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Female R&D Teams and Patents as Quality Signals in Innovative Firms

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Abstract

Innovative firms use patents to signal the quality of their R&D teams in evaluation processes affected by asymmetric information. Examples of these processes occur when applying for finance from external sources or when searching for collaboration partners for innovation projects. In this paper we provide evidence that, in these cases, firms' external agents undervalue patents of female R&D teams as compared to patents of male R&D teams. We investigate this issue using data of Spanish innovating firms from PITEC, spanning 2005-2014, a panel database that follows the structure of the European Community Innovation Surveys (CIS). We interpret our results as consistent with an evaluation bias against female researchers, making them to be subject to a greater scrutiny as compared to their male counterparts, and thereby suggesting the existence of gender discrimination in R&D.

Keywords: female R&D teams, patents, asymmetric information, quality signals.

JEL classification: O30, O34, C20, J16.

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1 Introduction

Firms' investments in R&D are subject to market imperfections, due to the fact that information regarding the potential success of a new technology is held asymmetrically between the firm and external agents. This asymmetry in information makes difficult for outsiders to evaluate the quality of firms performing R&D (Arrow, 1962) and, in particular, the quality of firms' research teams. Patents, although mainly aimed at protecting against imitation in product markets (Rumelt, 1984; Teece, 1986), may also be used to signal the quality of the research conducted by the R&D team of a firm in evaluation processes affected by asymmetric information.

Two important contexts where innovative firms need to signal the quality of their innovation team and projects arise when they ask for external finance for innovation or when searching for collaboration with third parties (Long, 2002; Hottenrott et al., 2016; Zhang et al., 2019). In this paper, we focus in these two cases and analyse whether firms' outsiders consider equally valuable patents registered by male R&D teams and patents registered by female R&D teams, after controlling for a number of firms' and market characteristics. In other words, we analyse the possibility of a *gender-biased evaluation* on the part of external agents who evaluate the firm's R&D team quality. This issue is important since the existence of such a gender bias would be consistent with the presence of stereotypes against the quality of patents obtained by female researchers (Jensen et al., 2018), what would add understanding to the obstacles found by women in areas of such a high value for society as industry and science. To our knowledge, this constitutes an entirely new contribution to the literature, since, although the role of patents as quality signals has been well documented previously, no study so far has addressed if, and how, the certificate effect of patents may differ by gender.

We investigate this issue using data from the Technological Innovation Panel (PITEC), a panel dataset recording the innovation activities of Spanish firms, conducted by the Spanish National Statistics Office (INE) since 2003, and which follows the structure of the European Community Innovation Surveys (CIS). In our analysis, we use information for the period 2005-2014. PITEC provides detailed information on a number of issues regarding the innovation activities carried out by firms both in manufacturing and in services sectors, including the number of patent applications by firms and the gender of their R&D workforce. We select those firms with a clear majority of researchers of one gender within their R&D team. The reason is that we want to look at teams that are clearly perceived by external lenders or potential collaborators as mainly composed by either male or female members. In particular, the condition we apply to consider an

R&D team to be male-/female-dominated (male and female teams, henceforth) is that it is composed of at least a 70 percent of male/female researchers.

Our underlying assumption is that external agents actually observe and take into account gender information of the R&D team and their patents. There are several reasons to support this assumption. Patent documents state the name of the inventors to whom the patent is granted.[1] Thus, when patent documents are used to certificate the quality of the firm and its innovation activities in negotiations with third parties, they directly disclose the name and gender of the inventors. On the other hand, to evaluate the prospects of the research project to be financed, financing institutions typically require detailed information regarding the composition and quality of the R&D team. For instance, credits for innovation offered by banks and other financing institutions, are most often fixed-purpose loans, which analyse with great detail both the project for which the funds are applied for and the team that will be responsible to undertake it.[2] Regarding R&D cooperation with other firms and institutions, which usually entails sharing crucial knowledge and ideas, pooling and combining complementary assets and resources, and working side by side, it is reasonable to consider that potential partners will take into account all the details about the composition and quality of the R&D team, including the gender of its members, before engaging in collaboration.

To analyse the possibility of gender-biased evaluation of patents we use the well known Oaxaca-Blinder decomposition, Oaxaca (1973) and Blinder (1973). This methodology has been traditionally applied to split gender gaps in a given outcome of interest, such as the wage gap, into a component explained by differences in characteristics that vary by gender, and an unexplained component. The latter is taken as an estimate of the unequal pay for individuals with equal characteristics but different gender, and it is interpreted as unobserved characteristics, usually discrimination, affecting the outcome.

Our empirical strategy consists of applying the Oaxaca-Blinder decomposition to two

[1]In the case of the Spanish Office of Patents and Trademarks, it is compulsory in patent applications to designate the inventors (Article 25, Law of Patents 24/2015, of 24th of July, https://www.boe.es/buscar/pdf/2015/BOE-A-2015-8328-consolidado.pdf). In European patent applications the names of the inventors must also be explicitly designated, and it is explicitly stated in the final patent certificate (https://www.epo.org/applying/european/Guide-for-applicants/html/e/ga_c4_1_7.html).

[2]To mention another example, the AEBAN (Spanish Association of Business Angels, member of BAE, Business Angels Europe), which constitutes one of the main associations for channelling private capital allocation to start-ups and innovative projects in Spain, explicitly states that the characteristics of the research team that will undertake the project are vital to decide in favor of providing the funds (AEBAN-2017 report, e.g page 6, https://media.timtul.com/media/web_aeban/Informe%20AEBAN%202017_ES_20180410072431.pdf), *last accessed January 2021.*

sets of dependent variables. First, we apply this method to variables that represent the outcome of processes where firms are subject to the external scrutiny of their innovation quality, namely, accessing external finance, and finding partners for innovation. In doing so, we will further distinguish between private and public lenders, and between private and public partners, respectively. These variables constitute our main focus of interest. Second, we apply it to a number of variables that serve us to implement a falsification or placebo-test strategy. The variables that serve as placebo are measures of firms' economic outcomes that do not involve a process of external assessment of the innovation quality of the firm's R&D team, such as innovative sales, labour productivity, and researchers' wages. In all cases, the main explanatory variable whose decomposition we are interested in is the number of patents of the firm.

The placebo-test strategy works as follows. If the Oaxaca-Blinder decomposition renders significant unexplained effects of patents on the variables related to external finance and research collaborators, we might still think that they could be driven by unobserved, or unmeasured, differences in quality between patents of female and patents of male R&D teams. The application of the Oaxaca-Blinder decomposition to the placebo variables allows us to rule out this possibility. More specifically, if the unexplained effects of patents were driven by unobserved differences in patents' quality by gender, then such unexplained effects would also arise in the decomposition of innovative sales, labour productivity, or researchers' wages, since the quality of patents is naturally expected to affect these variables. If, on the contrary, unexplained effects of patents only emerge in external finance and collaboration variables, we will be confident that they may be attributed to discrimination.

To anticipate our results, we find that patents of female R&D teams reveal a significant unexplained effect in accessing external finance and in finding partners to collaborate in innovation. The possibility that different quality of patents by gender could be driving the results is discarded by the lack of evidence of unexplained effects of patents in variables such as firms' innovative sales, labour productivity and researchers' wages, which may be considered as firms' outcomes not subject to evaluation processes from outsiders.

Our results provide empirical evidence consistent with the existence of a gender bias against female researchers in the evaluation of their patents. One important implication of these results is that female R&D teams would need to account for a higher number of patents than male R&D teams in order to have the same chances to reach collaborating contracts with third parties or to obtain external funding for innovation, other things equal. On more general grounds, our findings provide empirical support to the existence of gender biases against female researchers. Thus, the evidence provided by this paper is an additional step towards acknowledging and understanding the roots of gender discrimination, and could help policy makers to design instruments to fight the gender bias in science and entrepreneurial activities undertaken by women.

The rest of the paper is organized as follows. Section 2 describes the different strands of the literature related to our study and points out our main contributions. Section 3 provides a description of our empirical strategy and describes the data and variables used in the estimation setting. Section 4 reports and discusses the results, and finally, Section 5 concludes.

2 Related literature and contribution

Our study is linked and contributes, at least, to three strands of the literature. First, our paper is linked to the recent literature on gender inequality in science, and, in particular, to the empirical evidence on gender gaps in patenting activity. This line of research suggests that women might face higher barriers and obstacles in their participation and progress in this area of high value for society. Second, our paper is clearly associated with the IO literature on signaling in markets affected by asymmetric information. In particular, our work relates to the literature that has studied the role of patents as a mechanism to convey information to outsiders about the innovation quality of a firm or a research team. The search for external finance and collaboration partners for innovation are two of the most relevant cases where an innovative firm needs to convey such information. Finally, our study is also linked to the literature on gender discrimination, that is, on the existence of biased beliefs against women abilities, in general, and in the area of science in particular. In the following lines we point out the findings of these strands of the literature that are most closely related to ours, and specify how our work contributes to them.

Gender gaps in patenting.

The lower involvement of female researchers in patenting, in both industry and academia, has been extensively documented. The works of Naldi and Parenti (2002) and Naldi et al. (2004), for instance, report a substantial gender gap in patenting in a patent database covering six European countries, although the gap differs from country to country and by sector. In an extended sample covering 14 countries, Frietsch et al. (2009) show that, although the share of women's patent outputs seems to have evolved positively over time, it is still clearly lower than that of men.

Gender differences in patenting either at the firm-level or across technologies, as well as in particular fields, have been also reported. For instance, the study of Link and Hasselt (2019) documents fewer patent applications in small women-owned entrepreneurial firms, compared to men-owned firms, using a random sample of firms whose research projects were supported through the US Small Business Innovation Research (SBIR) program between 1992 and 2001. Also, gender gaps in information technology in US and Japan are examined in Ashcraft and Breitzman (2007), whereas in the case of Spain gender differences across technologies are analyzed by Mauleón and Bordons (2009, 2010). In the case of Finland, the work of Heikkilä (2019) reports evidence of gender gaps in different types of property rights (utility models, design rights and trademarks).

The reasons for the existence of a pronounced gender gap in patenting rates in the US have been put forward by Hunt et al. (2013), who stressed that much of this gap may be explained by women's under-representation in engineering and in jobs involving development and design.[3] However, in terms of quality and impact, it is less clear that such a gender gap exists. For example, examining the patenting results for more than 1,000 life scientists in the US, Whittington and Smith-Doerr (2008) find that the patents of female scientists seem to be as good, or better, than those obtained by their male counterparts. The authors measure patenting quality using citation rates and indicators of interdisciplinary nature and applicability (following Hall et al., 2001), and find that, while women engage less and produce fewer patents than their male counterparts, those who do have equal or better citation rates, originality, and broad applicability.

Given the role of patents in firms' success in many dimensions (such as productivity, profits, competition or survival), a considerable gender gap in patenting may help explain other gender gaps in industrial performance. Thus, disentangling the obstacles found by women in patenting may be one of the ways to promote women' success in industry. Our paper contributes to this line of research by adding a new perspective to the gender gap in patenting, namely, the possible existence of a gender gap against the value of female patents in external evaluation processes. If it is the case that female R&D teams find it more difficult to translate their patents into credible signals when needed, it follows that they would need to patent even more than male researchers to receive the same appraisal by external lenders or potential partners.

Patents as quality signals.

Building upon the concept of job market signals (Spence, 1973), a number of studies

[3] Other references on gender gaps in patenting are those of Ding et al. (2006); Murray and Graham (2007); Meng and Shapira (2010); Blume-Kohout (2014); Meng (2016, 2018), among others.

have considered industrial patents as a way to provide quality signals that may mitigate informational asymmetries between the firm and outsiders. Asymmetric information in financial markets, for instance, raises the costs of external capital and it often constitutes a barrier very difficult to overcome. Patents may provide a signal, first and foremost, of the quality of the R&D team of the firm, but also of the general quality of the firm in other dimensions.

Long (2002) distinguishes between the role of patents as a mechanism of establishing intellectual property rights, and as a tool to credibly convey information to outsiders about the underlying innovation. Patents have properties that make them good and reliable proxies for the assessment of the quality of R&D performing firms. First, they are costly to obtain and easily observable and verifiable by outsiders. Second, possessing a patent is the result of previous R&D success, thus patents may be used by external agents to assess the innovation or technological capabilities of the R&D performing firms, which are usually difficult to observe or to evaluate. In support for this, the results of Henderson and Cockburn (1994) reveal that patent counts act as a measure of firms' technological capabilities in the pharmaceutical industry, and Harhoff (2009) shows that patents signal the quality of the R&D team of the firm.

In addition, several studies have documented that patents stocks are positively associated with a number of relevant firms' economic outcomes, as well as with other unobservable assets and managerial traits of firms. For instance, patent stocks are positively associated with the firms' market value and provide additional information on the rest of firms' knowledge assets (Hall, 2000; Hall et al., 2005; Czarnitzki et al., 2006). Helmers and Rogers (2011) and Hall et al. (2013) provide evidence that patenting firms grow faster and are more productive, as compared to firms that do not patent. In terms of profitability, Levitas and McFayden (2009) state that, by protecting firms against competition, patents raise the prospects of future returns, and Kulatilaka and Lihui (2006) note that, by facilitating the licensing of technology, patents generate additional returns to the patented technologies. Also in terms of survival, several studies report a positive association between holding patents and firms' survival (Wagner and Cockburn, 2010; Mann and Sager, 2007). Therefore, external investors may use patents to evaluate the prospects and future value of the firm.

In the specific context of the firms' search for finance, several studies have provided evidence that patents act, indeed, as effective signals of a firms' innovative and general quality. For instance, Hottenrott et al. (2016) show that patents attenuate financial constraints for small firms when information regarding the success or the quality of a new technology is held asymmetrically between the R&D-performing firm and potential lenders and investors. Also, Hsu and Ziedonis (2008, 2013) show, for a sample of semiconductors start-ups, that their patent stock has a strong impact on venture capital financing, while Haeussler et al. (2014) and Hoenen et al. (2014) find similar results for biotech firms. Finally, Conti et al. (2013) explore the role of patents as quality signals for venture capital in a sample of Israeli start-ups, and Useche (2014) provides evidence on how patents increase the amount of finance received from investors at initial public offering of high-tech software firms in the US and Europe.

Hence, the fact that patents may act as signals of firms' innovative quality seems to be out of question, that is, patents convey information about relevant unobserved characteristics of the firm. However, even if the emitted signal is itself powerful, its final effect will also depend on how the signal receiver processes it. For instance, if the sender of the signal were discriminated against (i.e., if there were an *unfavourable evaluation bias*), this would run counter the positive information contained in the signal and, thus, the effective effect of the signal would diminish. Our paper makes a novel contribution in this line, which consists in providing evidence of such an evaluation bias against female researchers in two of the most important contexts where an innovative firm needs to convey a signal of its quality: when searching for finance for innovation and when searching for collaboration partners.

In the following lines we review existing evidence suggesting that such an evaluation bias might exist.

Gender biases in science and business.

The existence of biased beliefs against women abilities in general, and in the labour market in particular has been extensively documented (Arrow, 1973; Gorman, 2005). As found in psychological studies (Hilton and von Hippel, 1996), the association of different beliefs regarding the attributes of men and women operates to women's disadvantage. Established stereotypes tend to consider men as being aggressive, competitive, courageous, assertive, etc., to a larger extent than women (Buttner and Rosen, 1988), and these beliefs negatively affect women at the workplace (Powell et al., 2002). These stereotypes work against women participation and progress in areas of high value for society such as science. The disadvantage of women in science is not only due to stereotypes regarding gender-specific attributes, but it is also shaped by social and structural factors, with science been imprinted as a masculine area traditionally dominated by men (Fox, 2001).

The work of Kanze et al. (2018), entitled "*We ask men to win and women not to lose: closing the gender gap in startup funding*", provides clear evidence of a cognitive bias associated with stereotypical judgements that leads potential investors to ask gendered questions to research teams asking for finance. Using a field study conducted on question-and-answer interactions in venture capital allocation to start-ups, they show that investors tend to ask male entrepreneurs promotion-focused questions while they ask prevention-focused questions to female entrepreneurs. The induced corresponding entrepreneurs' responses result in a bias in funding outcomes in favor of male entrepreneurs.

There is a growing literature analysing the obstacles that women-led firms face in their access to credit. Although some studies fail to find evidence of discrimination in financial markets (Blanchflower et al., 2003; Cavalluzzo et al., 2002), the evidence in the opposite direction is more abundant. For instance, the work by Bellucci et al. (2010) reports that female entrepreneurs are more likely to be denied credit, and Fabowale et al. (1995) find that firms run by women face different loan contract terms that place them at a relative disadvantage. More recently, Aristei and Gallo (2016) provide additional evidence of gender differences in firms' access to credit using data for 28 transitional EU countries, giving support to the hypothesis of a gender bias discrimination in access to credit against women-led businesses. In addition, Moro et al. (2017), using a sample of small European businesses, find that female-led firms obtain less bank financing.

Regarding collaboration networks, and although the existing literature has not directly referred to a conscious bias against women, they might also constitute another context where women may encounter greater obstacles, both in business and in academic science. While some works have found a high willingness of female entrepreneurs to collaborate and develop networking activities (Sorenson et al., 2008; Dawson et al., 2011), or little actual networking differences by gender, both in business (Foss, 2010; Watson, 2011) and in academic science and universities (Bozeman and Gaughan, 2011; Gaughan and Bozeman, 2016), others have documented that women might find it more difficult to establish collaboration networks. For instance, within the innovation management literature, some studies highlight that women are restricted in their access to collaboration networks in businesses (see, e.g., Achtenhagen et al., 2013; Ozkazanc-Pan and Muntean, 2018), and other studies in academic science have clearly stressed that female scientists seem to find more difficulties to collaborate with industry as compared to male colleagues (Tartari and Salter, 2015; Meng, 2016). Research into the nature and origin of these obstacles is of great interest if, as Amoroso and Audretsch (2020) find, female entrepreneurs obtain greater benefits from their networks in terms of complementing internal RD capabilities with external knowledge resources. Besides the just cited reference, and to the best of our knowledge, the literature examining specifically gender differences in corporate R&D collaboration patterns remains virtually unexplored. Our paper constitutes then a novel contribution in this line of research by analysing the role of patents and the existence of possible gender biases when searching for collaboration partners.

Within the literature on gender and patenting, Jensen et al. (2018) also provide evidence on a gender bias against female patentees. They examine the individual prosecution histories of around 2.7 million US utility patents applications from 2001 to 2014 to the US Patent and Trademark Office (USPTO), and find robust gender disparities in obtaining and maintaining patent rights, with a remarkable disadvantage for female inventors. More specifically, they find that patent applications by female inventors are more likely to be rejected than those of male inventors, that rejections are less likely to be appealed by the applicant team (inventor, assignee and prosecuting attorney), and, further, that, conditional on being granted, the patent applications of female inventors are less likely to have their claims allowed.

We contribute to this literature by providing evidence of gendered differences in the valuation of patents made by firms' external agents, and showing that these differences may be consistent with the presence of discrimination against female researchers. As stated above, we analyse the R&D teams of a representative sample of innovative firms in both manufacturing and services sectors. To our knowledge, this is an entirely novel contribution for, at least, two reasons. First, regarding gender inequality in patenting, our focus is on research teams of innovative firms in industry and services, while previous work has mainly focused on academics and publication productivity. And, second, we add to the analysis of gender disparities in financial markets by analysing also gender differences in their difficulties to find partners for collaboration in innovation, what constitutes an unexplored line of research.

Summing up, our paper contributes to the existing literature mainly on two fronts. First, we add a new perspective to the analysis of gender gaps in patenting, namely, the possible existence of a gender bias against the value of patents of female researchers. In particular, we provide evidence on the difficulties faced by female R&D teams in industrial and services firms in two of the most important contexts where an innovative firm needs to convey a signal of its quality: external finance and collaboration markets. Second, we add to the literature on the signaling effect of patents by providing evidence that gendered evaluation biases may weaken the power of the signal, even if the quality of the patent is in principle the same.

3 Empirical strategy and data.

In this section we first describe the empirical strategy we follow to identify possible differences in the impact that patents may have in the success of firms in finding external finance and partners for their innovation processes, depending on the prevalent gender of their R&D team. The strategy is based on the application of the well-known Oaxaca-Blinder decomposition to two sets of dependent variables for which we would expect significant and non-significant unexplained effects of patents, respectively, if discrimination was present. Then, we describe the data used in our analysis.

3.1 Empirical strategy and methods.

We use two sets of outcome variables. The first set refers to variables that represent the outcome of processes where firms are subject to the external scrutiny of their innovation quality, namely, accessing external finance for innovation activities and finding partners to collaborate in innovation. The second set refers to variables that measure firms' economic outcomes that do not involve a process of external evaluation of a firm's innovation quality, namely, innovative sales, labour productivity (turnover per employee), and wages of researchers. We will refer to these two sets of variables as set-1 and set-2, respectively, throughout the rest of the paper.

First, to have a first approximation to explore gender differences in the effect of patents, we apply standard estimation methods, as detailed below, to the two sets of dependent variables just mentioned. In this case, we will include in estimation the interaction of patents with female R&D teams to capture such gender differences.

Second, and constituting the main piece of our empirical strategy, we will apply the well known Oaxaca-Blinder decomposition, Oaxaca (1973) and Blinder (1973), *OB decomposition* henceforth. This methodology has been traditionally applied to split gender wage gaps into a component explained by differences in characteristics that vary by gender, and an unexplained component. The latter is taken as an estimate of the unequal pay for employees with equal characteristics but different gender. We apply the OB decomposition to the two sets of dependent variables.

Formally, the difference in the expected value of a given outcome, $\overline{Y}_{it}$, between two groups of interest (female and male R&D teams, in our case) can be decomposed as follows:

$$\overline{Y}_{it}^{M} - \overline{Y}_{it}^{F} = \beta^{M}(\overline{X}_{it}^{M} - \overline{X}_{it}^{F}) + (\beta^{M} - \beta^{F})\overline{X}_{it}^{F} \quad (1)$$

where superscripts M and F stand for male and female teams, respectively, and $\overline{X}_{it}$ is a vector containing the averages of the group characteristics that explain the outcome. Specifically, the vector X_{it} includes the number of patents of the firm, which is the variable of our foremost interest in this paper; in addition, it also contains a list of variables to partial out the effect of other firms' characteristics that are potentially correlated both with patents and with our outcome variables.

In the above two-fold decomposition, the first component is the part of the outcome differential that is *explained* by differences in the average values of the characteristics of the two groups; the second component is the *unexplained* part. The explained component measures outcome differentials accounted for by differences in the two groups' characteristics if these characteristics affected the two groups' outcomes as they do in male teams (as captured by β^{M}). The second component captures the part of the differential that is due to different responses of the two groups' outcomes to a same average vector of characteristics if such common vector were the one of the female group.

The unexplained component is usually attributed to discrimination, but it could also reflect unobserved or unmeasured traits affecting some variables. Patents are precisely one of these cases since they are potentially affected by differences in quality that are hard to be observed or measured. In fact, the empirical literature using patent-counts as measures of firms' innovation outcomes has pointed out the likely heterogeneity in the unobserved quality of patents as a potential limitation of their use.

Our empirical strategy permits us to rule out systematic differences by team-gender in the quality of patents as a potential driver of the unobserved part of the OB decomposition of the set-1 variables. This strategy is outlined in Figure 1. Unobserved differences in the quality of patents by team-gender should show up as significant unexplained differences in the decomposition of the set-2 variables. For instance, if patents of male-teams were of higher quality than those of female-teams on average, we should observe that, beyond observed differences in the number of patent-counts, patents would contribute in an unexplained way to increase innovative sales, labour productivity, or researchers' wages, in the case of firms with male R&D teams. In other words, in our empirical strategy the estimation of the unexplained component in the set-2 variables serves as a *falsification (or placebo) test*: if discrimination rather than differences in patents' quality were behind the unobserved effects of patents in the OB decomposition of the set-1 variables, then variables in set-2 should not display such unobserved effects; if, on the contrary, differences in the quality of patents were present, then the decomposition of the set-2 variables would reflect unobserved effects of patents.[4]

As mentioned above, we first apply a set of estimation methods that do not decompose the gender gap in the outcomes of interest. Next, we apply the OB decomposition. Our set-1 variables are based on self-reported answers by firms in the questionnaire when asked to rate on a 1 to 3 scale the extent of difficulty (from high to low) that they experience in obtaining external finance for their innovation projects or in finding partners to collaborate in innovation.[5] Since these are ordered categorical variables, we first estimate them as an ordered probit model. However, for ordered probit estimation there is not decomposition of the contribution of a specific explanatory variable into explained and unexplained components (Bauer and Sinning, 2008; Sinning et al., 2008).[6] For this reason, we will base the OB decomposition both on the OLS estimation of the 1-to-3 variables and on the probit estimation of binary variables that we define as taking value 1 if reported difficulty is low (answer=3 of the ordered variables) and 0 otherwise. If it is the case that the ordered probit estimating results are consistent with those coming from the OLS and probit estimation, we will be confident that we can rely on the OB decomposition of these two latter models. As for the set-2 variables, we apply standard OLS estimation to all variables, with the exception of the innovative sales variable; in this latter case, given the high proportion of zero values, we apply a 2-stage Heckman selection model (Heckman, 1979) instead of ordinary least squares regression.

In what follows, we present and describe our estimation sample, and provide further details about the main variables of the analysis.

[4]A placebo or falsification test consists in designing an estimation strategy, that is, an estimation equation and/or sample, for which there is no reason to believe that the alleged effect exists. That is, the placebo estimation, which has neither a theoretical nor an empirical basis, must show no significant effects, thereby ruling out the possibility that the results obtained with the valid estimation strategy are found 'by chance'.

[5]See Table A2 in the Appendix for details on the definition and construction of variables.

[6]Although there exist different methods to perform a Oaxaca-Blinder type decomposition in nonlinear estimation models, for the specific case of ordered discrete choice models there is not detailed decomposition. This is because while the sign of an estimated coefficient in an ordered model gives the direction of the effect on the probability of the highest and lowest categories, the sign does not always determine the direction of the effect on the intermediate categories (Madden, 2010). Differently, for linear regression or a binary choice model (e.g. probit) it is possible to obtain the individual contribution of a given explanatory variable to the explained and unexplained components.

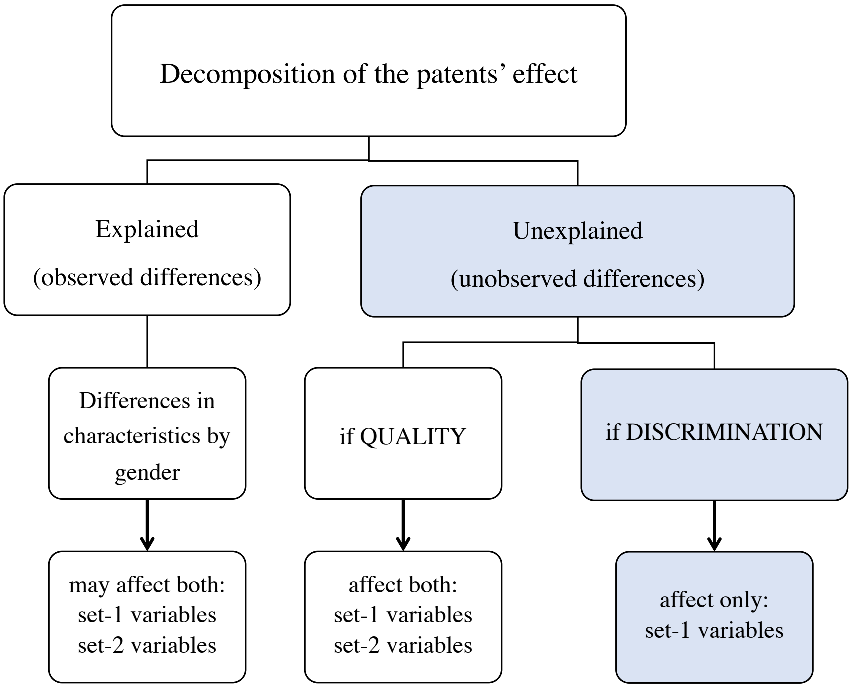

Figure 1: *Empirical Strategy: Oaxaca-Blinder two-fold decomposition applied to set-1 variables (with external evaluation: finding finance and partners for innovation) and set-2 variables (without external evaluation: innovative sales, labour productivity, and researchers' wages).*

3.2 Data and variables: PITEC

In this paper we use data from the Technological Innovation Panel (PITEC) for the period 2005-2014. PITEC is a firm-level panel data set carried out annually by the National Statistics Institute in Spain (INE) that collects information at the firm-level related to innovation activities of firms with more than ten employees in manufacturing, services and other non-manufacturing sectors (agriculture, mining, construction, and utilities).[7] PITEC follows the structure of the European Community Innovation Surveys (CIS) and, hence, it provides widely accepted innovation indicators and variables. However, differently to CIS data, PITEC is designed as a panel data survey, and answering the survey

[7] A description of the survey (*Panel de Innovación Tecnológica*) can be found at the following link (in Spanish): https://icono.fecyt.es/pitec.

is mandatory for firms.

PITEC classifies firms at two-digit NACE-2009 industry level. In order to select our working sample, we use two criteria. First, since our focus is on R&D teams, we only consider firms with in-house R&D employees, for whom PITEC provides information on the number and gender shares by occupational categories within the lab (researchers and lab-technicians). Second, since our interest is on comparing R&D teams by the gender of their researchers, we select only those firms with a clear majority of researchers of one gender; the reason is that we want to focus on teams that are clearly perceived by financing institutions or potential collaborators as mainly composed by either male or female members. In particular, the condition we apply to consider an R&D team to be male-/female-dominated is that it is composed of at least a 70 percent of male/female researchers, respectively.

After applying these criteria, our working sample comprises 38,645 observations, where 5,990 correspond to firms with female R&D teams (15.5 %), and the remaining 32,655 to firms with male R&D teams (84.5 %). Thus, a first observation is the fact that male R&D teams are clearly much more prevalent than female R&D teams. Figure 2 and Figure 3 show the sectoral breakdown in the estimation sample of the share of female R&D teams and the gender gap in patenting firms, respectively.[8]

Figure 2 highlights how in all the manufacturing sectors, except Pharmaceuticals, the share of firms with female R&D teams is clearly below 50 percent. In some industries, such as Transport Equipment, Computing and Electronics, and Aeronautics, female teams are virtually non-existent. Besides Pharmaceuticals, we find a relatively higher presence of female teams in Chemical, Food and Wearing Apparel. In services and other non-manufacturing sectors, shown in Figure 2, the gender imbalance of R&D teams is even more pronounced, since we do not find shares above 40 percent in any case, with Health and Education showing up as the two sectors with higher presence of female researchers.

In Figure 3 we show the gender gap in patenting activity by sector. We define this gender gap in patenting as the difference between the percentage of patenting firms with female R&D teams and the percentage of patenting firms with male teams (divided by the total percentage of patenting firms in the sector, to normalize by the whole patenting activity of each sector). Negative values in the graphs correspond to cases where the percentage of male teams that patent is higher than the percentage of female teams. The average proportion of patenting firms in the sample for female R&D teams is 13.52%, while this proportion is 17.41% for male R&D teams (see Table A1 in the Appendix).

[8] Table A1 in the Appendix provides full details of the figures and names of the sectors presented in the graphs.

Thus, the figure shows also in this case a clearly skewed distribution by gender, with most patenting activity accounted for by male teams in the majority of sectors. Again, Pharmaceutical, Chemical, Food and Education are among the few sectors where female teams show a relatively higher patenting activity.

In relation to the variables used for estimation we use two sets of dependent variables that will serve to trace out the possible different role that patents play as signals of innovation quality in male vs. female R&D teams. These are set-1 and set-2 variables, as defined above (further details are provided in Table A2 in the Appendix). The variables in set-1 refer to outcomes that depend on external evaluation of firms' innovation quality, namely, difficulty in accessing external finance for innovation activities and in finding partners for innovation. In particular, our main variables for set-1 outcomes come from the questions on the PITEC questionnaires that ask firms to rate on a 1 to 3 scale the extent of difficulty they experience in obtaining external finance for their innovation projects and in finding partners to collaborate in innovation (where value 1 reflects high difficulty, while value 3 reflects low or no difficulty). Admittedly, the self-reported level of difficulty might be combining actual with perceived difficulty. Thus, our results with these variables have to be interpreted with this piece of caution henceforth. However, to rule out the concern that our results could be driven to a large extent by these subjective perceptions, we complement the analysis with objective information available in PITEC regarding the amount of in-house R&D expenditures financed by private and public funds, as well as on the type of R&D collaboration partners that firms have, distinguishing between private and public partners.

The variables in set-2 correspond to firms' economic outcomes that do not depend upon a process of external evaluation of the innovation quality of the firm's R&D team, namely, innovative sales, labour productivity (turnover per employee), and average wage of researchers in its R&D team.

Basic descriptive statistics by R&D team gender are offered in Table 1 for these set-1 and set-2 variables.[9] Regarding the self-reported difficulty measures in set-1, we find statistically significant differences in favour of firms with male R&D teams in accessing external financing and in finding partners for innovation. As regards the more objective measures, the figures at this descriptive level are somewhat more inconclusive, since we find that the percentage of total RD funds from the private sector is higher in the case of firms with female R&D teams, while they are less likely to collaborate in R&D with private partners. With respect to set-2 variables, we observe that firms with male R&D

[9]The descriptive statistics in Table 1 are based on firm-year observations.

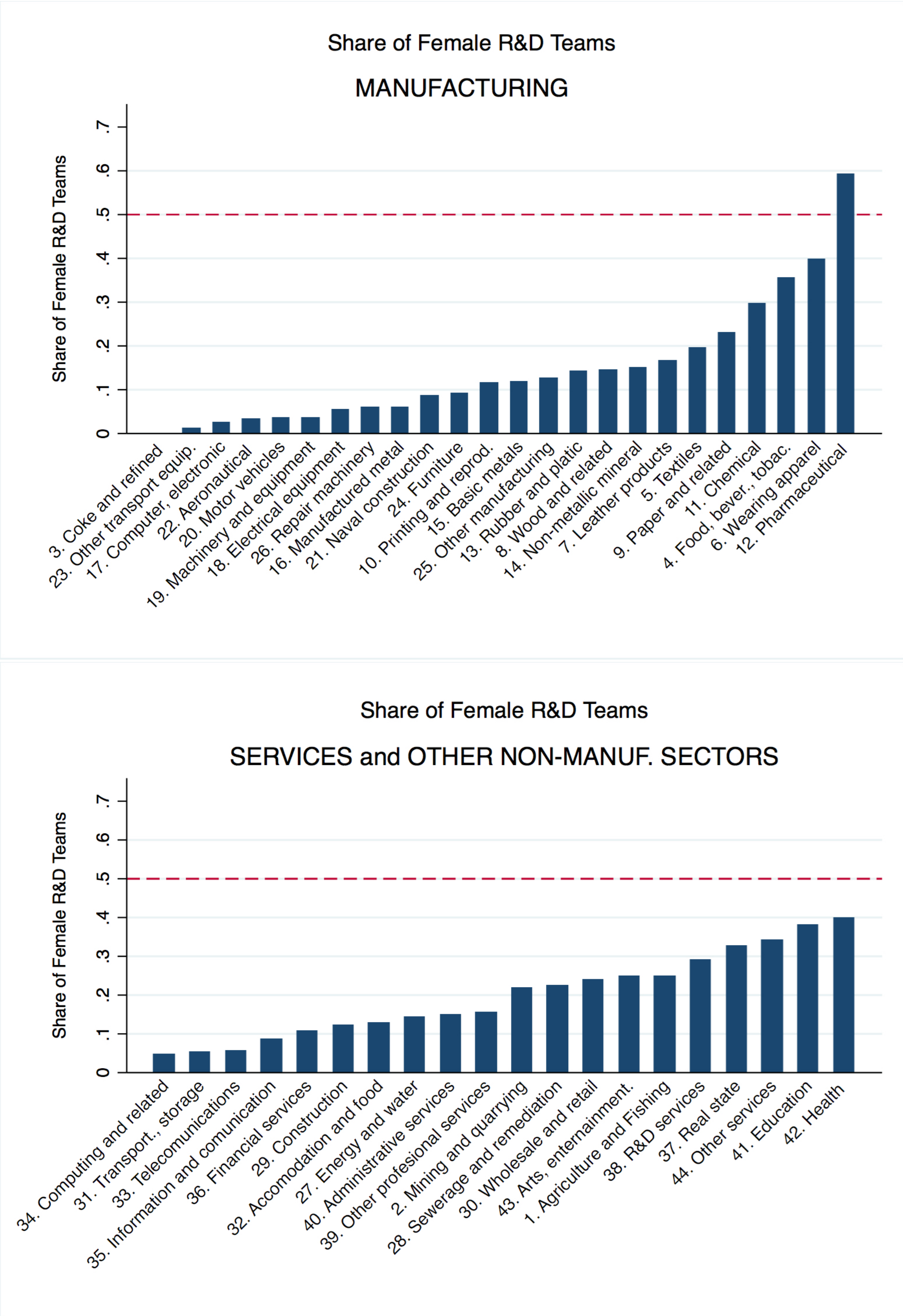

Figure 2: *Share of firms with Female R&D Teams in the estimation sample.*

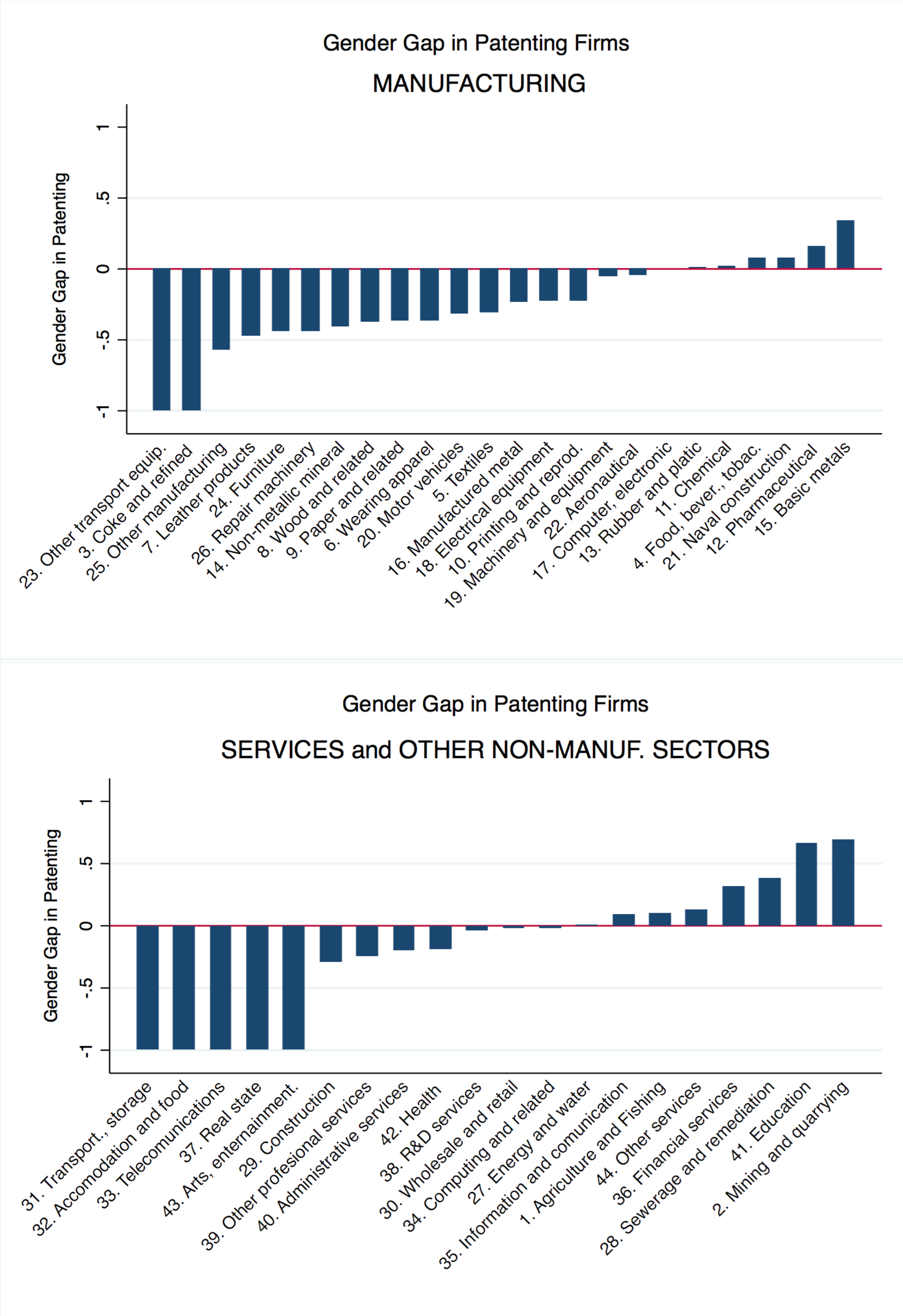

Figure 3: ***Gender Gap in Patenting Activity:*** *percentage of patenting firms with female R&D teams minus the percentage of patenting firms with male R&D teams over the total percentage of patenting firms in each sector. A value of -1 indicates that 100 percent of patents are obtained by firms with male teams.*

teams are more likely to report innovative sales, report a higher amount of innovative sales on average, and display higher average wages of their researchers. Differently, in the case of labour productivity we observe larger average values for female R&D teams.

In relation to the explanatory variables, the central variable in our analysis is the number of a firm's patents (*Patents*). The information on patents given by PITEC, which we use in the analysis, is the number of patents applied for by the firm during the current year and the two previous years; thus, this variable is as a sort of 3-year moving stock of patents.[10] Table 1 shows that the number of patents is higher in firms with male R&D teams than in firms with female counterparts, and that this difference is statistically significant.

Additionally, we include in the analysis a set of covariates characterising both the firm itself and its R&D team, to help isolate the effect of interest (patents) from other potential confounding effects. In particular: i) to capture how male- or female-prevalent is the environment within the firm, we include the share of male employees of the firm, *Firm male share*; ii) to characterise the composition of the firm's R&D team, we include the number of employees in the R&D lab, *R&D team size*, and the share of R&D researchers with postgraduate education, *Postgraduates-share*; iii) to account for the type of innovation mostly pursued by the firm, we include the percentage of in-house R&D expenditures on basic research (over total in-house R&D), as opposed to applied R&D expenditures, *Basic R&D*; iv) to control for other aspects of the firm, we include the firm's age, five intervals of firm size (quintiles of the distribution of the firms' number of employees in PITEC), ownership variables (three dummy variables indicating whether the firm belongs to a group, and holds foreign and public capital participation, respectively), information on the nature and size of markets where firms operate (local, national, EU, or world markets), whether the firm has experienced an acquisition or liquidation process associated with a reduction in turnover, and a full set of dummies to account for specific-effects of two-digits NACE-2009 sectors (see Table A1 in the Appendix), regions in Spain (corresponding to the 17 Spanish Autonomous Communities), and years.

As shown in Table 1, R&D teams are on average larger in firms with male R&D teams. However, the qualification of R&D researchers and the percentage of in-house R&D expenditures on basic research are higher in the case of firms with female R&D teams. In addition, firms with male R&D teams display a higher percentage of male employees, are larger both in total turnover and in number of employees, and are more likely to belong to a group and to export to the world market than firms with female

[10]Some authors propose to construct a measure of *stock of patents* as the relevant variable to signal the quality of the firm's innovation performance (see, e.g. Hottenrott et al., 2016).

Table 1: Descriptive statistics of the main variables.

	Male R&D teams ≥ 70% men	Female R&D teams ≥ 70% women	Differences Male-Female[1]
Variables subject to external scrutiny (*set-1* variables)			
Finance, self-reported difficulty from 1-to-3 (average)	1.982	1.948	0.034*
Finance, high difficulty: 1	11.21%	12.69%	
Finance, medium difficulty: 2	26.72%	26.43%	2.303** [2]
Finance, low/no difficulty: 3	62.07%	60.88%	
Partners, self-reported difficulty from 1-to-3 (average)	2.509	2.482	0.027*
Partners, high difficulty: 1	35.21%	36.04%	
Partners, medium difficulty: 2	31.42%	33.12%	2.879*** [2]
Partners, low/no difficulty: 3	33.37%	30.83%	
Private funds	1.357	1.864	-0.507*
Public funds	11.797	11.656	0.142
Private partners	0.272	0.246	0.026**
Public partners	0.235	0.238	-0.003
Variables not subject to external scrutiny (*set-2* variables)			
Prob(Innovative sales)>0	0.461	0.388	0.073***
(log)Innovative sales	14.076	11.115	2.962***
Productivity	221 324.694	248 576.833	-27252.140**
Researchers' wages	27 930.173	24 776.242	3 153.931***
Patents, composition of the firm's R&D team and type of R&D activities.			
Patents	0.886	0.437	0.449***
R&D team size	14.943	9.247	5.697***
Postgraduates-share	25.203	29.646	-4.443***
Basic R&D	2.648	3.658	-1.010***
Other characteristics of firms			
Firm male-share	74.439	53.894	20.546***
Firm turnover	8.09e+07	4.58e+07	3.50e+07***
Employees	278.824	200.199	78.625**
Size_0-15 employees	0.179	0.211	-0.031***
Size_16-35 employees	0.221	0.232	-0.011
Size_36-95 employees	0.257	0.261	-0.004
Size_96-295 employees	0.200	0.180	0.019*
Size_295+ employees	0.143	0.116	0.027***
Age	26.148	26.425	-0.277
Group	0.405	0.380	0.026*
Foreign capital	0.135	0.131	0.004
Public capital	0.017	0.019	-0.001
Acquisition/Liquidation	0.012	0.011	0.001
Local market	0.050	0.060	-0.010*
National market	0.214	0.233	-0.019*
EU market	0.143	0.155	-0.012*
World market	0.593	0.551	0.041***
Number of observations	32 655	5 990	38 645

The figures in this table are based on firm-year observations. All monetary variables (innovative sales, productivity, researchers' wages and firm turnover) are in euros. See Table A2 in the Appendix for the detailed definition and construction of all the variables.

[1] Firm-level clustered standard errors are used to compute the t-tests on the equality of means. Significance level: * p-value<0.10, ** p-value<0.05, *** p-value<0.01.

[2] Wilcoxon-Mann-Whitney rank-sum test (Wilcoxon, 1945; Mann and Whitney, 1947) on the null of equal distributions of the discrete variables. Significance level for rejection of the null: ** p-value<0.05, *** p-value<0.01.

teams. Differently, firms with female R&D teams are relatively more oriented towards the local, national and EU markets. Given that most of the just mentioned covariates exhibit statistically significant differences by R&D team gender, we include them in the specification of our estimation equations.

4 Estimation results

Tables 2 to 7 display our estimation results. In Tables 2 and 3 we report the results for set-1 variables, that is, the variables related to external finance and partners for innovation, before applying the OB decomposition. Then, Tables 4 and 5 display the OB decomposition for these outcomes. Next, Tables 6 and 7 report the corresponding results, without and with the OB decomposition, for set-2 variables, that is, firms' outcomes that do not explicitly involve any external evaluation of the firm's innovation quality.

4.1 Estimation results for set-1 variables.

Table 2 displays the non-decomposed results for the finance-related variables. To partial out the impact of firms' economic results on the difficulty of finding finance, we add the firm's level of turnover among the set of regressors. The Table displays the results of the OLS estimation (column 1), ordered probit estimation (columns 2 to 5, where both the estimated coefficients and the estimated marginal impacts on each level of the variable are reported), and probit estimation (column 6, with the estimated marginal effects). A first result to notice is the negative and significant sign of the estimated effect of the *Female R&D team* indicator variable in columns (1), (2) and (6). This result indicates that female R&D teams find more difficult than male teams accessing finance from external sources, once other observable differences have been partialled out. More importantly, the interaction effect of the female indicator with the number of patents exhibits a negative sign in the same columns indicating that although patents seem to contribute to raise finance from external sources (positive and significant effect of patents in the columns), the effect is significantly lower in the case of female R&D teams. These results are strongly robust across estimation methods. In particular, the results in column (6) for the probit marginal effect of patents and their interaction with the female indicator virtually coincide with the estimates coming from the ordered probit for the category=3 (column 5). This supports the validity of relying on the OB decomposition of the OLS estimation and, in particular, of the probit estimation.

In the last two columns of Table 2 we also estimate by OLS the amount of external funds for innovation raised by firms, distinguishing between funds from private lenders (column 7) and funds from public lenders (column 8). This additional analysis is interesting because of two reasons. First, because it permits us to shed light on the possible heterogeneity of results coming from the nature of the financing unit or institution. Second, and more importantly, because these variables are objective rather than more subjective measures of perceived difficulties in raising funds to finance innovation, and thus are not affected by the possibility of gender biases in the self-reported measures. The results in column (7) point out that patents of female teams contribute less than patents of male teams to the amount of funds raised from private lenders. However, the opposite is observed in column (8) when we look at funds that come from public institutions, where patents seem to increase the amount of finance to a greater extent in the case of female R&D teams. This finding could be reflecting the outcome of some institutional innovation policies initiated in the past years in Spain whereby public institutions (e.g., universities, regional administrations and central government) implemented measures for preferential treatment to female researchers in order to redress gender imbalances in research.[11]

Table 3 displays the same set of results for the partners-related variables. All the estimation methods render a negative estimated coefficient for the interaction of patents with the female indicator. Nevertheless, the estimation of this coefficient is not statistically significant at conventional levels in any case. Again here, the results in column (6) for the probit marginal effect of patents and their interaction with the female indicator virtually coincide with those coming from the ordered probit for category=3. In the last two columns of the table, and similarly to the private-public differences analysed for finance, we report additional estimation results from a biprobit model applied to the probability of finding private and public partners to collaborate in innovation. These variables are objective measures on whether the firm has effectively collaboration partners, and thus are not affected by the possibility of gender biases in the self-reported measures of difficulties in finding partners. The distinction between private partners (competitors, clients, providers in the private sector) and public partners (universities, public research institutes, and other public institutions) used here was made available in PITEC from 2012 onwards. Thus, we rely on this smaller sample to offer these complementary set of results. Results in column (7) show that the estimated contribution of patents to the probability of finding private partners is smaller for female teams. This negative differential for female teams is statistically significant. When it comes to public partners, we

[11]The fact that in Spain many public calls to finance research projects have offered preferential treatment to female teams is itself an indicator of the acknowledged greater difficulties that female researchers usually face to raise funds in the private sector.

find a positive differential for female teams, though the estimated effect is not significant in this case.

The general conclusion from this first analysis is that patents help female R&D teams to find finance and partners for innovation to a lower extent than they do for male R&D teams. More precisely, this lower contribution of patents for female R&D teams is particularly noticeable in the case of private third parties, either private financing institutions or collaboration partners in the private sector. These findings are unlikely to be driven by gender biases in the self-reported variables, since objectively defined variables confirm them to a large extent.[12] These results could respond to the possibility that the private sector is less subject to the scrutiny of gender biased practices, while public institutions have a greater commitment in terms of avoiding gender discrimination.

We proceed next to the OB decomposition of set-1 variables in tables 4 and 5 for finance-related and partner-related variables, respectively, which we base on the OLS and probit estimation.[13] The main result is the positive and statistically significant estimate of the unexplained effect of patents in columns (2) and (4) in both tables. In terms of expression (1), this means that β^M exceeds β^F, that is, a same number of patents alleviates difficulties in raising finance and finding partners to a larger extent in the case of male R&D teams than in the case of female counterparts. Although the size of the estimated impacts is certainly modest, the magnitude of these estimates should be compared to the size of the absolute differences between male and female RD teams in the outcome variables. In Table 1 these differences amount to 0.034 and 0.027 for the ordered variables measuring difficulty in finding finance and partners, respectively. Taking into account such differences, the unexplained estimated effects in Table 4 (0.0045) and Table 5 (0.0027) would account for 13.23% and 10%, respectively, of the existing differences. This suggests that alternative variables of finance/collaboration obstacles, and with different scales of measure, would naturally be able to show results of different magnitude. Also, if we look at columns

[12]In case of a systematic bias in the female responses to the self-reported difficulty questions, which could potentially affect the estimation of the patent coefficient, we would also expect it to show up in spurious effects in other regressors, something that does not seem to occur in our data. We consider that these results rule out the subjectivity of perceived difficulties as an important driver of our results.

[13]We implement the Oaxaca-Blinder decomposition (Blinder, 1973; Oaxaca, 1973) with the Stata command oaxaca (Jann, 2008). In both cases, OLS and probit estimation, the oaxaca command first estimates β^M and β^F separately using the male and the female samples, respectively. With the estimated β^M and β^F , the decomposition in equation (1) is applied in the case of the OLS estimation, using also the sample averages of the regressors for each gender group. For probit estimation, the command follows Yun (2004), where the decomposition in (1) is performed instead following the expression $\overline{Y}_{it}^M - \overline{Y}_{it}^F = [\Phi(\overline{\beta^M X_{it}^M}) - \Phi(\overline{\beta^M X_{it}^F})] + [\Phi(\overline{\beta^M X_{it}^F}) - \Phi(\overline{\beta^F X_{it}^F})]$, with $\Phi(\cdot)$ referring to the cumulative distribution function of a normal distribution and where the upper bar represents the values of the sample's averages.

Table 2: Difficulty in finding FINANCE (external scrutiny involved)

		Ordered Probit						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	Coefs.	Marg. effects 1	Marg. effects 2	Marg. effects 3	Probit (marg. effects)	OLS Private funds	OLS Public funds
Female R&D team	-0.0420**	-0.0622**	0.0220**	-0.0006*	-0.0214**	-0.0298**	0.1775	-0.6496
	(0.0210)	(0.0300)	(0.0106)	(0.0004)	(0.0103)	(0.0120)	(0.1635)	(0.5253)
Firm male share	-0.0002	-0.0003	0.0001	-0.0000	-0.0001	-0.0000	0.0098***	0.0090
	(0.0004)	(0.0006)	(0.0002)	(0.0000)	(0.0002)	(0.0002)	(0.0036)	(0.0112)
Patents	0.0038***	0.0068***	-0.0024***	0.0001**	0.0024***	0.0023***	0.0242*	-0.0179
	(0.0010)	(0.0018)	(0.0006)	(0.0000)	(0.0006)	(0.0007)	(0.0135)	(0.0205)
Patents×Female	-0.0088***	-0.0144**	0.0051**	-0.0001*	-0.0050**	-0.0050**	-0.0799**	0.2403***
	(0.0033)	(0.0060)	(0.0021)	(0.0001)	(0.0020)	(0.0025)	(0.0360)	(0.0889)
Firm turnover	0.0639***	0.0919***	-0.0325***	0.0009***	0.0316***	0.0284***	-0.5199***	-0.5050**
	(0.0054)	(0.0079)	(0.0027)	(0.0003)	(0.0027)	(0.0031)	(0.0816)	(0.2216)
R&D team size	-0.0008***	-0.0012***	0.0004***	-0.0000**	-0.0004***	-0.0005***	0.0201***	0.0081
	(0.0002)	(0.0003)	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0032)	(0.0054)
Postgraduates share	0.0002	0.0002	-0.0001	0.0000	0.0001	0.0002	0.0046**	0.0319***
	(0.0003)	(0.0004)	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0021)	(0.0062)
Basic R&D	0.0001	0.0002	-0.0001	0.0000	0.0001	0.0002	0.0021	-0.0529***
	(0.0005)	(0.0007)	(0.0003)	(0.0000)	(0.0003)	(0.0003)	(0.0055)	(0.0122)
Constant	1.3916***						16.8143*	7.0915
	(0.1118)						(10.0673)	(4.8524)
Constant cut1		1.3815***						
		(0.1678)						
Constant cut2		2.2393***						
		(0.1683)						
Observations	38,624	38,624				38,624	33,691	33,691
R-squared	0.0741						0.0632	0.1123

Clustered standard errors by firm in parentheses. Significance level: * p-value<0.10, ** p-value<0.05, *** p-value<0.01. All columns include firm age and a full set of dummies to control for firm size, ownership, acquisition/liquidation, market, sector, year, and region.

Table 3: Difficulty in finding PARTNERS (external scrutiny involved)

		Ordered Probit					Biprobit Private-Public Partners	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	Coefs.	Marg. effects 1	Marg. effects 2	Marg. effects 3	Probit (marg. effects)	Pr(private partners) (marg. effects)	Pr(public partners) (marg. effects)
Female R&D team	-0.0114	-0.0191	0.0036	0.0035	-0.0071	-0.0038	-0.0394**	-0.0014
	(0.0174)	(0.0309)	(0.0058)	(0.0057)	(0.0115)	(0.0121)	(0.0192)	(0.0193)
Firm male share	0.0005	0.0008	-0.0001	-0.0001	0.0003	0.0002	0.0000	-0.0001
	(0.0004)	(0.0006)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0004)	(0.0004)
Patents	0.0002	0.0005	-0.0001	-0.0001	0.0002	0.0003	0.0014	0.0058**
	(0.0008)	(0.0016)	(0.0003)	(0.0003)	(0.0006)	(0.0006)	(0.0014)	(0.0022)
Patents×Female	-0.0057	-0.0098	0.0019	0.0018	-0.0037	-0.0040	-0.0041*	0.0176
	(0.0036)	(0.0063)	(0.0012)	(0.0012)	(0.0024)	(0.0028)	(0.0023)	(0.0109)
Firm turnover	0.0258***	0.0433***	-0.0082***	-0.0080***	0.0161***	0.0123***	0.0292***	0.0286***
	(0.0046)	(0.0080)	(0.0015)	(0.0015)	(0.0030)	(0.0032)	(0.0052)	(0.0050)
R&D team size	-0.0002	-0.0003	0.0001	0.0001	-0.0001	-0.0002	0.0008***	0.0008***
	(0.0002)	(0.0003)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)
Postgraduates share	-0.0005**	-0.0009**	0.0002**	0.0002**	-0.0003**	-0.0003*	0.0003	0.0006**
	(0.0002)	(0.0004)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)
Basic R&D	-0.0003	-0.0004	0.0001	0.0001	-0.0002	-0.0002	-0.0012	-0.0003
	(0.0004)	(0.0007)	(0.0001)	(0.0001)	(0.0003)	(0.0003)	(0.0008)	(0.0008)
Constant	2.2295***							
	(0.1546)							
Constant cut1		-0.2785						
		(0.1728)						
Constant cut2		0.6431***						
		(0.1726)						
Observations	38,624	38,624				38,624	8,472	8,472
R-squared	0.0302						0.1931	0.1776

Clustered standard errors by firm in parentheses. Significance level: * p-value<0.10, ** p-value<0.05, *** p-value<0.01. All columns include firm age and a full set of dummies to control for firm size, ownership, acquisition/liquidation, market, sector, year, and region.

Table 4: OAXACA DECOMPOSITION for FINANCE variables (external scrutiny involved)

	Self-reported 1-to-3 OLS		Self-reported 1-0 Probit		Private funds OLS		Public funds OLS	
	(1) explained	(2) unexplained	(3) explained	(4) unexplained	(5) explained	(6) unexplained	(7) explained	(8) unexplained
Firm male share	-0.0038	-0.0738	-0.0034	0.0120	0.2021***	1.6766***	0.1835	3.5028**
	(0.0087)	(0.0493)	(0.0051)	(0.0434)	(0.0733)	(0.5569)	(0.2291)	(1.5611)
Patents	0.0011**	0.0045***	0.0008*	0.0039**	0.0102	0.0264**	-0.0044	-0.0897**
	(0.0005)	(0.0017)	(0.0004)	(0.0020)	(0.0063)	(0.0122)	(0.0095)	(0.0435)
Firm turnover	0.0127	-0.3061	0.0082**	-0.3034	-0.0841***	0.6246	-0.0821*	-1.0678
	(0.0135)	(0.2436)	(0.0035)	(0.2688)	(0.0208)	(3.6026)	(0.0480)	(9.7691)
R&D team size	-0.0043*	0.0056	-0.0020**	-0.0075	0.1185***	-0.0966	0.0460	-0.5796**
	(0.0023)	(0.0054)	(0.0008)	(0.0082)	(0.0206)	(0.0935)	(0.0326)	(0.2738)
Postgraduates share	-0.0005	-0.0137	0.0001	-0.0109	-0.0208**	0.1193	-0.1461***	0.3003
	(0.0012)	(0.0147)	(0.0007)	(0.0143)	(0.0096)	(0.1752)	(0.0379)	(0.4859)
Basic R&D	-0.0001	-0.0035	0.0001	-0.0028	-0.0022	0.0397	0.0551***	-0.1300
	(0.0004)	(0.0052)	(0.0003)	(0.0032)	(0.0058)	(0.0427)	(0.0184)	(0.0939)
Estimated averages of the dependent variables:								
Firms with male R&D teams	1.9818***		0.6480***		1.3552***		11.7961***	
	(0.0264)		(0.0051)		(0.0570)		(0.2263)	
Firms with female R&D teams	1.9481***		0.6399***		1.8641***		11.6559***	
	(0.0441)		(0.0106)		(0.1562)		(0.5308)	
difference	0.0337		0.0081		-0.5089***		0.1402	
	(0.0358)		(0.0114)		(0.1663)		(0.5661)	
explained	-0.0114		-0.0062		-0.3642***		-0.4105	
	(0.0230)		(0.0066)		(0.0821)		(0.3609)	
unexplained	0.0452		0.0143		-0.1446		0.5507	
	(0.0278)		(0.0118)		(0.1637)		(0.5200)	
Constant		1.0995***		0.6503		6.1550		-45.5196**
		(0.2230)		(0.4498)		(10.4914)		(23.1681)
Observations	38,624		38,624		33,691		33,691	

Clustered standard errors by firm in parentheses. Significance level: * p-value<0.10, ** p-value<0.05, *** p-value<0.01. All columns include firm age and a full set of dummies to control for firm size, ownership, acquisition/liquidation, market, sector, year, and region.

Table 5: OAXACA DECOMPOSITION for PARTNERS variables (external scrutiny involved)

	Self-reported 1-to-3 OLS		Self-reported 1-0 Probit		Private Partners Probit		Public Partners Probit	
	(1) explained	(2) unexplained	(3) explained	(4) unexplained	(5) explained	(6) unexplained	(7) explained	(8) unexplained
Firm male share	0.0087	-0.0288	0.0039	-0.0338	0.0017	0.0668	-0.0004	-0.0566
	(0.0073)	(0.0545)	(0.0055)	(0.0369)	(0.0091)	(0.0438)	(0.0232)	(0.6637)
Patents	0.0000	0.0027***	0.0001	0.0020**	0.0006	0.0017*	-0.0019	0.0052
	(0.0003)	(0.0010)	(0.0002)	(0.0010)	(0.0006)	(0.0009)	(0.1015)	(0.0614)
Firm turnover	0.0067	-0.1906	0.0035	-0.1623	0.0017*	-0.0015*	0.0079	-0.0045
	(0.0070)	(0.2806)	(0.0037)	(0.2107)	(0.0010)	(0.0009)	(0.4112)	(0.0534)
R&D team size	-0.0007	-0.0014	-0.0009	-0.0008	0.0009	0.2102	-0.0005	0.0863
	(0.0010)	(0.0075)	(0.0006)	(0.0086)	(0.0059)	(0.2728)	(0.0268)	(1.0218)
Postgraduates share	0.0022*	-0.0198	0.0013	-0.0179	0.0078*	-0.0145	-0.0056	0.0029
	(0.0012)	(0.0191)	(0.0008)	(0.0133)	(0.0044)	(0.0131)	(0.2967)	(0.0353)
Basic R&D	0.0003	0.0005	0.0001	0.0015	-0.0017	0.0012	0.0022	-0.0130
	(0.0003)	(0.0043)	(0.0002)	(0.0029)	(0.0011)	(0.0138)	(0.1145)	(0.1520)
Estimated averages of the dependent variables:								
Firms with male R&D teams	2.5088***		0.6208***		0.3965***		0.3330***	
	(0.0188)		(0.0125)		(0.0207)		(0.0176)	
Firms with female R&D teams	2.4821***		0.6082***		0.3391***		0.3346***	
	(0.0276)		(0.0179)		(0.0358)		(0.0337)	
difference	0.0267		0.0126		0.0573*		-0.0016	
	(0.0215)		(0.0142)		(0.0307)		(0.0288)	
explained	0.0113		0.0054		0.0237		0.0006	
	(0.0165)		(0.0106)		(0.0217)		(0.0189)	
unexplained	0.0154		0.0072		0.0336**		-0.0023	
	(0.0132)		(0.0090)		(0.0154)		(0.0178)	
Constant		0.1613		-0.2692		-0.7086**		0.1505
		(0.2549)		(0.1819)		(0.2796)		(1.7821)
Observations	38,624		38,611		8,445		8,443	

Clustered standard errors by firm in parentheses. Significance level: * p-value<0.10, ** p-value<0.05, *** p-value<0.01. All columns include firm age and a full set of dummies to control for firm size, ownership, acquisition/liquidation, market, sector, year, and region.

(1)-(2) and (3)-(4) in Table 4, the total contribution of patents to explain differences in the dependent variables would be the sum of the explained plus the unexplained effects of patents; over the total amounts, the unexplained effect of patents accounts for around 85 percent and 83 percent in the OLS and probit estimation, respectively. In Table 5 the unexplained component is the only one that is statistically significant in both estimations.

Finally, and in line with the above mentioned results, the estimates in columns (5)-to-(8) in both tables provide further support for the hypothesis that it is in the private sector where female R&D teams encounter their difficulties. In column (8) of Table 4 we again find evidence of some degree of positive discrimination in favour of female R&D teams in obtaining public funds, since the unexplained effect reveals that in this case $\beta^M < \beta^F$. As for public partners in column (8) in Table 5, no significant effects are found.

4.2 Estimation results for set-2 variables.

Tables (6) and (7) show the results for the same type of analysis in the case of set-2 variables, that is, variables that represent firms' economic outcomes that are not directly subject to the assessment of external agents. The first variable of interest in Table (6) is the amount of firms' innovative sales coming from product innovations that are new to the market. Given the high proportion of 0's in this variable (around 55 percent of the sample observations), we apply a 2-stage Heckman selection model (Heckman, 1979). The results in column (1) correspond to the first-stage equation, that is, a probit model to estimate the probability that a firm reports positive innovative sales during the period; column (2) displays the results for the (log of) innovative sales, after accounting for selection.[14] Patents are included in the estimation equation both on their own and also interacted with the *Female R&D teams* indicator variable. A significant effect of such interaction term would be indicating a differential return to patents in the case of female as opposed to male R&D teams.

The results in column (1) show, first, that firms with female R&D teams are less likely to report innovative sales than firms with male R&D teams, and that firms with a higher share of male employees (male-prevalent firms) are more likely to do so. The number of patents contributes positively and significantly to the probability that a firm reports innovative sales, while the effect is not significant in the quantity equation in column (2). More interesting for the sake of our paper is the fact that patents do not exhibit any

[14]For identification purposes, the first-stage probit incorporates the squared values of firms' age and firms' male-share, which proved to be significant in the probit equation while non-significant in the second stage equation. The results for these two added variables have been omitted in the tables for the sake of simplicity in exposition.

significant differential effect in the case of female teams as compared to patents of male teams. This result indicates, then, that patents obtained by female R&D teams do not exhibit differential returns in terms of innovative sales as compared to patents obtained by male counterparts. This suggests, in turn, that there is no evidence to support the view that patents of female R&D teams have lower scope or quality than those obtained by male teams.

The same general conclusion arises when we use the turnover per employee (productivity) and the average wage of researchers as the outcome variable of interest in columns (3) and (4), respectively. Again, patents exhibit a positive and significant estimated effect on these variables, but no significant differences emerge by gender of the R&D team. An additional and interesting result in column (4) is the lower average wage bill of female R&D researchers (around 8 percent lower than male counterparts), after controlling for the characteristics and size of the R&D team, the share of postgraduates in the R&D lab, and the number of patents obtained (among other controls). This is a result that merits attention in itself, but that we consider out of the scope of this paper. This result is consistent with the literature documenting the existence of a gender wage gap against female employees (Blau and Kahn, 2017, and references therein), a gap that has been reported also in science (European Commission, 2019).[15]

At this stage, however, the fact that the estimated effects of patents do not exhibit any significant pattern by gender when interacted with female teams could be the result of observable (explained) and unobservable (unexplained) effects of opposite signs. Thus, to investigate further gender differences in the effect of patents we proceed in Table (7) to analyse the results of the OB decompositions.

Table (7) shows that observable differences in the number of patents in favour of firms with male R&D teams have positive and significant impacts on the observed differences in all the four dependent variables considered in the table, that is, innovative sales (both their probability and quantity), productivity and wages. However, the most remarkable result for the sake of our analysis, is the absolute lack of significant evidence of unexplained effects of patents on these variables. As discussed before, this result permits us to rule out important unobservable differences in the quality of patents between female and male R&D teams: if differences in patents' quality were at play, we should observe unexplained effects of the number of patents between the two groups of firms in variables such as innovative sales, productivity or wages.

The bottom half of Table (7) displays the estimated differences of the dependent vari-

[15] At the European level, women employed in scientific R&D activities earned on average a 17 percent less than their male counterparts (European Commission, 2019).

Table 6: Heckman 2-stages and OLS estimation, set-2 variables (no external scrutiny involved)

	(1) Heckman 1st stage Prob(Innovat. sales>0) (marginal effects)	(2) Heckman 2nd stage (log) Innovat. sales	(3) OLS Productivity	(4) OLS Researchers' wages
Female R&D team	-0.0300**	0.0984	0.0149	-0.080***
	(0.0122)	(0.0759)	(0.0294)	(0.018)
Firm male-share	0.0031***	0.0040***	0.0043***	0.001**
	(0.0008)	(0.0014)	(0.0010)	(0.000)
Patents	0.0062**	-0.0026	0.0012*	0.003***
	(0.0028)	(0.0032)	(0.0007)	(0.001)
Patents×Female	-0.0027	0.0258	0.0000	0.001
	(0.0044)	(0.0252)	(0.0017)	(0.003)
R&D team size	0.0015***	0.0027***	0.0014***	-0.000
	(0.0003)	(0.0006)	(0.0004)	(0.000)
Postgraduates-share	0.0004***	0.0005	-0.0000	0.012***
	(0.0001)	(0.0008)	(0.0003)	(0.000)
Basic-R&D	0.0001	0.0009	-0.0007	-0.000
	(0.0003)	(0.0017)	(0.0006)	(0.000)
Constant		13.4625***	11.4930***	9.103***
		(0.4203)	(0.1583)	(0.277)
Observations	38645	38645	38624	38619
R-squared			0.3665	0.299
	Test for independent equations:			
	Chi-sq(1) (rho=0)	1012.61***		
	p-value	(0.0000)		

Clustered standard errors by firm in parentheses. Significance level: * p-value<0.10, ** p-value<0.05, *** p-value<0.01. All columns include firm age and a full set of dummies to control for firm size, ownership, acquisition/liquidation, market, sector, year, and region. First stage Heckman: squared values of firms' age and firms' male-share included.

ables between the two groups of the decomposition (firms with male R&D teams and firms with female R&D teams). Here we observe a positive and significant difference in favour of firms with male R&D teams in the average probability of reporting sales from products new to the market, in the average level of such innovative sales, and in the average level of wages of the R&D researchers (columns 1 to 4, and columns 7 and 8); as for productivity, we obtain a positive though small and not significant difference in favour of firms with female R&D teams (columns 5 and 6). In columns (1) to (4), and columns (7) and (8), the explained part of the decomposition accounts for 57 percent, 51 percent and 32 percent, respectively, of the difference. Thus, a considerable part of the difference cannot be explained on the basis of observed differences between the explanatory factors of the estimation model. A higher number of patents and average R&D-team-size of male R&D teams, on the one hand, and a higher proportion of postgraduates as researchers in the case of female teams, on the other hand, seem to be behind the observed differences in most of the cases.

In summary, we find that patents of female R&D teams reveal a significant unexplained

Table 7: OAXACA DECOMPOSITION for set-2 variables (no external scrutiny involved)

	Prob(Innovat. sales>0)		(log) Innovat. sales		Productivity		Researchers' wages	
	(1)) explained	(2) unexplained	(3) explained	(4) unexplained	(5) explained	(6) unexplained	(7) explained	(8) unexplained
Firm male share	0.0674***	0.2301*	0.0425	-0.4538*	0.0881***	-0.1891***	0.017**	0.032
	(0.0194)	(0.1246)	(0.0710)	(0.2638)	(0.0054)	(0.0378)	(0.007)	(0.047)
Patents	0.0030**	0.0025	0.0152**	0.0245	0.0005**	0.0010	0.002***	-0.001
	(0.0014)	(0.0025)	(0.0069)	(0.0168)	(0.0002)	(0.0010)	(0.001)	(0.002)
R&D team size	0.0072***	-0.0081	0.0614**	0.2075***	0.0079***	-0.0196***	-0.002	-0.001
	(0.0017)	(0.0067)	(0.0253)	(0.0524)	(0.0009)	(0.0052)	(0.001)	(0.009)
Postgraduates-share	-0.0017***	0.0108	-0.0288***	0.0755	0.0001	-0.0475***	-0.052***	-0.006
	(0.0007)	(0.0103)	(0.0112)	(0.0909)	(0.0007)	(0.0128)	(0.009)	(0.014)
Basic R&D	-0.0002	0.0039*	-0.0058	0.0056	0.0007*	-0.0033	0.000	-0.003
	(0.0003)	(0.0023)	(0.0041)	(0.0212)	(0.0004)	(0.0033)	(0.000)	(0.003)
Estimated averages of the dependent variables:								
Firms with male R&D teams	0.4608***		6.4731***		11.8122***		9.950***	
	(0.0052)		(0.0756)		(0.0053)		(0.009)	
Firms with female R&D teams	0.3880***		5.3501***		11.8326***		9.833***	
	(0.0106)		(0.1511)		(0.0141)		(0.018)	
difference	0.0729***		1.1228***		-0.0203		0.117***	
	(0.0115)		(0.1651)		(0.0150)		(0.020)	
explained	0.0417***		0.6222***		-0.0054		0.038**	
	(0.0065)		(0.0948)		(0.0108)		(0.015)	
unexplained	0.0312***		0.5005***		-0.0149		0.080***	
	(0.0121)		(0.1702)		(0.0128)		(0.017)	
Observations	38,645	38,645	34,980	34,980	38,624	38,624	38,619	38,619

Clustered standard errors by firm in parentheses. Significance level: * p-value<0.10, ** p-value<0.05, *** p-value<0.01. All columns include firm age and a full set of dummies to control for firm size, ownership, acquisition/liquidation, market, sector, year, and region. First stage Heckman: squared values of firms' age and firms' male-share included.

effect in obtaining external funds and in finding partners for innovation. Thus, our results provide evidence of female R&D teams being subject to a harder scrutiny, as compared to male teams, when accessing external finance for innovation and when searching for partners to collaborate in innovation, that is, in processes where firms are subject to the external evaluation of their innovation quality. These results would indicate that firms' outsiders undervalue patents of female R&D teams as compared to patents of male R&D teams. As an exception, providers of public funds seem to value relatively more female teams' patents, probably as a response to some of the public initiatives addressed to favour female R&D projects. The possibility that different quality of patents by gender could be driving the results is discarded by the lack of evidence of unexplained effects of patents in variables such as firms' innovative sales, productivity and researchers' wages, which may be considered as firms' outcomes that do not depend upon external evaluation from outsiders.

Thus, our findings support the existence of a gender bias against the value of patents as signals of innovation quality of female R&D teams as compared to patents of male R&D teams, and they are consistent with the presence of stereotypes against female researchers already documented in the literature.

5 Conclusion

Patents are used by firms as a signal of the quality of their R&D team, in particular in processes characterised by asymmetric information between the innovative firm and outsiders. Two contexts where these processes take place are when accessing external finance for innovation activities and when searching for partners to collaborate in innovation projects. In this paper we have used a representative sample of Spanish innovative firms for the period 2005-2014, to analyse the possibility of a gender-biased evaluation against patents of female R&D teams, as compared to male counterparts.

In our empirical approach we have applied the well-known Oaxaca-Blinder decomposition to two sets of dependent variables. The first set refers to outcomes that depend on external evaluation of firms' innovation quality, namely, accessing external finance for innovation activities, and finding partners to collaborate in innovation. The second set of variables are firms' outcomes that do not involve an external evaluation by third parties, such as innovative sales, labour productivity and researchers' wages. These two sets of variables have served us to trace out the different role that patents may play as signals of innovation quality in male versus female R&D teams.

Using the Oaxaca-Blinder decomposition, we have found that patents of female R&D

teams reveal a significant negative unexplained effect in accessing external finance for innovation and in finding partners to collaborate in innovation, suggesting discrimination against the value of patents of female R&D teams. The possibility that different quality of patents by gender could be driving the results has been discarded by the lack of evidence of unexplained effects of patents in variables such as firms' innovative sales, labour productivity and researchers' wages, which may be considered as firms' outcomes not subject to evaluation processes from outsiders.

Our estimated results have provided evidence of a lower signaling value of patents of female researchers, that is, the effect of patents on accessing external finance and finding partners is found to be smaller in female R&D teams, as compared to male counterparts. These findings indicate the existence of a gender bias against the value of patents of female R&D teams, that is, evidence in support of female R&D teams being subject to a harder scrutiny, as compared to male teams, in those processes where the innovation quality of firms are subject to external evaluation due to information asymmetries, such as accessing external finance to innovate and finding partners to collaborate in innovation. These findings are important if we take into account that both obtaining external funding and forming alliances to collaborate in innovation are key factors determining firms' success and survival prospects in the marketplace, so that firms with female researchers are at a disadvantage, as compared to firms with male researchers. It would be of great interest to count on additional future research that could either contrast with or confirm our findings using different sources of data an different measures of access to capital and collaboration markets.

By showing that female R&D teams are subject to a gender bias in the signalling value of their patents, our study has a number of important implications. First, since our results suggest negative stereotypes and discrimination against female researchers, addressing gender inequality in science will require a cultural shift in attitudes towards female researchers, not only in business but also in science and innovation. By increasing the awareness of the existence of these negative stereotypes our study may help raising a red flag against discrimination of female researchers in the marketplace. Second, gender disadvantages against female researchers ultimately operate to the detriment of technological change and economic growth and calls for policies aimed at promoting gender parity in research and science. Actions to be taken could include the use of instruments to create an environment of encouragement to disrupt negative stereotypes about the capacity of female researchers in science and technology, helping to ensure female researchers have full access to financing and collaboration opportunities, as much as male counterparts. Two policy instruments could be the development of mechanisms to facilitate access to financial resources to those firms with female researchers, and the promotion of public organisations providing networking opportunities for female researchers, helping to identify industry contact or collaboration partners, encouraging active engagement within these organisations.

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Appendix

Table A1. Sample distribution and proportion of patenting firms by sector.

	Male R&D teams (≥ 70% men)		Female R&D teams (≥ 70% women)	
	N. Observ.	% patenting firms	N. Observ.	% patenting firms
Primary sector				
Agriculture, forestry and fishing	443	9.93	148	12.16
Mining and quarrying	93	4.30	26	23.08
Manufacturing				
Coke and refined petroleum products	6	16.67	-	-
Food, beverages and tobacco	1680	7.68	931	8.92
Textiles	691	14.76	167	7.78
Wearing apparel	127	10.24	84	4.76
Leather and related products	154	9.09	31	3.23
Wood and products of wood and cork	264	9.85	45	4.44
Paper and paper products	256	11.33	77	5.19
Printing and reproduction of recorded media	227	10.57	30	6.67
Chemicals and chemical products	1880	11.65	796	12.19
Pharmaceutical products	268	19.03	391	26.34
Rubber and plastic products	1270	21.26	211	21.80
Non-metallic mineral products	938	14.50	165	6.06
Basic metals	641	12.48	87	25.29
Fabricated metal products (except machinery and equipment)	2224	22.84	142	14.08
Computer, electronic and optical products	1991	19.24	52	19.23
Electrical equipment	1,429	27.43	81	17.28
Machinery and equipment n.e.c.	3638	26.22	136	23.53
Motor vehicles, trailers and semi-trailers	1179	22.56	43	11.63
Naval construction	105	17.14	10	20.00
Aeronautical and aerospace construction	112	27.68	4	25.00
Other transport equipment	173	28.32	2	0.00
Furniture	605	25.62	61	9.84
Other manufacturing	394	32.49	57	8.77
Repair and installation of machinery and equipment	174	23.56	11	9.09
Utilities				
Energy and water supply	218	24.31	37	24.32
Sewerage, waste management and remediation activities	199	7.04	58	15.52
Construction	878	18.00	122	9.84
Services				
Wholesale and retail trade	1330	14.36	419	13.60
Transportation and storage	269	11.52	15	0.00
Accommodation and food service activities	61	4.92	9	0.00
Telecommunications	234	8.97	14	0.00
Computer programming, consultancy and related activities	3124	8.48	161	8.07
Other services of information and communication	469	5.54	45	6.67
Financial and insurance activities	399	3.26	48	6.25
Real estate activities	31	16.13	15	0.00
R&D services	981	34.66	402	31.59
Other professional, scientific and technical activities	2412	16.42	443	9.93
Administrative and support service activities	557	12.39	98	8.16
Education	101	0.99	62	4.84
Human health and social work activities	236	8.47	157	5.73
Arts, entertainment and recreation	18	16.67	6	0.00
Other service activities	176	5.11	91	6.59
Total	32655	17.41	5990	13.52

Table A2. Definition and construction of variables

Variables subject to external scrutiny (set-1 variables)	
Finance	Discrete variable taking values from 1 to 3 rating the firm' assessment on how difficult is finding external finance for innovation (where a value of 1 reflects high difficulty, and a value of 3 low or no difficulty). The question in the survey corresponds to the current (t) and the previous two years.
Partners	Discrete variable taking values from 1 to 3 rating the firm' assessment on how difficult is finding partners to collaborate in innovation (where a value of 1 reflects high difficulty, and a value of 3 reflects low or no difficulty). The question in the survey corresponds to the current (t) and the previous two years.
Private funds	In-house R&D expenditures financed by private funds (percentage over total in-house R&D) during the current (t).
Public funds	In-house R&D expenditures financed by public funds (percentage over total in-house R&D) during the current (t).
Private partners	Binary indicator variable taking on the value 1 for firms with collaboration agreements for innovation with other firms in the private sector (clients, providers, competitors) during the current (t); 0 if otherwise. This variable is available from 2012 onwards.
Public partners	Binary indicator variable taking on the value 1 for firms with collaboration agreements for innovation with the public sector (universities, public research institutes, and other public institutions) during the current (t); 0 if otherwise. This variable is available from 2012 onwards.
Variables not subject to external scrutiny (set-2 variables)	
Prob(Innovative sales)>0	Dummy variable equal to one (and zero otherwise) if the firm has a positive turnover from products that are new in the market introduced during the current (t) and the previous two years.
(log)Innovative sales	Firm's turnover (in euros) corresponding to products that are new in the market introduced during the current (t) and the previous two years. In estimation, we use the log of this variable.
Productivity	Ratio of firm's turnover (in euros) over total employees (full time equivalents) in t. In estimation, we use the log of this variable.
Researchers' wages.	Average yearly wage of researchers in the R&D team (in euros). Firms report the wage bill paid to their R&D employees distinguishing two categories: researchers and lab technicians. We construct the variable as a weighted average from these payments with the weights corresponding to the total employee share accounted for by each type. In estimation, we use the log of this variable.
Patents, composition of the firm's R&D team and type of R&D activities.	
Patents	Number of firm's patents applications during the current (t) and the previous two years.
R&D team size	Total employees (full time equivalents) employed in in-house R&D during the current (t).
Postgraduates-share	Percentage of total employees (full time equivalents) employed in-house R&D that are researchers and hold a postgraduate degree (PhD, MSc or similar) during the current (t).
Basic R&D	In-house R&D expenditures on basic research (percentage over total in-house R&D) during the current (t).

(continued)

(continued. Table A2. Definition and construction of variables.)

Other firms' characteristics.	
Firm male-share	Percentage of male employees over total number of firms' employees (full time equivalents) during the current (t).
Firm turnover	Total firm's turnover (in euros) during the current (t). In estimation, we use the log of this variable.
Employees	Firm's number of employees (full time equivalents) in t.
Size_0-15 to Size_295+	A set of 5 dummy variables accounting for the quintiles of the firms' size distribution in PITEC (firms' total number of employees). The resulting intervals are: 0-15, 16-35, 36-95, 96-295, and more than 295 employees. Each dummy variable is equal to one (and zero otherwise) if the firm's number of employees is in the corresponding quintile.
Age	Firm's age in years.
Group	Dummy variable taking value one (and zero otherwise) if the firm belongs to a group of firms in t.
Foreign_capital	Dummy variable taking value one (and zero otherwise) if the firm has foreign capital participation in t.
Public_capital	Dummy variable taking value one (and zero otherwise) if the firm has public capital participation in t.
Acquisition/liquidation	Dummy variable equal to one (and zero otherwise) if the firm experiences an acquisition or liquidation process associated with a decrease in turnover by 10% or more.
Local market	Dummy variable equal to one (and zero otherwise) if the firm sells at most to the local market in t.
National market	Dummy variable equal to one (and zero otherwise) if the firm sells at most to the national market in t.
EU market	Dummy variable equal to one (and zero otherwise) if the firm sells at most to countries of the European Union, European Free Trade Association (EFTA) or EU candidates in t.
World market	Dummy variable equal to one (and zero otherwise) if the firm sells at most to countries of the rest of the world in t.
Sectors	PITEC classifies firms at two-digit NACE-2009 level (44 sectors).
Years	Year dummies.
Regions	Region dummies corresponding to the 17 Spanish Autonomous Communities.