ECONOMICS
& Sociology

Muñoz, R. T., Graña, C. P. (2016), The Effects of Gender on the Quality of University Patents and Public Research Centres in Andalusia: is it Better with a Female Presence? *Economics and Sociology*, Vol. 9, No 1, pp. 220-236. **DOI: 10.14254/2071-789X.2016/9-1/15**

THE EFFECTS OF GENDER ON THE QUALITY OF UNIVERSITY PATENTS AND PUBLIC RESEARCH CENTRES IN ANDALUSIA: IS IT BETTER WITH A FEMALE PRESENCE?

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Received: October, 2015
1st Revision: November, 2015
Accepted: December, 2015

DOI: 10.14254/2071-789X.2016/9-1/15

ABSTRACT. Much work has been done about the quality of patents as a tool to improve economic growth. However, investigations concerning the analysis of women's participation in technological research are very limited. The aim of this article is to determine if female participation in a specific invention influences the quality of the patent. The research is based on the analysis, of the information which shows 498 patent applications and 1838 inventors from Universities and Public Research Centres in Andalusia (Spain), between 1990 and 2006. The main conclusion is the fact that the quality of the patent is higher when the inventor team includes both, male and female presence. According to the results obtained in this work, we argue that it is therefore necessary to implement policies to promote greater contribution by women and the resultant implication in the fields of science and technology.

JEL Classification: O31, O32, J16

Keywords: Gender and Patents, Innovation, Quality of Patents, Female Presence, Economic growth.

Introduction

Important efforts are being made to study and promote the position of women within the fields of science, research and technological innovation. Examples of this on a European level are: European Commission. Directorate-General for Research (2009) and, on a national level: Spanish Foundation for Science and Technology (FECYT) (2005). In general, the studies done indicate their low presence and representation both at international level and within our country. It is possible, through the ability to innovate and create economic value within technological knowledge, to promote economic growth and make it possible for regions and countries to become more competitive (Basile *et al.*, 2012; Sener & Saridogan, 2011). If we understand the innovative capacity of a country to be the ability to achieve economic growth, social welfare and sustainability, the human factor is the key to achieving these objectives. This means that the underemployment of the talent, knowledge and skills of women is something that should be addressed. The waste of women's talents, knowledge and skills weighs heavily in the science system (Kugele, 2010). As indicated by Fox (2001) women in science have overcome obstacles, both with regard to self-selection within the different fields, as well as through selection by institutions. However, they have not yet been able to achieve complete integration at the highest levels. In Spain, despite the fact that women represent 37.6% of the teaching staff in Spanish Public Universities[1], (35.8% in Andalusia) and 39.8% of researchers in higher education, only 16.6% of those holding university chairs are women (16% in Andalusia).

Consequently, our first objective in this work is to analyse, from the perspective of gender, the technological contribution of the researchers belonging to the most relevant public research centres in Andalusia[2] (amongst these, both the Universities and Centres belonging to the Spanish National Research Council in Andalusia). Secondly, we refer to the quality of the contribution, studying whether or not there may be differences which depend on the gender of the researchers. Based on the analysis of the information which resulted in a total of 498 Andalusian patent applications and the estimation of a counting model, our intention is to provide a response to the following question:

Is the quality of the patent higher when the inventor team includes both male and female inventors?

The article is structured as follows: The following section (1) reviews the existing literature regarding studies about women's engagement in patenting activity and asks the questions that we seek to answer. There follows a description of the methodology used. The data, model estimate and results are presented in sections 2 to 4. Finally, the most relevant conclusions are commented upon in conclusions.

1. Review of the literature and question to be considered

Universities have increased their obligations towards society over recent decades, by not solely limiting their functions to training or investigation; extending their functions as well as to contribute to the economic growth of the regions in which they are situated. As indicated by Whittington (2011), many agree that the traditional image of the scientist is being replaced by a new model, the scientist-entrepreneur, who creates a balance between institutional responsibilities and academic activities. In this sense, technology transfer is one of the main instruments for the development of this function, as has been demonstrated by the important growth of the commercial activities of these institutions, within which, patents play an significant role (Kleinman & Vallas, 2001; Owen-Smith & Powell, 2004; Azoulay *et al.*, 2007).

The economic dimension of sustainable development is based on innovation. The creation of knowledge and innovation must be understood as a process. In this process, the individual knowledge is increased and internalized as a part of organizational knowledge (Nonaka, 1991). Innovation is done by scientists, or by teams of inventors. The tendency of the inventors to share their knowledge is crucial in order to establish the innovation ability of the organization. In other words, there exists a positive relationship between sharing knowledge and innovation within the organization (Camelo Ordaz *et al.*, 2010). To understand and manage the innovation process, it is crucial to consider the human factors of innovation (Jung & Ejermo, 2014). Investigating aspects of gender in invention suggests possibilities for more efficient use of human resources. The under-representation of women in science and technology in the European Union causes special concern, considering that as well as the low percentage of women researchers there is an even lower percentage of women inventors (Busolt & Kugele, 2009). To achieve the full engagement of women at all levels in

[1] According to the data collected from National Statistics Institute for the academic year 2009-2010.

[2] An important Spanish region with autonomy at university level which constitutes 18% of the country's population and produces 13.4% of its GDP.

this field will allow an important step forward in, and consolidation of, the progress of science and technology.

There have been very few studies on the specific involvement of women in technological innovation. The analysis of this phenomenon creates a problem due to the reduced number of indicators on the subject and, in many cases, the difficulty in obtaining gender disaggregated data. The need to gather all of the data relative to the contribution and productive input to the science and technology system, by gender, is a constant demand (as reflected, in the case of Spain, in the second edition of the study *Women and Science* performed by the Spanish Foundation for Science and Technology or in the case of the European studies carried out by the "Helsinki group", amongst which should be highlighted those called *She Figures,* carried out in 2003, 2006, 2009, 2012 and 2015). Despite the lack of data, important advances are being made in the study of women's contribution to technological development. Some studies take the researcher or inventor as the unit of analysis so that, based on their particular characteristics, they can establish if there are differences according to gender. The problem posed by this methodology is the absence of databases that include this information. The only way to obtain it would be by means of surveys as, for example, those by Murray & Graham (2007). They research this subject with interviews undertaken at universities. They analyse the causes that lead to women patenting less (in the Universities analysed, 23% have patented at least once, compared with 74% of men) and the factors that cause these differences to be maintained over time (fewer opportunities and relations with agents linked to this activity). They conclude that this gap is smaller for younger female researchers. Thursby & Thursby (2005), analyse patenting activity in 11 of the most important American Universities, studying different areas of knowledge. They indicate that the probability of male researchers obtaining an invention is 43% higher than female researchers. Although there is a trend towards convergence, the disparity between men and women still exists. The lack of consensus in regard to the "productivity puzzle" in sciences leaves the question open as to whether or not gender differences in participation exist and, if this is the case, the pattern which causes these differences to occur.

The majority of the studies are centred on the area of life sciences which, according to Ding *et al.* (2008), occupy the first place in technology transfer from Universities. The work of Ding *et al.* (2006) is based on American University researchers and demonstrate that inventions patenting by women are less than those done by men. Although this difference has improved over time, the trend still persists. One year later, the work of Azoulay *et al.* (2007) yielded the same results. By analysing a group with the same composition, concluded that the trend to patent is 49% less for women than the level achieved by men. The research of Whittington & Smith-Doerr (2005); Whittington & Smith-Doerr (2008), also focus on the differences by gender between academics and industry in this area. The same topic has been analysed by the same author in all sectors (Whittington Bunker, 2006). The study includes amongst other fields: Molecular Biology, Biochemistry, Organic Chemistry, Medical Sciences, Biochemical Engineering and Bioengineering. The main results are gender differences in patenting activity (or participation in this activity), in the volume of patents (or contribution), as well as in quality. The balance for women is unfavourable. However, the quality of their inventions is similar or even better.

Diverse studies, use one of the most important products of technological activity, the patents, as the observation unit (McMillan, 2009; Mauleón & Bordons, 2010). Patents are considered to be good indicators of technological activity (Griliches, 1990; Archibugi, 1992; Basberg, 1987; Nesta & Patel, 2005; Baldini, 2006; OECD, 1997). Patents are one of the most common instruments used. From patent applications we can obtain gender disaggregated information concerning inventors. McMillan (2009), analyses the biotechnological industry in the U.S. and the differences, by gender, in patents. It is analysed different topics, such as female participation in technological knowledge, the quality of the patents, and the transfer of knowledge between science and technology. One of his most notable conclusions is the fact that women patent less because they find this activity to be less attractive. He highlights that it is necessary for women to take part in R&D activities from start to finish. This fact would make it possible to get more benefits from research activities. The research of Hunt *et al.* (2012), quantified the gender patenting gap in USA: abolishing the gap in participation between males and females in science and engineering areas would increase GDP per capita by 2.7%, and commercialized patents by 24%. As indicated by McMillan (2009), women patent less than men. However, the quality of patents whose authors are "solely women" is higher than patents whose authors are men or patents applied for jointly by men and women. Other studies, support this result, such as that done by Whittington & Smith-Doerr (2005). The main finding highlights that despite the fact that women patent less than men, the quality of their patents is better. Conversely, Mariani & Romanelli (2007), indicate the higher quality of patents presented by men. They attribute this result to the low representation of women in the sample used.

The increasing number of patents in recent years leads us to raise the issue of analysing their quality. Previous research (Merges, 1994; Barton, 2000; Kingston, 2001), conclude that the increase in patent generating activity has had a negative effect on quality. The use of patents as an indicator or measurement for the study of contribution to technological activity has a series of limitations, considering that not all inventions are patented, nor are they all patentable. Conversely, innovative capacity does not only consist of obtaining a given "technological output". It is also reflected in the presence of a series of fundamental determining factors, such as: investments and policies which determine the success/failure of the innovative effort, the existence of important differences between countries as regards their patenting systems and policies, the different propensity for patenting between companies in different sectors of activity, etc. These difficulties have already been indicated by numerous authors (Pavitt, 1985; Basberg, 1987; Archibugi, 1992). However, the advantages of using patents as a measurement indicator surpass the disadvantages.

Among the comparative studies between different countries we can highlight (Naldi *et al.*, 2005) who carried out analyses in six European countries[3]. Among his outstanding results is the fact that the scientific activity of women is greater in publications than in patents[4]. This author also finds that Spain is one of the countries with a higher percentage of women inventors. In the same vein (Frietsch *et al.*, 2009), compare 14 countries, concluding that in all of them the presence of women in patent applications is rising but it is still lower than men. They highlight that Spain is a country with a higher involvement of females in patenting. Wisła & Sierotowicz (2015) studied the patent activity in the 28 European countries belonging to the European Union between 1999 to 2013. They concluded that female patent inventors are growing in all of the countries included in the study and the share of men is decreasing in all of the countries analysed. Other studies based on different aspects of commercial activity, such as advice to companies (Ding *et al.*, 2008) and creation of businesses (Rosa & Dawson, 2006; Dahlstrand & Politis, 2013), also emphasize a lower participation of female researchers. In the case of Spain, we should point out the work of (Mauleón & Bordons, 2010), who studied this topic in Universities and the Spanish National Research Council. The results indicate that only 16% of the patents analysed include a woman amongst its inventors, with a 9% contribution to technological output.

All of the questions outlined above lead us to reflect on contribution and participation to technological activity, from the point of view of gender, in a way that will allow us to achieve a better understanding of women's input to technological knowledge. We have,

[3]The countries analysed are Germany, Spain, Italy, France, the United Kingdom and Sweden.
[4]To see the relationship between the publishing and patenting of a researcher read Stephan *et al.*, 2007, amongst others.

therefore, considered it to be necessary to ascertain whether gender influences contribute to technological activity. This is a complex and little-analysed area, due to the lack of data on the subject.

2. Data source

We have created a database with the information obtained from the Spanish Patent Office, related to all the patents applied for by Universities and Public Research Centres in Andalusia (Spain). Therefore, this paper makes use of population-level longitudinal data. All of the patent applications have been analysed. There are 489 in total. The analysis covers the period from 1990 to 2006. All economic sectors have been taken into consideration.

In order to construct this database we have individually and manually extracted the information contained both in the patent applicant and in the State of the Art Report on the Technique (SAR. The initials are in English from here on). The SAR is a document, drawn up exclusively by the Patents Office, with reference to a specific patent application. It supplies information regarding the originality of the invention to be patented. We have collected information from the SAR from a total of 1,635 patent claims regardless of the X or Y influence. The section "model and variables" contains a detailed explanation of the use given to the data obtained from this document to build the econometric model.

The following information has been gathered from the patent application: number of inventors and their gender (1,838), number of patents cited (951), number of scientific publication cited (4,000), cooperation between different institutions, number of countries for which patent protection is requested and the number of assignments in the international patent classification. The process is summarised in *Figure 1*.

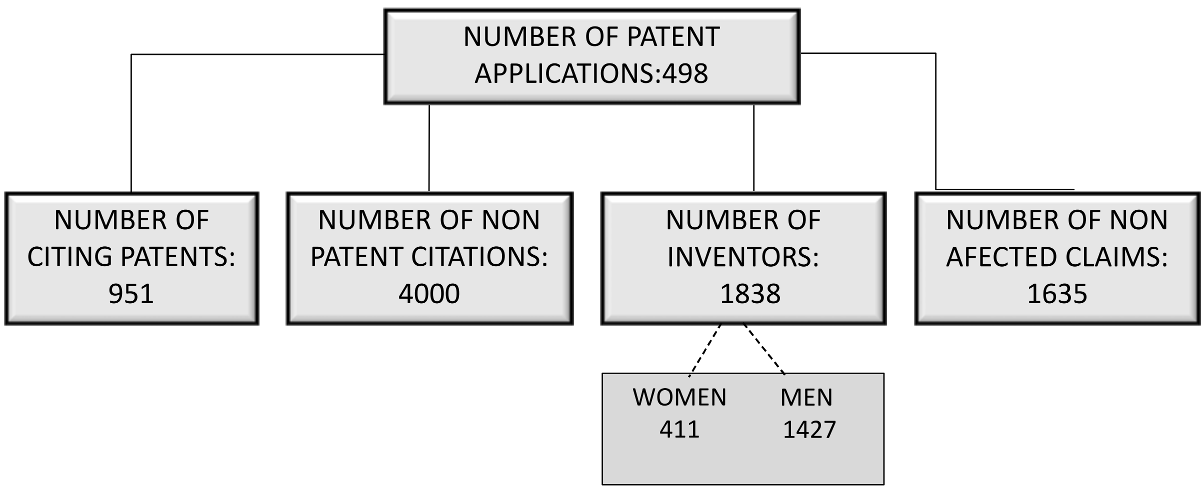

Figure 1. Information extracted from Patents Aplications
Source: Spanish Patent Office.

3. Model and variables

3.1. Model

The basic model used to contrast our question relative to the quality of university patents is a counting model based, on Poisson and Binomial Negative distributions. This is due to the nature of the dependent variable, which can only take integer values, including zero.

As pointed out Acosta *et al.* (2011), the application of a Poisson model requires the assumption of equality of means and variances, a requirement that cannot always be met in practice. The generally accepted model for avoiding this overdispersion is the Negative Binomial. If the data show overdispersion, the standard errors of the Poisson model will be biased in favour of the low end, therefore giving high values for the individual significance statistics (Cameron & Trivedi, 1986).

There is a high percentage of zeros in the variable, 45.6% to be precise, which means that it will be necessary to use and compare the ZINB (Zero Inflate Negative Binomial) and ZIP (Zero Inflate Poisson) count data models.

3.2. Variables

There follows a description of the variables, extracted from our database, which have been included and used in the model.

3.3. Dependent variable

- Number of claims in a patent (nac_i): Over the last few years there has been an important increase in the number of claims included in the patents[5]. This variable is analysed by Tong & Frame (1994), as well as by Lee *et al.* (2007), finding a positive relation with the value of the patent. In order to construct the variable, we have only taken into account those claims from each SAR with neither type X influences (which affect the originality of the patent and which would indicate that an invention equal to that requested has been found) nor any type Y influences (which affect the capacity for invention and which indicates that, by combining other documents cited in the report, it would have been possible to resolve the problem suggested).This differentiation is used by Schmoch (1993), who considers that this type of influence limits the claims made by the inventor in the patent, while Sampat & Ziedonis (2005) affirm that, when the content of the patent is included in the patent literature or in other foreign patents, the quality of the patent is inferior. In our database we have collected a total of 1635 claims not affected by either X or Y type influence.

It should be noted that the variable most used in this type of analysis is the "Forward patent citation" or the number of times the patent has been cited by others. This makes it possible to measure the technological impact of the inventions. It is considered to be one of the best variables for measuring quality (Trajtenberg, 1990; Harhoff *et al.*, 1999; Harhoff *et al.*, 2003; Sapsalis *et al.*, 2006). However, this information is not available for Andalusian patents. For this reason, it makes impossible to use as an endogenous variable to be included in the econometric model.

3.4. Explanatory variables

- Gender ($gender_i$): The reasons exposed in section two are enough to include in the model gender as an explanatory variable to explain the quality of Andalusian patents. We took the names of each of the inventors in order to identify female presence in the patents. When there have been doubts about the inventor´s name, or only the initials of the name appeared, we carried out an individualised search regarding that specific author. This was done either by means of a search of University or CSIC personnel databases, or using other

[5](van Zeebroeck *et al.* (2009) analyse the factors which, during recent years, have motivated the increase in the claims which appear in patents.

sources of information like personal web sites or others where these authors or some of their work may have appeared, in order to determine their gender. There are 1838 inventors in total, 411, (29%) are women and 1427, (71%) are men. A variable dummy has been created to include female presence within the group of inventors. It takes the value 1 if there is female presence in the patent. If this is not the case it takes the value 0.

- Number of Citing Patents (cp_i). This includes the patents cited in the central body of the patent document, allowing the measurement of the frameworks for the transfer of knowledge (Criscuolo & Verspagen, 2008; Hall *et al.*, 2005), however, consider these to be an incomplete measure of the flow of knowledge, as they only include the prior technological knowledge susceptible to being patented but not that which cannot be included in a patent. Trajtenberg (1990) finds that there is a direct relationship between this variable and the value of the patent. The following works (Sapsalis & van Pottelsberghe de la Potterie, 2007), are on the same subject. He highlights that 50% of studies find a positive impact on the value of the patent. In order to construct this variable we counted the number of patent citations included in the main body of the patent application. We collected a total of 951 patent citations. In order to reduce the dispersion we considered the variable in natural logarithm. ($lncp_i$).

- Number of scientific citations or Non Patent Citations (npc_i). In order to construct this variable we counted the number of scientific citations included in the patent application. We have collected 4.000 scientific citations. To reduce the dispersion we have taken the natural logarithm to the variable ($lnnpc_i$). This variable is frequently used to deal with the value of patents as well as their connection with "basic research" or the relation between science and technology (Narin *et al.*, 1997). However, the conclusions reached are not always the same. Meyer (2000) finds that, occasionally, the scientific citations included in patents correspond to other reasons and interests. Boyack& Klavans (2008), conversely, highlight the interaction between science and technology. Sapsalis *et al.* (2006) conclude that this variable does not determine the value of the patent, although they attribute this to the fact that the study is based on university patents. This kind of patent has a high propensity for citing scientific literature. However, when differentiating between citations in general and self-citations, they observe that the latter give them a higher value since, in some way, their own scientific knowledge is transferred to the patent. The study of German patents undertaken by Harhoff *et al.* (2003) find the relationship mentioned before. Otherwise the conclusions highlighted in another study, in the field of biotechnology and pharmacy, are contradictory.

- Size of the patent family ($fsize_i$). This variable shows the degree of extension and circulation of the patent, deciding on those countries where there is a decision to protect the invention, taken into account that they have a greater capacity for developing the patents or the existence of close lines of research. Highlighting the fact that patents with a presence in several countries have a higher value than those which only are protected in one country or region (Sapsalis *et al.*, 2006). The OECD (2009), considers this variable to be an indicator of the value of the patents, even using the concept of «triadic patent families», which only counts those applications presented simultaneously in the European, American and Japanese patent offices. Several works (Putnam, 1997; Harhoff *et al.*, 2003; Lanjouw *et al.*, 1998), also share this point of view in the sense of patents with a large international family have a special value. Nevertheless, according to Lanjouw & Schankerman (2004), more than two thirds of patent owners do not seek protection outside their national markets. In order to construct this variable we counted the countries in which protection for the patent had been applied for. To reduce the dispersion we took the natural logarithm to the variable ($lnfsize_i$).

- Number of assignments in the International Patent Classification (ipc_i). The patents may be assigned different IPC codes. They were established by the Strasbourg Agreement in 1977. "Provides for hierarchical system of language independent symbols for the classification of patents and utility models according to the different areas of technology to which they perform". The empirical literature for this variable suggests that the greater the technological diversity, the greater the value of the patent will be (Lerner, 1994), but that there is also a higher probability of evidence being presented to the effect that the patent does not comply with criteria for patentability (opposition), because, for example, it is not new. Whereas, Harhoff & Reitzig (2004) argued that greater technological diversity leads to less probability of opposition because, as the invention is of a more general nature, its launch on the market has less relevance. In order to construct the variable we counted the different IPC codes assigned to each patent.

- Number of inventors ($ninv_i$). From this point of view Ernst *et al.* (2000) find a positive relationship between the number of participants in the research process, the development of the patent and the technological quality. This connection is also found in (Adams *et al.*, 2005), especially basing themselves on the relationship between the number of inventors and the technological value of the patent. We have counted the number of inventors included in patent applications and collected 1,838 inventors over the period being studied.

- Collaboration ($colab_i$). It takes the value 1 if there is collaboration between different public research organisms and the value 0 if this is not the case. The model includes this fact in a dummy variable. This is a variable which has not been widely studied when determining the value of the patent. The research of Sapsalis & van Pottelsberghe de la Potterie (2007), note that this collaboration has a special value when two research knowledge bases are combined, since they can create synergies that increase their value. Moreover, if a public research institution is involved, greater value can be expected, since the basic knowledge of the invention could be more strongly related to research in the scientific sector. Following Balconi & Laboranti (2006), the establishment of collaborative networks between academic researchers and industry improves productivity, both from the point of view of the discovery and from that of the invention.

In *Table 1* there are compressing the explanatory variables.

Table 1. Definition of explanatory variables

Definition of explanatory variables	
cp_i	Number of the patents cited in the central body of the patent document on each patent. We considered the variable in natural logarithm. (LNCPi).
npc_i	Number of scientific citations included in the patent application. We considered the variable in natural logarithm. (LNN`PCi).
$fsize_i$	Number of countries in which protection for the patent had been applied for. We took the natural logarithm to the variable ($LNFSIZE_i$).
ipc_i	The variable captures the different IPC codes assigned to each patent.
$ninv_i$	Number of inventors on each patent.
$colab_i$	Binary variable. It takes the value 1 if there is collaboration between different public research organisms. Otherwise, the value is 0
$gender_i$	Binary variable that takes a value of 1 if there is female presence in the patent. Otherwise, the value is 0
inter1i	Interaction-term: $lnnpc_i*gender_i$
inter2i	Interaction-term: $lncp_i*gender_i$
Analysis of the robustness of the model:	
$prwom_i$	proportion of women in each patent. We use this variable instead of Gender
$inter3_i$	Interaction-term: $lnnpc_i*prwom_i$.We use this variable instead of *inter1*
$inter4_i$	Interaction-term: $lncp_i*prwom_i$.We use this variable instead of *inter2*

The substitution of these explanatory variables presented in *Table 1* in the function of the quality of the patents, measured by the number of claims not affected by X and Y, leads us to the following equation:

$$nac_i=f(ipc_i, lnnpc_i, lncp_i, lnfsize_i, ninv_i, colab_i, gender_i, u_i), i=(1, 2, \ldots 489).$$

Where u_i captures the unobservable effects.

The correlations between variables are shown in *Table 2*.

Table 2. Correlations

Table 2. Correlations

	nac	ipc	lnnpc	lncp	lnfsize	gender	colab	ninv
nac	1							
ipc	0.1001	1						
lnnpc	0.0759	-0.0748	1					
lncp	0.1305	0.1134	0.1061	1				
lnfsize	0.1085	0.1306	0.1306	0.2549	1			
gender	0.1125	0.0304	0.1329	0.0834	0.0284	1		
colab	-0.0196	0.003	0.1313	0.1287	0.1881	0.0864	1	
ninv	0.0451	0.0496	-0.0161	0.0534	0.104	0.4113	0.2359	1

According to the results shown in the previous table there is no co-linearity between the variables.

In order to check whether or not the variables $lnnpc_i$ and $lncp_i$ have a greater effect on the quality of the patent, if the research team includes a female presence, the following variables (interaction terms) have also been taken into consideration:

$$inter1_i=lnnpc_i*gender_i$$
$$inter2_i=lncp_i*gender_i$$

The second model proposed would be:

$$nac_i=f(capitn_i, lnnpc_i, lncp_i, lnfsize_i, ninv_i, gender_i, colab_i, inter1_i, inter2_i, u_i), i=(1, 2, \ldots 489).$$

Where u_i captures the unobservable effects.
Descriptive statistics are shown in *Table 3*.

Table 3. Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
1	2	3	4	5
nac	3.343558	5.720663	0	46
ac	4.481557	5.935975	0	33
quimic	0.5132924	0.5003351	0	1
ninv	3.770961	2.188994	1	16
prwom	0.1837832	0.2345789	0	1
gender	0.4580777	0.4987497	0	1
ipc	1.208589	0.4263934	1	3
colab	0.1574642	0.3646109	0	1
lnfsize	0.3452117	0.5548121	0	3.496508

1	2	3	4	5
lncp	-0.86879	1.78933	-2.302585	3.332205
lnnpc	0.5777928	2.232485	-2.302585	4.276666
inter1	0.4249778	1.565419	-2.302585	4.276666
inter2	-0.3235308	1.290114	-2.302585	3.178054
inter3	0.1868934	0.7045377	-2.302585	3.218876
inter4	-0.1379246	0.5645963	-2.302585	1.94591

4. Results

4.1. Core results

The statistics indicate that the zero inflated negative binomial model (ZINB) is better than the zero inflated Poisson model (ZIP). The results of the model, which includes interaction terms, are included in the ZINB(II) model. The correlation coefficient between $inter1_i$ and $lnnpc_i$ is 0.68 and 0.64 between $inter2_i$ and $lncp_i$. Due to the co-linearity, $inter1_i$ and $inter2_i$ variables in the ZINB(II) model are not significant.

If we estimate the following model, ZINB(III), *lnnpc* and *lncp* are not included, the variables *inter1* and *inter2* will be significant:

$$nac_i=f(capitn_i, lnfsize_i, ninv_i, gender_i, colab_i, inter1_i, inter2_i, u_i), i=(1, 2, \ldots 489).$$

Where u_i captures the unobservable effects.

This means that there exist co-linerity between $inter1_i$, $lnnpc_i$ and $inter2_i$, $lncp_i$.

In summary, we could conclude that variables $inter1_i$ and $inter2_i$ have an influence on the quality of the patents.

The core results are shown in *Table 4*. It includes from ZINB(I) to ZINB (III) models.

Table 4. Core results

Number of obs: 489 Non zero obs: 262 Zero obs: 227			
variables	ZINB(I)	ZINB(II)	ZINB(III)
1	2	3	4
$const_i$	1.4*** (0.231)	1.335*** (0.233)	1.285*** (0.209)
ipc_i	0.083 (0.144)	0.044 (0.145)	0.070 (0.141)
$lnnpc_i$	0.067*** (0.019)	0.076** (0.035)	
$lncp_i$	0.048** (0.022)	0.053 (0.053)	
$lnfsize_i$	0.452*** (0.125)	0.44*** (0.13)	0.446*** (0.133)
$gender_i$	0.242** (0.134)	0.281** (0.13)	0.334*** (0.144)
$colab_i$	-0.042 (0.190)	-0.28 (0.192)	-0.032 (0.192)

1	2	3	4
$ninv_i$	-0.006 (0.028)	-0.011 (0.028)	-0.020 (0.027)
$inter1=lnnpc_i*gender_i$		0.027 (0.054)	0.099*** (0.040)
$inter2=lncp_i*gender_i$		0.065 (0.067)	0 .113*** (0.047)
log likelihood	-1029.337	-1030.951	-1033.06
Vuongstatistic	3.37***	3.21***	3.20***
Alfa (α)	0.90** (0.167)	0.91** (0.168)	0.95** (0.19)

***1% level significant
**5% level significant
*10% level significant

According to the results obtained from the models mentioned above and included in *Table 4*, we can point out the following:

- The variables ipc_i (Number of assignments in the International Patent Classification), $colab_i$ (whether or not there exists a collaboration between different research centres) and $ninv_i$ (number of inventors), have no influence on the endogenous variable.
- Those that have a positive influence, i.e., they increase the value of the patent are: international presence ($lnfsize_i$), the number of scientific citations ($lnnpc_i$), the number of patent citations ($lncp_i$) and the existence of mixed research teams ($gender_i$).
- The positive effect of the $lnnpc_i$ and $lncp_i$ variables on the quality of the patents is even greater when there is a female presence in the research team.

If we concentrate on the gender aspect, we can confirm that our results are along the same lines as those obtained by (McMillan, 2009). However, they are not comparable, since we have not differentiated between exclusively male, female and mixed patents as this author does. For our research it is impossible to do this, due to the low representation of patents applied for only by women. The research of Whittington & Smith-Doerr (2005) was centred on the inventors and the quality of their patents by gender, which means that comparison is not possible here either, because they are different units of analysis. These results are different from those obtained by Mariani & Romanelli (2007), although these authors analyse the inventor, not the patent, which means it is difficult to establish comparisons.

4.2. Analysis of the robustness of the model

Bearing in mind the limited data and the type of model used, we have considered it to be advisable to analyse the robustness of the model. We have estimated a series of models, details of which are given below:

1. Substitution of the variable $gender_i$ for that of $prwom_i$ (proportion of women in each patent):

$$nac_i=f(ipc_i, lnnpc_i, lncp_i, lnfsize_i, ninv_i, prwom_i, colab_i, u_i),$$
$$i=(1, 2, \dots 489).$$

Where u_i captures the unobservable effects.

2. Introduction of the interaction terms $inter3_i$ and $inter4_i$. In order to check whether or not the variables $lnnpc_i$ and $lncp_i$ have a greater effect if there is a higher proportion of women

in the research team, the following variables (interaction terms) have also been taken into consideration:

$$inter3_i = lnnpc_i * prwom_i$$
$$inter4_i = lncp_i * prwom_i$$

The model to be studied would be as follows:

$$nac_i = f(ipc_i, lnnpc_i, lncp_i, lnfsize_i, ninv_i, prwom_i, colab_i, inter3_i, inter4_i, u_i),$$
$$i = (1, 2, \ldots 489).$$

Where u_i captures the unobservable effects.

The effects are shown in *Table 5A*. The correlation coefficient between $inter3_i$ and $lnnpc_i$ is 0.62, and 0.57 between $inter4_i$ and $lncp_i$. Due to the co-linearity, $inter3_i$ and $inter4_i$ variables in the ZINB(V) model are not significant. The ZINB(VI) has been constructed to demonstrate co-linearity, reaching the conclusion that the variables $inter3_i$ and $inter4_i$ have an influence on the quality of the patents. We can observe that the results obtained are similar to those shown in *Table 4*. To conclude, we can say that when there is a higher proportion of women in the research group, the positive effect of the $lnnpc_i$ and $lncp_i$ variables on the quality of the patent is even greater.

3. Elimination of minus observations in the $lnnpc_i$ and $lncp_i$ variables and the estimation of the positive values in these variables. The sample is reduced to 151 observations. The results are shown in *Table 5B*. The results are similar to those of the original model except in the case of the variable $lnnpc_i$.

Table 5. Robustness of the model

TABLE 5						
Table 5A Number of obs: 489 Non zero obs: 262 Zero obs: 227				Table 5B Number of obs: 151 Non zero obs: 76 Zero obs: 75		
variables	ZINB(IV)	ZINB(V)	ZINB(VI)	variables	ZINB(VII)	ZINB(VIII)
1	2	3	4	5	6	7
CONST	1.312*** (0.235)	1.312*** (0.236)	1.345*** (0.239)	CONST	1.92*** (0.421)	2.018*** (0.421)
IPC	0.075 (0.151)	0.065 (0.15)	0.101 (0.150)	IPC	0.163 (0.267)	0.137 (0.565)
LNNPC	0.091*** (0.027)	0.084 (0.034)		LNNPC	-0.026 (0.095)	-0.030 (0.098)
LNCP	0.086** (0.037)	0.070 (0.049)		LNCP	0.032** (0.23)	0.018** (0.23)
LNFSIZE	0.467*** (0.128)	0.461*** (0.13)	0.481*** (0.135)	LNFSIZE	0.558*** (0.275)	0.546*** (0.271)
PRWOM	0.444** (0.247)	0.506* (0.31)	0.681** (0.274)	GENDER	0.451** (0.262)	
COLAB	-0.032 (0.191)	-0.028 (0.192)	-0.033 (0.194)	PRWOM		1.304** (0.565)
NINV	-0.002 (0 .027)	-0.003 (0.028)	-0.015 (0.027)	COLAB	-0.083 (0.479)	-0.818 (0.472)

1	2	3	4	5	6	7
INTER3=LNNPC*PR WOM		0.025 (0.095)	0.169** (0.076)	NINV	-0.033 (0 .071)	-0.043 (0 .074)
INTER4=LNCP*PR WOM		0.075 (0.147)	0.202** (0.114)			
log likelihood	-1031.515	-1031.366	-1034.319	log likelihood	-328.330	-327.267
Vuong statistic	3.21***	3.13***	2.89***	Vuong statistic	3.31***	3.25***
Alfa (α)	0.927** (0.176)	0.927** (0.178)	0.982** (0.199)	Alfa (α)	1.084** (0.358)	1.11** (0.39)
***1% level significant **5% level significant *10% level significant				***1% level significant **5% level significant *10% level significant		

Conclusions

In this work we have answered the question proposed.

Is the quality of the patent higher when the inventor team includes both male and female inventors?

Based on the analysis carried out during our work, we have concluded that the quality of the patent is higher when there are both, male and female presence in the team of inventors. This result might be the consequence of the different way in which both genders develop their respective tasks in the team. Those differences produce interactive positive synergies on the invention development. Moreover, a higher proportion of women in research teams would, probably, increase the quality of the patent. Therefore, according to the results obtained, gender is a determining factor as regards the quality of the patent.

As in most regions, there is scarce female representation among the authors of Andalusian University and Research Group patents.

According to the results obtained in this work and, given the capacity of human resources to generate wealth in a specific area, it is necessary to implement policies to promote a greater contribution and implication of women in the field of science and technology. The diversification of their participation in the workforce where their representation is at a minimum, such as engineering and technology, as well as the incorporation of gender sensitive aspects into research, product development and technology, are factors which contribute to the success of economic and competitive development in a globalised economy (Schraudner & Bessing, 2006). In the same way, Matthies (2006) states that uniformity leads to the inefficient use of human resources; hides creativity, and reduces innovation and economic development.

In order to promote research and create policies that will help to reduce the difference between the participation of men and women, it is important to increase productivity and foster the innovative capacity of a society.

Other variables which have emerged as significant and positive as regards the quality of the patent, as already contrasted in numerous prior studies, are the size of the patent family, the number of patents cited and the number of scientific citations. When there are a higher proportion of women in the research group, the positive effect of the citing patents and non-patents citations variables on the quality of the patent is even greater.

Those which do not appear to be relevant to explain the quality of Andalusian patents are the collaboration between different research centres, the size of the research team (measured by the number of inventors) and the number of assignments in the International Patent Classification.

With a view to future research we would like to underline our interest in extending the study to all of the Spanish regions, in order to establish comparisons.

A limitation of the present study is the possibility of analysing gender influence just in mixed patents and comparing them with patents developed by men. Unfortunately it has not been possible to compare patents invented just by men with the ones invented by women. This fact is due to the scarce existence of patents with a female ownership.

Acknowledgments

Our thanks to the lecturers Ph.D. Daniel Coronado Guerrero and Ph.D. Manuel Acosta Seró, without whose collaboration and support it would have been impossible to write this article.

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