practices affecting the organizational procedures in the firm (supply chain management, systems of knowledge management, efficient production, quality management, systems of training, etc.), ii) new organizational methods to improve the share of responsibilities and the decision-making process (team management, decentralization, department restructuring, etc.), iii) new managerial methods of external relations with other firms and public institutions (alliances, partnerships, outsourcing or subcontracting, etc.).

5. Empirical Results

Table 5 presents the impacts of the gender diversity index in the R&D department on the number of patents registered by a firm. Column (1) shows the estimation for the impact of generation of all types of patents, Column (2) considers the estimation of OEPM patents, Column (3) shows the estimates of EPO patents, Column (4) the estimates of USPTO patents, and Column (5) reports the estimates for the PCT patents. According to the Mills ratio, a problem of sample selection exists that requires control. Hence, our results will show the conditional estimations for firms with R&D labs.

Table 5. Conditional estimation of the determinants of a firm's capacity to register patents. Generalized Methods of Moments controlling for endogeneity.

	(1)	(2)	(3)	(4)	(5)
	Patents	***OEPM patents***	***EPO patents***	***USPTO patents***	***PCT patents***
Patents $_{i,t-1}$	0.0135***				
	(0.0014)				
OEPM patents $_{i,t-1}$		0.0405***			
		(0.0048)			
EPO patents $_{i,t-1}$			0.0259***		
			(0.0021)		
USPTO patents $_{i,t-1}$				0.0485***	
				(0.0097)	
PCT patents $_{i,t-1}$					0.0461***
					(0.0026)
$blauGender_{i,t-1}$	-0.451	-0.670**	-0.360	0.0261	0.735
	(0.320)	(0.297)	(0.370)	(0.546)	(0.541)
$blauCateg_{i,t-1}$	0.525**	0.465**	0.829**	1.336*	0.675
	(0.242)	(0.234)	(0.407)	(0.762)	(0.472)
$blauEduc_{i,t-1}$	-0.0809	-0.0890	0.0347	-0.843*	-0.0030
	(0.187)	(0.176)	(0.254)	(0.432)	(0.256)
$sizeRDdept_{i,t-1}$	0.0009*	0.0012**	0.0009	0.0008	0.0006
	(0.0005)	(0.0006)	(0.0006)	(0.0010)	(0.0009)
$size_{i,t-1}$	0.414***	0.294***	0.470***	0.494***	0.322***
	(0.0728)	(0.0600)	(0.0796)	(0.118)	(0.0798)
$age_{i,t-1}$	0.0607	0.113	0.0293	0.0576	-0.147
	(0.0832)	(0.0863)	(0.107)	(0.186)	(0.105)
$exp_{i,t-1}$	0.488***	0.270***	0.616***	0.753**	0.390***
	(0.105)	(0.0946)	(0.184)	(0.369)	(0.139)
$group_{i,t-1}$	-0.0218	-0.168	0.297	0.567**	0.136
	(0.145)	(0.145)	(0.196)	(0.259)	(0.229)
$matrix_{i,t-1}$	0.219	0.183	0.0775	0.458	0.564***
	(0.205)	(0.177)	(0.275)	(0.297)	(0.212)
$RDext_{i,t-1}$	0.0086*	-0.0005	0.0139**	0.0124	0.0129
	(0.0050)	(0.0045)	(0.0064)	(0.0092)	(0.0098)
$RDint_{i,t-1}$	0.369***	0.269***	0.450***	0.643***	0.433***
	(0.0628)	(0.0524)	(0.0574)	(0.0729)	(0.0874)
$coopera_{i,t-1}$	0.0313	0.328***	-0.0541	-0.445***	0.0770
	(0.0984)	(0.120)	(0.120)	(0.152)	(0.140)
constant	-5.640***	-4.943***	-8.268***	-11.11***	-7.335***
	(0.834)	(0.712)	(0.713)	(0.931)	-1029
Mills ratio	-0.714***	-0.416*	-1.309***	-0.803*	-1.280***
	(0.240)	(0.222)	(0.279)	(0.431)	(0.396)
Observations	16,524				
			Test of overidentifying restriction		
Hansen's J χ^2	1.75541	11.01	2.34558	4.30275	3.90195
$P>\chi^2$	0.7806	0.0265	0.6725	0.3666	0.4194

Notes: 1. *** Significant at 1%, ** Significant at 5%, * Significant at 10%. 2. All models include dummy for years. 3. Numbers in parenthesis are the coefficient standard errors.
Instruments for equations: Explanatory variables, organizational innovations and the sectoral blau index.

The estimated effect associated with the variable gender diversity is negative, although statistically non-significant for our main estimation with all patent types. However, the coefficient becomes significant when we consider the registration of patents in the OEPM (the Spanish type). Hence, teams with a more gender diverse composition exert a negative and significant impact on the generation of OEPM patents. Conversely, the coefficient is positive when considering the production of patents that have a larger coverage. That is, those firms that have been generating in the US patent office or under cooperative patents benefit from having a more diverse team in the R&D department. However, the coefficient becomes statistically non-significant.

The fact that the gender diversity variable has turned out to be non-statistically significant in determining the capacity to generate more complex patents is quite revealing. This result suggests that the mechanism that makes firms develop and produce more complex patents (EPO patents, USPTO patents and PCT patents) is quite different from that which encourages firms to protect their knowledge and do this through the Spanish system (OEPM patents). We could conclude that firms with R&D departments and with more gender-diverse teams is not a crucial determinant to register EPO patents, USPTO patents and PCT patents. However, the opposite effect is true for firms with R&D teams and their capacity to generate OEPM patents.

EPO patents, USPTO patents and PCT patents may in fact also be used to measure the internationalisation of inventive activities. One argument is that firms may be interested in protecting their most significant innovations abroad, given that the EU and the US are larger markets than that of Spain. Secondly, these patents are more likely to include the most economically important inventions, i.e. those that anticipate returns high enough to outweigh the cost of filing a patent abroad. Therefore, the difference encountered in terms of gender diversity may capture the relationship between the environment of the R&D team and the different nature of the inventions being produced.

Concerning the diversity of education and categories inside R&D departments, we observe that education level does not exert a significant impact and, in fact, shows a negative impact for the number of US patents. Conversely, the diversity of categories has a positive and a significant effect on the number of patents registered by a firm. Our results therefore seem to highlight the higher relevance of the diversity of categories inside a firm than the education level.

This difference may highlight the potential complementarity between the different roles inside an R&D department, where technicians and researchers may complement their activities. Finally, another crucial variable to measure the potential capacity to register patents is the number of researchers inside the R&D department. This variable shows a significant and positive sign for the general estimation (Column (1)), but it only remains significant for the estimation with the OEPM patents (Column (2)).

With respect to the analysis of a persistence in the capacity to patent, we have observed that there is a positive relationship. In other words, those firms patenting more in the past have greater capacity to register patents in the future. Our results highlight a certain persistence of firms that will have the capacity to develop new knowledge susceptible to protection through patents.

The results regarding firm characteristics confirm previous results. Larger firms have more capacity to generate patents, regardless of patent type. Firm age does not show a statistically significant impact on a capacity to generate patents[10]. We must highlight the fact that there is a positive relationship between export activity and the capacity to generate patents. Finally, belonging to a group does not show a significant impact in general, whilst if the firm is the parent establishment, this will exert a positive and significant impact on the number of PCT patents.

With respect to those variables more closely related with innovation effort, internal and external R&D efforts show a significantly positive impact on the capacity to generate patents for our general estimation (Column (1)). However, the analysis made according to types of patents shows that investing in external R&D is only significant for the generation of EPO. Conversely, as is expected, internal R&D investment shows a significant impact on the number of patents registered by a firm, regardless the patent type.

Finally, the R&D cooperation show a non-significant impact for our general estimation (Column (1)), however the sign is positive and statistically significant for the estimation of OEPM patents (Column (2)) while the impact becomes negative and significant for the number US patents. Our results highlight the fact that those firms which register their patents in the Spanish

[10] Estimates made with quadratic firm age did not show any statistically significant relationship.

patent office have a certain dependence on their capacity to develop new knowledge, given the positive influence that participation in R&D participatory projects has on the capacity to register new patents.

To sum up, an initial overall conclusion is that gender diversity exerts a non-significant impact in general. However, the most significant result is that R&D teams which develop OEPM patents are somewhat different from those that protect their knowledge with EPO patents, USPTO patents or PCT patents. This potential negative relationship between gender diversity and patents registered by a firm is not found for firms with a greater capacity to protect their knowledge.

These results are also confirmed when taking into account the percentage of female researchers in R&D departments (see Table A-4 in the appendix). We have therefore observed a negative incidence of the percentage of female researchers in the production of patents registered in the Spanish patent office. This negative effect disappears when taking into account the register in international patent offices. In fact, the sign becomes positive and statistically significant for PCT patents.

Table 6 shows the estimated conditional effects for the variables on the intensity of patent generation. Here, our dependent variable is the number of patents according to the number of employees. We aim to capture the existence of economies of scale in the capacity to generate patents. These new estimations may be important in revealing the influence of team-based gender diversity on the productivity of each researcher to develop patents.

With respect to our variable of interest, the estimated conditional coefficient of gender diversity presents a negative effect, and which depends on patent type. On the one hand, the coefficient shows a statistically significant negative impact in terms of the generation of the OEPM and EPO patents per researcher. On the other hand, the estimated coefficient does not show a statistically significant impact on the generation of more complex patents per researcher (Column (4) and (5)). This result may suggest that gender composition in R&D teams may not have such a positive impact in the generation of patents. In fact, a more gender-diverse composition of an R&D team will decrease a firm's capacity of a researcher to generate more patents registered in the Spanish patent office and the European Patent Office.

Table 6. Conditional estimation of the determinants of the productivity to register patents. Generalized Methods of Moments controlling for endogeneity.

	(1)	(2)	(3)	(4)	(5)
	Patents intensity	*OEPM patents intensity*	*EPO patents intensity*	*USPTO patents intensity*	*PCT patents intensity*
Patents intensity $_{i,t-1}$	0.190***				
	(0.0104)				
OEPM patents intensity $_{i,t-1}$		0.249***			
		(0.0283)			
EPO patents intensity $_{i,t-1}$			0.649***		
			(0.100)		
USPTO patents intensity $_{i,t-1}$				1.755***	
				(0.193)	
PCT patents intensity $_{i,t-1}$					0.289***
					(0.0202)
$blauGender_{i,t-1}$	-1.241***	-1.360***	-1.004*	-0.143	0.105
	(0.330)	(0.321)	(0.513)	(0.564)	(0.456)
$blauCateg_{i,t-1}$	-0.0145	-0.0362	-0.132	0.358	-0.271
	(0.332)	(0.315)	(0.515)	(0.646)	(0.622)
$blauEduc_{i,t-1}$	-0.184	-0.349*	-0.322	-0.982*	0.107
	(0.196)	(0.186)	(0.299)	(0.557)	(0.300)
$sizeRDdept_{i,t-1}$	-0.0009	-0.0076	-0.0004	-0.0011	-0.0028
	(0.0014)	(0.0052)	(0.0014)	(0.0018)	(0.0025)
$size_{i,t-1}$	-0.105	-0.0918	0.0053	0.167	-0.0057
	(0.0774)	(0.0876)	(0.0936)	(0.148)	(0.106)
$age_{i,t-1}$	-0.0457	0.0140	-0.0428	-0.0800	-0.288**
	(0.107)	(0.120)	(0.115)	(0.139)	(0.121)
$exp_{i,t-1}$	0.460***	0.308**	0.719***	1.024***	0.827***
	(0.144)	(0.143)	(0.168)	(0.261)	(0.181)
$group_{i,t-1}$	-0.160	-0.308**	0.132	0.151	0.0049
	(0.153)	(0.157)	(0.192)	(0.255)	(0.300)
$matrix_{i,t-1}$	0.292	0.0543	0.182	0.0753	0.654*
	(0.202)	(0.262)	(0.270)	(0.272)	(0.343)
$RDext_{i,t-1}$	6.05e-05	-0.0040	0.0021	0.0116	0.0058
	(0.0057)	(0.0061)	(0.0062)	(0.0095)	(0.0110)
$RDint_{i,t-1}$	-0.126*	-0.0740	-0.0134	0.282**	0.0337
	(0.0726)	(0.0805)	(0.0857)	(0.122)	(0.151)
$coopera_{i,t-1}$	0.122	-0.0091	-0.190	-0.296	-0.0915
	(0.118)	(0.138)	(0.126)	(0.207)	(0.119)
constant	-0.695	-1.357	-3.610***	-8.223***	-4.095**
	(0.967)	-1.135	-1094	-1618	-1608
Mills ratio	-0.171	-0.0090	-0.450*	0.105	-0.673
	(0.254)	(0.235)	(0.252)	(0.341)	(0.491)
Osbservations	16,524				
Test of overidentifying restriction					
Hansen's J χ^2	11.0607	16.7919	1.06325	7.6515	2.4728
P>χ^2	0.0259	0.0021	0.9001	0.1052	0.6495

Notes: 1. *** Significant at 1%, ** Significant at 5%, * Significant at 10%. 2. All models include dummy for years. 3. Numbers in parenthesis are the coefficient standard errors.
Instruments for equations: Explanatory variables, organizational innovations and the sectoral blau index.

Other variables that are relevant to the productivity of patents per researcher are as follows. First, those firms with researchers whose productivity to patent is high will continue to show greater productivity to patent. Second, those variables more closely-related to the environment in the department do not seem to exert an impact on productivity. Third, the estimated coefficient of export activity shows a significant positive coefficient for all patent types; however, the sign is not significant when making distinctions in accordance to different patent types.

6. Conclusions

Gender diversity has been addressed recently as an important factor in generating positive synergies between groups and in increasing innovative performance in firms. However, this impact is not clearly-defined, given the opposite tensions between these positive externalities and the negative tensions that may exist in a more diverse environment. The effects of gender diversity are still more crucial in a process involving the generation of knowledge, where interaction, creativity and solving problems are normal tasks in environments where new discoveries are to be made.

In a sample of innovative Spanish innovative firms, this paper aims to examine the extent of the effect of gender diversity on R&D teams in the generation of patents. After controlling for endogeneity and sample selection bias, we have found that gender diversity does not exert an impact on the generation of patents in general. However, there are some interesting results according to patent coverage type. Firstly, gender diversity in R&D teams reveals a dual effect. The impact of gender diversity is statistically negative with regards to the capacity to generate OEPM patents, while the sign becomes positive for those firms that register EPO, USPTO and PCT patents. All in all, our results seem to point out that the mechanism that makes firms develop and produce more complex patents is quite different from that which drives firms to protect knowledge and protect through the Spanish system (OEPM patents). Secondly, our results highlight the importance of the diversity of categories that exists in R&D departments. Our results show that the complementarity of categories of in R&D may still be more crucial than the gender composition in the R&D team in order to foster the development of new knowledge that is likely to be protected through patents.

One gap in this research is that we have not been able to ascertain the quality of the patents or their potential market value. We are aware of the fact that differentiation according to patent coverage type is an imperfect way of determining the quality of new knowledge; however it does provide information on the potential capacity of a firm to capture the market value of new knowledge and, consequently, its implicit quality. Furthermore, we do not have information on patent citations, as an indicator of their relative importance.

Despite these drawbacks, we have contributed to the literature available by analysing the relationship between the gender diversity of R&D teams and the generation of new knowledge. There is scarce literature that analyses the relationship between gender and innovation (Alsos et al., 2013), and still less that analyses the gender diversity of R&D teams and their capacity to produce new patents. Research lines in the future may analyse into the nature of innovative firms that are generating new knowledge and investigate interactions with other diversity indexes.

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Table A-1. Description of variables		
Dependent variables	*Patents*	Total number of patents (in logs)
	OEPM patents	Total number of patents registered in OEPM
	EPO patents	Total number of patents registered in EPO
	USPTO patents	Total number of patents registered in USPTO
	PCT patents	Total number of patents registered in under PCT treaties
Independent variables	*blauGender*	Blau index for the gender diversity of the R&D team.
	blauCateg	Blau index for the diversity of categories of the R&D team. CIS survey considers three categories: researchers, technicians and auxiliary research staff.
	blauEduc	Blau index for the education level using of the R&D team.
	sizeRDdept	Total number of researchers (in logs)
	size	Total number of employees (in logs).
	age	Firm age and its quadratic value (in logs).
	exp	Dummy equal to 1 if a firm exports.
	group	Dummy equal to 1 if a firm is part of a group.
	matrix	Dummy equal to 1 if a firm is the parent establishment.
	RDext	Expenditure on external R&D per employee (in logs).
	RDint	Expenditure on internal R&D per employee (in logs).
	coop	Dummy equal to 1 if a firm cooperates with other companies.
	ResWomen	Percentage of female researchers in the R&D department

Table A-2. Statistical summary (mean and standard deviation in parenthesis). 2004-2014.

	All database	Firms patenting only in OEPM	Firms patenting other different offices in OEPM	Firms patenting only in OEPM and other patent offices
Patents	0.6378	2.9950	3.4360	9.1405
	6.7561	18.5786	6.4854	21.8619
blauCateg	0.2382	0.2506	0.2879	0.2890
	0.2017	0.1982	0.1864	0.1842
size	4.0573	4.1564	4.5038	4.6977
	1.4150	1.3594	1.4691	1.4260
age	3.0594	3.0138	2.9997	3.0975
	0.7313	0.7808	0.8242	0.7931
exp	0.6150	0.6832	0.7906	0.8012
	0.4866	0.4653	0.4070	0.3992
group	0.3772	0.3639	0.5649	0.5428
	0.4847	0.4812	0.4960	0.4983
matrix	0.0713	0.0951	0.1295	0.1487
	0.2574	0.2934	0.3359	0.3559
RDext	-9.3085	-4.8860	-2.7410	-2.4099
	10.5284	11.6158	11.6290	11.6824
RDint	-1.1042	5.4872	7.0964	7.4875
	11.8534	8.1460	6.5758	5.9212
blauCateg	0.6258	0.4805	0.4602	0.4743
	0.3437	0.2800	0.2487	0.2268
blauEduc	0.7953	0.6941	0.6643	0.6777
	0.2803	0.2773	0.2470	0.2284
coop	0.3136	0.5004	0.5805	0.5873
	0.4640	0.5001	0.4937	0.4925
sizeRDdept	10.3644	19.5682	33.3744	42.1538
	38.2083	52.0061	76.7243	86.6372

Source: own elaboration

Table A-3. Pearson correlations.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	*Patents*	1																
(2)	*OEPM patents*	0.813*	1															
(3)	*EPO patents*	0.619*	0.173*	1														
(4)	*USPTO patents*	0.366*	0.116*	0.466*	1													
(5)	*PCT patents*	0.568*	0.135*	0.631*	0.408*	1												
(6)	*blauGender*	0.042*	0.015*	0.047*	0.046*	0.051*	1											
(7)	*size*	0.087*	0.051*	0.089*	0.075*	0.065*	0.194*	1										
(8)	*age*	0.027*	0.011*	0.028*	0.005	0.010*	0.013*	0.342*	1									
(9)	*exp*	0.046*	0.031*	0.040*	0.033*	0.035*	0.003	0.166*	0.166*	1								
(10)	*group*	0.055*	0.028*	0.059*	0.060*	0.051*	0.150*	0.484*	0.089*	0.089*	1							
(11)	*matrix*	0.022*	0.010*	0.020*	0.038*	0.027*	0.080*	0.195*	0.100*	0.062*	0.319*	1						
(12)	*RDext*	0.081*	0.050*	0.078*	0.072*	0.069*	0.154*	0.138*	0.001	0.150*	0.146*	0.065*	1					
(13)	*RDint*	0.071*	0.047*	0.063*	0.057*	0.057*	0.187*	0.049*	-0.059*	0.207*	0.077*	0.065*	0.356*	1				
(14)	*blauCATEG*	-0.036*	-0.026*	-0.029*	-0.027*	-0.028*	0.219*	-0.008	0.095*	-0.130*	-0.043*	-0.036*	-0.260*	-0.847*	1			
(15)	*blauEDU*	-0.036*	-0.022*	-0.033*	-0.036*	-0.029*	0.087*	-0.041*	0.080*	-0.110*	-0.070*	-0.034*	-0.184*	-0.594*	0.642*	1		
(16)	*coop*	0.067*	0.043*	0.063*	0.052*	0.056*	0.169*	0.172*	-0.014*	0.096*	0.172*	0.083*	0.376*	0.332*	-0.250*	-0.172*	1	
(17)	*sizeRDdept*	0.197*	0.103*	0.228*	0.220*	0.157*	0.142*	0.291*	0.026*	0.066*	0.138*	0.071*	0.176*	0.219*	-0.149*	-0.105*	0.208*	1

Source: Own elaboration from PITEC
* *p<0.01*

Table A-4. Conditional estimation of the determinants of a firm's capacity to register patents. Generalized Methods of Moments controlling for endogeneity. Percentage of women

	Patents	*OEPM patents*	*EPO patents*	*USPTO patents*	*PCT patents*
Patents $_{i,t-1}$	0.0148***				
	(0.0014)				
OEPM patents $_{i,t-1}$		0.0411***			
		(0.0047)			
EPO patents $_{i,t-1}$			0.0266***		
			(0.0023)		
USPTO patents $_{i,t-1}$				0.0508***	
				(0.0095)	
PCT patents $_{i,t-1}$					0.0458***
					(0.0026)
ResWomen$_{i,t-1}$	-0.0030	-0.0056**	0.0001	0.0004	0.0068**
	(0.0023)	(0.0022)	(0.0032)	(0.0047)	(0.0033)
blauCateg$_{i,t-1}$	0.928***	0.827***	1.083***	1.675**	0.904*
	(0.252)	(0.246)	(0.410)	(0.763)	(0.507)
blauEduc$_{i,t-1}$	-0.337**	-0.332**	-0.149	-1.048***	-0.0834
	(0.171)	(0.167)	(0.238)	(0.398)	(0.247)
sizeRDdept$_{i,t-1}$	0.0023***	0.0023***	0.0017***	0.0012	0.0013
	(0.0004)	(0.0005)	(0.0006)	(0.0010)	(0.0009)
size$_{i,t-1}$	0.271***	0.166***	0.384***	0.411***	0.263***
	(0.0646)	(0.0527)	(0.0798)	(0.118)	(0.0841)
age$_{i,t-1}$	0.0601	0.107	0.0205	0.0989	-0.167*
	(0.0783)	(0.0889)	(0.107)	(0.170)	(0.0969)
exp$_{i,t-1}$	0.433***	0.236**	0.594***	0.753**	0.372***
	(0.111)	(0.0974)	(0.181)	(0.363)	(0.140)
group$_{i,t-1}$	0.0070	-0.149	0.314	0.649**	0.195
	(0.145)	(0.143)	(0.193)	(0.255)	(0.238)
matrix$_{i,t-1}$	0.276	0.234	0.124	0.480*	0.563***
	(0.211)	(0.176)	(0.269)	(0.281)	(0.203)
RDext$_{i,t-1}$	0.0143***	0.00407	0.0180***	0.0163*	0.0157*
	(0.0051)	(0.0045)	(0.0064)	(0.0088)	(0.0094)
RDint$_{i,t-1}$	0.118***	0.0641***	0.308***	0.560***	0.333***
	(0.0304)	(0.0151)	(0.0681)	(0.0816)	(0.106)
coopera$_{i,t-1}$	0.0941	0.374***	-0.0275	-0.406**	0.128
	(0.105)	(0.117)	(0.129)	(0.160)	(0.134)
constant	-2.805***	-2.567***	-6.650***	-10.14***	-6.173***
	(0.541)	(0.420)	(0.825)	-1. 014***	-1241
Mills ratio	-1.032***	-0.664***	-1.491***	-0.958**	-1.408***
	(0.252)	(0.240)	(0.286)	(0.426)	(0.411)
Observations	17,588				
		Test of overidentifying restriction			
Hansen's J χ^2	1.20754	9.80532	2.55317	5.75687	3.6452
P>χ^2	0.8769	0.0438	0.6351	0.2181	4561

Notes: 1. *** Significant at 1%, ** Significant at 5%, * Significant at 10%. 2. All models include dummy for years. 3. Numbers in parenthesis are the coefficient standard errors.
Instruments for equations: Explanatory variables, organizational innovations and the sectoral blau index.