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THE EFFECTS OF UNIVERSITY-LEVEL POLICIES ON WOMEN'S PARTICIPATION IN ACADEMIC PATENTING IN ITALY

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Abstract

A growing stream of the academic literature has investigated the factors that hamper the participation of women researchers in patenting and commercialization activities; however, limited research has examined the policies that address these forms of the gender gap. In this paper, we explore whether the ownership arrangements of university patents and the presence of university-level support measures such as technology transfer offices (TTOs) and linkages with science and technology parks are positively associated with women's involvement in academic patenting. We test our hypotheses on a sample of 2538 academic patents by Italian inventors in the period 1996-2007. The results of our analyses highlight a positive role of university policies in addressing the gender gap in technology transfer activities.

INTRODUCTION

Technological progress is a key driver of economic development and it depends upon the full participation of the scientific workforce (Hunt et al., 2013). As underscored by several scholars, however, gender disparities in the exploitation of human resources for innovation exist. This situation is generally known as *gender gap* and it occurs whenever women's involvement in the commercialization of science and technology is limited in respect to the male counterpart (Melo-Martin, 2013). This means that women scientists are less likely to disclose inventions, to patent, and to engage in entrepreneurial activities, as confirmed by the rapidly growing literature on gender gap in science, entrepreneurship and innovation (Ding et al., 2006; Ding et al., 2012; Giuri et al., 2007; Frietsch et al., 2009; Stephan & El-Ganainy, 2007; Sugimoto et al., 2015).

Starting from the premise that women represent a considerable unexploited source of entrepreneurship and innovation, equal participation in the production and diffusion of scientific knowledge has emerged as a major political, economic, and social issue and calls for additional research to explicitly address gender dynamics. As underscored by Ranga and Etzkowitz (2010: 9), the recent attempts to promote scientific excellence and innovation "can no longer ignore the gender aspects of research organizations, managers, programs, policies and outcomes".

An area in which the need to sustain a more inclusive participation of the whole scientific workforce is particularly pronounced is the academic sector (Ding et al., 2006). In this context, a series of legislative reforms, starting from the Bayh-Dole Act in the United States, and organizational infrastructures, like the creation of Technology Transfer Offices (TTOs) and science parks, have been implemented around the world to sustain academic technology transfer and entrepreneurship. The underlying reasoning is that Third Mission activities of universities have the potential to enhance economic growth, address societal challenges and generate financial rewards for scientists and their institutions and, therefore, it has to be formally supported.

As far as the gender gap in academia, there is a growing stream of academic literature that has investigated the factors that hamper the participation of women in academic patenting and commercialization activities (Ding et al., 2006, 2012; Hunt, Garant, Herman, & Munroe, 2012; Meng, 2016; Murray & Graham, 2007; Tartari & Salter, 2015; Whittington & Smith-Doerr, 2005, 2008). Most of these factors make women scientists less productive and less involved in commercial activities than male scientists because they experience fewer opportunities than men throughout the course of their careers (Sonnert & Holton, 1996). According to this literature, the fewer opportunities are due to several determinants, including a hostile work environment, disproportionate domestic responsibilities, and a social capital deficit (GuMeng, 2016; Stephan, P.E. & El-Ganainy, A. 2007). However, to our knowledge, the extant literature has missed to investigate whether and how the presence of a strong and well defined institutional support for technology transfer activities within the university could also help addressing the gender issue in academia, in particular for what concern women's participation in academic patenting.

In order to address this issue, our study exploits a sample of 2538 patents produced by Italian academic inventors in the period 1996-2007 to explore the effect of (i) universities' policies concerning patent ownership and (ii) dedicated structures, both internal and external to universities, on the creation of a favorable environment for women scientists, able to foster their broader participation in patenting activities. More precisely, we address two main research questions. We first investigate whether the ownership arrangements of university patents are associated with women's participation in patenting, distinguishing between university-owned and university-invented academic patents (Geuna & Nesta 2006; Lissoni, 2012; Lissoni, et al., 2013; Giuri et al., 2013). We hypothesize a positive effect of university ownership on the likelihood of women academics engaging in patenting activities. In addition, we investigate the role of university TTOs and science and technology parks (in which universities participate) as bridging institutions in support of women researchers in patenting. We argue that women researchers will be more "responsive" than their male counterparts to the presence of TTOs and science parks because such supportive structures may provide advice, industry contacts, encouragement and visibility to women scientists, thus addressing a set of barriers that they can experience in traditionally male-dominated working environments (Murray & Graham, 2007; Roos & Gatta, 2009; Rosser, 2009; Stephan & El-Ganainy, 2007).

We contribute to the extant literature in at least two different ways: first, we provide an original improvement to the research on gender differences in innovation and entrepreneurship by focusing on the role of active policies that can be implemented to overcome the gender gap in the specific area of technology transfer. Second, we contribute to the growing literature on legislative changes that govern university intellectual property right (IPR) ownership (Geuna & Rossi, 2011; Grimaldi et al., 2011). In this regard, to date, the existing literature has examined: legislative changes that govern university IPR ownership in different countries (Mowery & Ziedonis, 2002); the distribution of academic scientists' patenting activity in various countries (Baldini et al., 2006; Lissoni et al., 2007); and the factors that might explain the assignment of academic patents to universities rather than to corporations or other applicants (Markman et al., 2008; Thursby et al., 2009). However, empirical evidence about the consequences of university IPR ownership arrangements on the broader participation of women faculty in technology transfer activities remains scant.

The rest of the paper is organized as follows. We first present a review of the relevant literature on gender differences in patenting and technology transfer. Then, we describe the research design, including the context of the study, the sources of data, the sample and the methodological approach. We present the results of the regression analyses, and in conclusion, we discuss the policy implications of our findings.

THEORETICAL BACKGROUND

The gender gap in science and technology transfer

The study of the gender gap has attracted the interest of scholars from different disciplines. In the specific case of universities, although the number of women academics has grown significantly in recent decades and positive advancements have been registered in terms of individual rank or scientific productivity, the involvement of women researchers in patenting and other forms of technology transfer remains quite limited (Murray & Graham, 2007; Rosa & Dawson, 2006; Thursby & Thursby, 2005; Whittington & Smith-Doerr, 2005; Sugimoto et al., 2015). The existing studies show that women faculty members engage in patenting activities at a decreased rate compared to their male counterparts (Morgan et al., 2001; Whittington & Smith-Doerr, 2005, 2008; Whittington, 2007) and are less frequently involved in scientific advisory boards and in new ventures' founding teams (Ding, et al., 2006, 2012; Stuart & Ding, 2006; Murray & Graham, 2007). Many studies have tried to identify the factors that hamper women's participation in scientific and technological activities. Generally speaking, most of the drivers seem to converge on the so-called gender gap "deficit model" (Sonnert & Holton, 1996). This model argues that women scientists are less productive and less involved in technology transfer and commercial activities than male scientists because they have fewer opportunities than men throughout the course of their careers and there are legal, political, social and organizational structural obstacles that prevent them from attaining the level of career success that male scientists are more likely to achieve (Corley & Gaughan, 2005; Long, 2001). An additional obstacle is represented by the greater burden of domestic responsibilities for women (Jacobs et al., 2004). There is evidence that women academics with children spend more hours per week than their male colleagues (with children) on childcare and fewer hours on their professional responsibilities (Mason & Goulden, 2004), especially when married with another academic (Ferber & Loeb, 1997). As consequence of such barriers is that women researchers might have less rich and diverse social capital and fewer bridging ties outside their local work contexts than do their male colleagues (Etzkowitz et al., 2000). Thus, women are likely to be more peripheral to situations in which resources, knowledge and reputation are exchanged and developed (Etzkowitz et al., 2000). Women in general manage fewer resources and are exposed to fewer opportunities for career advancement (Murray & Graham, 2007).

When we refer to studies specifically focused on women involvement in technology transfer activities, similar results are found. One of the most cited factors is represented by the limited access to different resources, e.g., financial, human, and social capital. (Mosey & Wright, 2008; Rosa & Dawson, 2006; Stephan & El-Ganainy, 2007). Ding et al. (2006), for instance, show that one of the major hurdles for women academics in relation to their engagement in technology transfer is the lack of exposure to the commercial sector. Additional explanations highlight a distinction between the factors that are related to the social construction of gender and the stereotypes that are associated to traditional gender roles, which assign more household chores to women (Etzkowitz et al., 2000) and lead to the conflict between family life and work (Shaw & Cassell, 2007). These factors may have an impact on academic women's decisions to engage in "extra" activities, in addition to teaching and research, such as those related to technology transfer. Other arguments rely on gender profiles that present women as having greater risk aversion, lower interest in money and financial transactions, and/or different attitudes toward competition (Niederle & Vesterlund, 2005; Stephan & El-Ganainy, 2007). The previous research has also found that women academics tend to experience less mentoring and collaboration opportunities during their scientific careers (Long & McGinnis, 1985), which, coupled with their 'argued' higher awareness of and sensitivity to the presence of organizational constraints (Fox & Ferri, 1992), largely contributes to their lower involvement in a wide range of job-related activities.

The role of university-level policies in addressing the gender gap

The commercialization of research has become a priority for many research organizations and universities. In order to foster a structural transformation to address the growing interest of governments in demanding universities to be more proactive in technology transfer (Villani et al., 2016), several universities in many parts of the world have started to invest in the creation of internal mechanisms (organizational procedures, incentives, regulations) and structures aimed at supporting technology transfer in its different forms (Baldini et al., 2006; Geuna & Rossi, 2011). These university-level mechanisms and policies - such as TTOs (Louis et al., 2001; Thursby et al., 2001), IPR regulations (Baldini et al., 2007; Giuri et al., 2013; Lissoni et al., 2013), incubators (Mustar & Wright, 2010), proof of concept programs and university seed funds (Bradley et al., 2013; Munari et al., 2018) - have contributed significantly to the professionalization of activities that encourage the exploitation of research results in various forms (Meyer, 2003; Siegel et al., 2003).

As far as legislative reforms on IPRs, these have been implemented to strengthen the assignment of patent ownership rights to universities and set up adequate incentives for universities to develop technology transfer capabilities and invest in patenting and commercialization structures (Geuna & Rossi, 2011; Grimaldi et al., 2011). Furthermore, through the creation of TTOs, universities can mitigate market inefficiencies, which arise due to the high information asymmetries and risks characterizing the commercialization of academic inventions (Bozeman, 2000; O'shea et al., 2005). In addition to being important signaling mechanisms for external stakeholders and investors (Baldini et al., 2014), such internal policies and mechanisms are designed with the goal of addressing the needs of internal actors, i.e., academic inventors, by providing professional support and assistance in the commercialization of their research results (Debackere & Veugelers, 2005).

As suggested by the findings of the qualitative studies on the gender gap in academia (e.g., Ding et al., 2006; 2012; Murray & Graham, 2007), these internal university policies and structures can also be more instrumental to a particular group of academic inventors, i.e., women scientists. Since university-level support mechanisms provide explicit and transparent information on the commercialization process, offering additional support and guidance, and facilitating access to financial resources and industry networks, they may be able to address some of the above-mentioned hurdles for women academics in relation to their commercial engagement. In the qualitative section of the study by Ding et al. (2006), based on a sample of 4227 life scientists in the United States, many women scientists reported a particular appreciation for the TTO support in particular for what concerns industry contacts, advice, and encouragement to develop the commercial potential of their research results. A parallel study based on interviews with life science faculty at a high-status university in the United States showed the decline of gender differences among junior faculty members prompted by the presence of institutional support, such as that provided by TTOs (Murray & Graham, 2007). However, with the partial exception of the work by Tartari & Salter (2015), there has been no previous attempt, to our knowledge, to systematically assess the influence exerted by university IPR policies and university-level support mechanisms on women's involvement in technology transfer.

HYPOTHESES

The role of university ownership of patents on academic women's patenting

University ownership of patents represents a fundamental prerequisite to allow universities to strengthen technology transfer procedures. An important distinction, in this regard, is the one between university-owned and university-invented academic patents (Geuna & Nesta 2006; Lissoni, 2012; Lissoni, et al., 2013; Giuri et al., 2013). The former case relates to situations in which patented inventions generated by academic inventors are owned by their university of affiliation. The latter case includes situations in which the ownership of patents generated by academic inventors remains with the inventors – or with a third party with which they collaborate (e.g. a company) – and it is not given to the affiliated university.

In the case of university-owned patents, universities should be more motivated toward the creation of a set of formal procedures and infrastructures able to centralize and optimize technology transfer activities. Conversely, university-invented patents are more likely to be generated by informal collaborations, directly established between researchers and external corporations. The extant literature has analyzed determinants and consequences related to legislative changes that govern university IPR ownership (Baldini et al., 2006; Crespi et al., 2010; Giuri et al., 2013; Lissoni et al., 2007; Lissoni et al., 2013; Markman et al., 2008; Mowery & Ziedonis, 2002; Thursby et al., 2009). However, to date, no direct attempt has been made to assess whether women academic inventors' involvement in university-owned patents differs from their involvement in university-invented patents.

Because women faculty tend to have fewer industry contacts and networks, as highlighted in previous research (Ding et al., 2006; Murray & Graham, 2007; Tartari & Salter, 2015; Meng, 2016), it is likely that they tend to be less involved in university-invented patents and, at the same time, benefit more from the support of formal infrastructures and policies, available in case of university-owned patents. Indeed, women's poorer relations with industry could be compensated, for instance, by the proactive role of TTOs, which may encourage women scientists to patent their inventions, and eventually support them downstream in the identification of potential commercialization partners.

In addition, the existing evidence shows that the participation and contribution of women in the patenting arena tend to increase with the number of co-inventors cited on the patent team, which could indicate a greater inclination on the part of women to co-operate and to participate in large research groups (Mauleon & Bordons, 2009; Naldi et al., 2004). According to the results of a large-scale study carried out in six major European countries, universities and research institutions tend to have a larger share of collaborative patents compared to firms (Giuri et al., 2007). This difference may be due to the diverse nature and missions of these two types of organizations. On the one hand, firms by definition are more competition-oriented and tend to internalize the inventive process as much as possible to avoid leakages of proprietary information. On the other hand, due to their traditional mission of knowledge diffusion, universities should, in principle, be more open to collaborative research efforts. This will ultimately result in a larger percentage of collaborative patented inventions being owned by the universities. Following this line of reasoning, university-owned patents should be associated with more collaborative inventive activity and thus enhance the involvement of women members of university research teams.

Based on the above arguments, we formulate the following hypothesis:

Hypothesis 1: University-owned patents have a higher likelihood of having at least one woman academic inventor in the patent, compared to university-invented patents.

The role of 'bridging' institutions in support of academic women's patenting

Companies are not generally able to assess the quality of inventions ex-ante and inventors may have difficulties in assessing the business value of their inventions, particularly when they arise in new technology areas (Markman et al., 2008). At the same time, as previously pointed out,

academics generally lack of important resources to properly manage and control all the phases of the patenting process. This scenario, by generating limitations in the engagement of academics in patenting, represents a fertile ground for understanding the role of TTOs and science parks as bridging organizations (Markman et al., 2005; Phan & Siegel, 2006; Siegel et al., 2003), with the potential to be instrumental in reducing the asymmetry of information between industry and science on the value of inventions.
As far as TTOs, they have been described by the extant literature as boundary-spanning units, which operate as supportive mechanisms for a smooth transition of research from academia to industry (Siegel et al., 2003), by providing technical advice, market expertise, networks and managing the commercialization processes related to the patenting, licensing and creation of start-up companies (Chugh, 2004; Feldman et al., 2002; Munari et al., 2015; O'Shea et al., 2005; Phan & Siegel, 2006; Powers & McDougall, 2005). In a similar vein, the literature has highlighted the important role that science and technology parks have in fostering technology transfer and innovation (Siegel et al., 2003; Lofsten and Lindelof, 2002). They represent ecosystems that bring together companies, universities, incubators, accelerators, start-ups and other organizations to support the commercialization of academic knowledge and, more generally, research-industry relationships (Phan et al., 2005). Science and technology parks can represent an important tool for universities to connect with the outside industrial world, bringing together all of those resources (knowledge, funding, networks) that are required for the successful valorization of research results. Thus, it is expected that the presence of these bridging units will facilitate academic involvement in knowledge transfer.

If in the reasoning we introduce gender differences, the benefits provided by institutional support are particularly relevant for women academics and they may mitigate the differences in academic engagement with industry between men and women. The connections to members of the business community and industry players, which both TTOs and science parks offer, can significantly reduce the perceived hurdles of patenting for women related to the lack of access to valuable industry connections and the difficulties to search for potential buyers of the invented technology (Ding et al. 2006; Stuart & Ding, 2006). A supportive institutional environment may also address the time costs related to technology transfer activities. As women are called to manage, in addition to the professional life of teaching and research, also domestic responsibilities (Jacobs et al., 2004), the time costs related to their engagement in extra activities like technology transfer are particularly high. However, the presence of supportive units may accelerate the technology transfer process, mitigating these costs and allowing women to effectively balance multiple elements, such as family, teaching, research, and commercialization. The positive effect that the presence of technology transfer support institutions may have on women academics' involvement in knowledge transfer has been documented by the interviews reported in the study by Murray and Graham (2007).

For these reasons, we assert the following:

Hypothesis 2a: Women's patenting is more likely to occur in universities with a TTO.

Hypothesis 2b: Women's patenting is more likely to occur in universities with established connections to science parks.

EMPIRICAL CONTEXT

We focused our analyses on the case of academic patents that are generated in Italy. Italy represents an optimal setting to address our research questions for several reasons. First, the gender gap in science and engineering has been historically pronounced in Italy. The statistics of the European Commission show that the share of women among scientists and engineers in Italy is at a much lower level compared to the average values of the EU-27 countries (European Commission, 2013). According to such data, there is also a clear pattern of female under-representation among university researchers in Italy (in this case, the Italian average proportion of female researchers is aligned to the average values of the EU-27 countries).

Second, the university system in Italy has been characterized by a set of important reforms, starting in the late 1990s, that have had profound implications on the rate of patenting activities by academic researchers. The most important reform occurred in 1996, when a new accounting-principle regulation was introduced (D.M. 9th February 1996), so autonomy and self-administration could be effectively implemented by Italian universities (Baldini et al., 2010; Lissoni et al., 2013). The new regime significantly changed the nature of Italian universities, which then had, for the first time, the possibility of planning and controlling their own budget, defining priorities for financing research and managing staff, and retaining the surplus that is generated by their activities. Such reform also led to a set of organizational changes among Italian universities in the field of technology transfer, which was centered on the adoption of internal policies and dedicated offices (TTOs) that were aimed at the fostering of technology transfer and the commercialization of academic inventions. As a result of such changes, the number of university-owned patent applications significantly increased after the publication of the 1996 Law (Baldini et al., 2010).

METHODOLOGY

Sample and data sources

Our data come from several sources. The initial source is the APE-INV (Academic Patenting in Europe) dataset, which consists of patent applications that are filed at the European Patent Office (EPO), with priority dates between 1996 and 2007 and with at least one inventor with an Italian address. The dataset is a result of a research project aimed at identifying university-owned and university-invented patents in Italy and other European countries. In this way, it constitutes a perfect base upon which to build reliable estimates of academic patenting in Italy throughout the 10-year period[1] (see Lissoni et al., 2013 for a more detailed description of the dataset).

[1] In the APE-INV dataset, Italian academic patents were identified through a process of name matching between disambiguated inventors of Italian EPO patents and academic personnel, and the latter's names were made available in 2000, 2005 and 2009 by the Italian Ministry of Education. This procedure produced "professor-patent" pairs that were

To obtain additional information on the patents and the names of the inventors on the patent team, we matched the APE-INV dataset with the PATSTAT dataset (the EPO's Worldwide Statistical Patent Database) at the patent-level. In addition, because the PATSTAT does not provide the gender of the inventors, our next step was name disambiguation and the assignment of gender based on the inventor's first name. More precisely, to identify whether a female scientist was a part of the patent team, we manually checked the first names of all of the inventors listed in the patents included in our initial dataset of academic patents from Italy. We thus identified whether female first names where included among the inventors, and we constructed the gender variables based on that finding. The dubious cases were double checked by searching the name of the inventor in question in online directories, which could help objectively establish whether the inventor was a male or a female.

To add information at the level of universities and respective local areas we also used the TASTE dataset (Bolzani et al., 2014)[2]. We also used both secondary and primary sources to collect additional information - which were not available in our datasets - at the level of universities, like links with university-related institutions such as TTOs, incubators, science and technology parks, and at the regional level. We identified the dates of introduction of the TTOs in the universities included in our sample by using the information provided by Baldini et al. (2006). We also checked the websites of Italian universities and TTOs to check this information. We also contacted by email the technology transfer offices of the universities when information was not available. To

obtained by attributing to each professor the patents that had been signed by the matched inventors. For a more detailed description of the dataset, the disambiguation process and matching algorithm, see Lissoni et al. (2013).

[2] The TASTE dataset systematically collects information on the population of 95 Italian universities, including the characteristics, in terms of economic development and innovation levels, of the 20 Italian regions in which they are located (Bolzani et al, 2014).

determine the concerns of the participation of a university in a science and technology park, we used the information provided by the ANVUR (National Agency for the Evaluation of the University and Public Research System)[3]. After matching and cleaning the data, our sample included information on 2538 Italian academic patents filed between 1996 and 2007.

For the purposes of the present research we rely on the definition of "academic patent," which is most commonly used in the existing literature with regard to patents that were signed by at least one academic scientist while working at his or her university, regardless of whether the patents are owned by the university, a public research organization (PRO), the scientist, a business company or any other organization, either exclusively or jointly with other assignees (Dornbusch et al., 2013; Lissoni, 2012; Lissoni et al., 2013). By applying this definition, we find that our sample contains 2034 university-invented academic patents, whereas 504 academic patents from the sample are university-owned (20% of the sample). In addition, 21% of the patents included in our sample have at least one female academic inventor.

One of the advantages of our sample is that it is geographically confined, which allows us to control for the differences that might arise from the contextual specificities (e.g., national policies and other specific public measures; socio-cultural and economic differences).

Variables

Dependent variable

[3] Since 2014, ANVUR began a systematic data collection effort on third mission activities that were undertaken by Italian universities, based on a mandate of the Italian Ministry for University and Research. Such information is publicly available on the ANVUR website (under the "SUA-RD Terza Missione" section). This section includes information about the participation of the university in a science and technology park, and the year of activation of such participation.

We estimate the likelihood of having at least one female academic inventor among the inventors in the patent team. This measurement of women's participation is common in the literature on the gender gap in patenting activities (for instance, see Naldi et al. 2004; Mauleon & Bordons, 2009). We thus introduce a dummy variable that is equal to 1 if at least one inventor on the patent team is a university-affiliated female scientist and is equal to 0 if there are no women inventors on the patent team (FEMALE ACADEMIC INVENTOR). In addition to this dummy variable, which does not precisely depict the weight of female academics within the patent team, we use an alternative dependent variable that measures the share of university-affiliated female inventors in the patent team (SHARE OF FEMALE ACADEMIC INVENTORS). This variable, representing a measure of intensity, is assessed as the number of female academics in the patent team divided by the total number of academics in the patent team.

Explanatory variables

The main explanatory variables in our estimations are related to the university ownership status of the patent and the presence of supporting institutions.

With regard to university patent ownership, we construct a dummy variable (UNIVERSITY PATENT OWNERSHIP) that is equal to 1 if the patent is either owned or co-owned by the university (that is, there is at least one university that is listed as an applicant of the patent) and is equal to 0 if there is at least one university inventor in the patent team but the patent is not owned or co-owned by the university (for university-invented patents).

The presence of a TTO is measured by a dummy variable that is equal to 1 if a TTO existed within the university of the academic inventor at the priority date of the patent[4] and is equal to 0 in the

[4]If, for a given patent, there are academic inventors from more than one university, we consider the university with the oldest date of TTO creation to build this variable.

opposite case. Because we take the inventor's university of affiliation as the reference university to construct this variable, in cases of inventors who are affiliated with different universities at the time of patenting, we acknowledge the presence of a TTO if at least one of these universities had a TTO in place at the priority date of the patent.

At the university level, we also use two alternative variables, to measure other specific actions supporting technology transfer. We use the dummy variable INCUBATOR, which is equal to 1 if the university of affiliation of the inventors had an incubator at the time of the patent and is equal to 0 otherwise. We also use the dummy variable UNIVERSITY PATENT REGULATION if the university had a patent regulation at the priority date of the patent.

Finally, we use the dummy variable SCIENCE PARK, which measures the presence of a bridge with external institutions, particularly through the equity participation of the university in a science and technology park.

Control variables

We include a set of controls at the level of the patent, the inventors, the university, and the geographical location of the university.

At the patent level, we include dummy variables for the priority year of the patent (from 1996 to 2007) to account for unobserved effects due to possible different social, cultural and institutional contexts that affect women's participation in inventive activities in universities. We also control for the technological class (WIPO classification) of the patent because previous studies have shown that women scientists tend to be underrepresented in certain research and technology fields, such as engineering and physics (e.g., Hunt et al., 2012)[5].

[5] We consider the 8 main sections of IPC patent classification scheme to construct such dummy variables: Human necessities; Performing operations, Transporting; Chemistry, Metallurgy; Textiles, Paper; Fixed

At the individual level, we account for the experience of the inventors in the patent team. We, thus, introduce the variable AVERAGE TEAM AGE, which measures the average age of the academic inventors in the patent team. We also control for academic seniority to capture possible gender differences in the involvement on patenting activity across different career stages. In particular, we use information on the presence of a more experienced academic member on the patent team (full professor) to consider the potential effect of academic status on women's engagement in patenting activities. We thus create three dummy variables (FULL PROFESSOR, ASSOCIATE PROFESSOR and ASSISTANT PROFESSOR), which are equal to 1 if there is at least one full, associate or assistant professor on the patent team, respectively, and 0 otherwise.

To account for the characteristics of the university, we measure the size of the university. As argued in the literature, larger universities tend to be more active in patenting due to larger R&D and patenting budgets, and they are more likely to employ "star" scientists who are more productive and better connected with the external environment (Rasmussen, Moen, & Gulbrandsen, 2006). To control for university size, we adopt the following classification of the Italian universities based on the number of students (as of year 2009): Large - over 20.000 students; Medium - 10.000-20.000 students; and Small - fewer than 10.000 students. In line with this classification, we introduce dummy variables for each of the categories (LARGE UNIVERSITY, MEDIUM UNIVERSITY, SMALL UNIVERSITY), with SMALL UNIVERSITY being the baseline case in our estimations. Of the 58 universities represented in our sample, 34 belong to the category "Large", 12 to the category "Medium" and the remaining 12 to the category "Small".

constructions; Mechanical engineering; Physics; Electricity. In our estimations, Human necessities is the baseline dummy.

In our estimations, we also cluster observations by a university identification code to group patents that are invented in the same organization.

Finally, we control for a few characteristics of the geographical area in which a university is located. We control for the share of women's employment (REGIONAL FEMALE EMPLOYMENT) in the region (source of data ISTAT, Italian National Statistical Office), as in work contexts with a stronger presence of women gender differences may be reduced (Tartari and Salter, 2015). We also take into consideration the level of investments in venture capital (REGIONAL VC INVESTMENTS) in the region (source: TASTE dataset[2]) assessed as the logarithm of the number of VC investments in the region. Indeed, VC is generally associated with a substantial increase in patenting (Mann and Sager, 2007), which may be reflected also in an increase in women patenting. Finally, Northern regions in Italy have been traditionally more endowed with resources compared to the central and southern regions and patenting activity is much more frequent in this area (Baldini et al. 2006: 8). So, in front of a higher critical mass of patents, we might expect women scientists from universities situated in the north of the country to be better placed to engage more extensively in patenting and commercialization activities. The dummy variables to control for university region (NORTH EASTERN ITALY, NORTH WESTERN ITALY, CENTRAL ITALY, SOUTHERN ITALY, ISLANDS) were constructed on the basis of a conventional classification. The CENTRAL ITALY area is our baseline. Table 1 presents the descriptive statistics of all our variables.

Insert Tables 1 about here

RESULTS

Descriptive statistics

We first discuss the temporal trends in the evolution of Italian academic patenting by type of ownership and by female participation in such academic patents.

Table 2 illustrates the change over time of the number of university patents (column A) and the share of university-invented and university-owned patents (columns B and C). We also show the number of patents with at least one female inventor, the number of patents with at least one female (columns D and E) and the number of university-invented and university-owned patents with at least one female academic inventor (columns F and G).

Insert Table 2 about here

As Table 2 shows, university-invented patents considerably prevail over university-owned patents, although there has been a marked increasing trend in Italian university ownership over the years. This is consistent with the existing evidence of a growing control, exerted by universities on IPs, over their scientists' inventions as a result of their increased autonomy beginning in the second half of the 1990s (e.g., Lissoni et al., 2013). In particular, with the advent of such autonomy, several Italian universities introduced explicit IP regulations starting in 1995 and, by 2008, over 70% of all Italian universities had adopted one (Baldini et al., 2010; Lissoni et al., 2013). However, in spite of the important changes in the autonomy and IP regulation at the university level, the share of academic patents with university ownership still remains significantly lower compared to the share of university-invented academic patents[6].

[6] Furthermore, if we focus on the distribution of university-owned patents among universities with and without TTO, we find that, on average, the proportion of university-owned patents coming from universities without TTOs is lower in respect to universities without TTOs (32.3% versus 67.7%). This scenario is particularly pronounced from 2005, with over 93% of university-owned patents coming from universities with a TTO. This result supports the idea that

For the purposes of our research, we thus specifically consider the distribution of academic patents with female participation. Because not all women on a patent team are from academia (i.e., some of them are not university-affiliated at the priority year of the patent), we control for this by distinguishing between the patents with at least one university-affiliated (academic)[7] female inventor. We can first observe that the number of academic patents with at least one female inventor and with at least one female academic inventor grow continuously over the years.

We further explore whether there are differences in terms of the type of ownership, which is in line with one of our hypotheses regarding the effect of institutional ownership on the share of female participation. Columns F and G of Table 2 confirms that the number of university patents with female academic inventors increases both for university-invented and university-owned patents. To better investigate the participation of women academics in university patents, we report on Figure 2 the annual share of: university patents with female inventors, university patents with female academic inventors, university-invented patents with female academic inventors and university-owned patents with female academic inventors.

We first observe that the share of women patenting grows over time in all categories, with the exception of university-owned patents in the first years of the period.

Second, the share by year of academic patents that include at least one female academic inventor reveals the higher participation of female academics in university-owned patents compared to university-invented patents over the entire period.

The growth in the share of university-owned academic patents with at least one university-affiliated female has been uneven, showing a drastic decline in the year 1999 and resuming growth in the

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TTOs act as facilitator for the development of patents owned by the mother universities. We thank an anonymous reviewer for suggesting us to point out this distinction.

[7]We use the term “university-affiliated” and “academic” interchangeably to say that an inventor comes from academia.

years 2000 and 2001. However, after 2001, the share of university-owned patents with female participation decreased again, whereas the percentage of university-invented patents continued to grow. This pattern could be explained by the fact that the introduction of a "professor's privilege" in Italy in 2001 (the Law 383/2001) may have had temporary adverse effects on the general amount of the academic university-owned patents due to a shift from the institutional ownership and the adjustment of the whole system. However, the previous figures do not exhibit such a vivid decline in the year 2002 for university-owned patents in general. The share of university-invented patents with female academic participation demonstrated, on the contrary, a growing trend up to 2007. This situation may point to a higher propensity of female academic inventors to assign the IP rights on the patented inventions to the industry in the period directly after the introduction of the "professor's privilege" in Italy or to collaborate more with industry inventors when the IP rights for the joint research results would go to the industry. As the Figure further shows, the share of university-owned patents with female participation started to grow again after the year 2004, when the new IP law (approved 23rd December 2004) reversed Law 383 for inventions that are made by public employees and arise from research that is financed at least partially by the private sector or stem from specific research projects that are funded by public organizations other than the inventors' organization(s), by granting IPRs on such inventions to the public employers rather than to employees (Baldini et al., 2006).

In general, as the descriptive statistics show, there has been a growing trend in the participation by Italian female academic inventors in patenting. The results also demonstrate that the number of university-owned patents with female participation has been steadily increasing over the years, exceeding the share of patents with non-institutional ownership in the last year of our observation.

Estimations and results

Table 3 presents the correlation among the regressors that are used in our analyses. In this table, we show that the three variables TTO, INCUBATOR and UNIVERSITY PATENT REGULATION are highly and significantly correlated. This correlation indicates that universities with a TTO are more likely to have an incubator for new ventures as well as specific regulations for the encouragement and the ruling of patenting activities of academic scientists. For this reason, we alternatively include these variables in our regressions. Additionally, through factor analysis, we create a single variable, UNIVERSITY TT ENGAGEMENT, to summarize the overall engagement of universities in technology transfer activities through the presence of a TTO, the specific support for the exploitation of business opportunities through the incubation of new companies, and the patenting of the results of scientific research. The factor analysis, which was carried out with the principal-component method, significantly supports the creation of a single factor, with high factor loadings for the three variables. We also find that the average age of the patent inventors in a team is substantially correlated with the academic seniority of the inventors. For this reason, we control for age and academic seniority of inventors in separate regressions.

To estimate our hypotheses, we run probit estimations of the probability of having at least one female academic inventor on a patent team, i.e., FEMALE ACADEMIC INVENTOR.

Models 1-3 of Table 4 display the marginal effects of the estimations, by progressively add our three main explanatory variables (UNIVERSITY PATENT OWNERSHIP, TTO and SCIENCE PARK) in the probit estimations. According to our hypotheses, we expect the university ownership to increase the likelihood of having a female academic inventor compared to other types of ownership (e.g., by a company or an individual). Moreover, we have hypothesized that the presence of university-level mechanisms in support of patenting and technology transfer – such as the presence of a technology transfer office and formal linkages with science and technology parks –

will also increase the probability of patents with at least one female academic on the inventors' team. The results below support these hypotheses.

Specifically, the results of the regressions show that university-owned patents demonstrate a higher probability of having at least one female academic inventor in a patent team compared to university-invented patents. Indeed, the coefficient of the dummy variable university-owned is positive (equal to 0.153) and statistically significant (at the 1% level) in Model 1, supporting Hypothesis 1. Further, our second hypotheses are confirmed: in Model 2 the presence of a TTO has a positive (equal to 0.076) and statistically significant (at the 1% level) effect on the probability of having female academic presence on a patent team, supporting Hypothesis 2a. A similar effect is shown for the existence of connection with science parks (the coefficient is equal to 0.069 and statistically significant at the 1% level) in Model 3, as suggested by our Hypothesis 2b. These results show that, for university-owned patent and in universities with a TTO and connections to science parks, the probability of women's patenting increases of 15.3%, 7.6% and 6.9% respectively. The effect of these three explanatory variables also remains significant in the full model (Model 3), with an increase in women's patenting of 13.6% in case of institutional prestige, 7.2% for the presence of a TTO and 6.9% for links with science parks. This indicates an instrumental role of the university's structured involvement in patenting in general, and of the TTO in particular as the support structure that may create additional value for female researchers by acting as a broker between individual inventors and internal and external stakeholders. It is notable that the stepwise inclusion of TTO and SCIENCE PARK produces small reductions in the size of the marginal effects, which indicates that these variables denote an autonomous contribution to the participation of female academics in patenting activities.

We, then, add at the full model the priority year of the patent among the controls in order to test the potential effect of temporal factors, due to an increasing attention by universities toward technology transfer over time, which results in an increase of patenting activity in general and of female involvement in patenting, more specifically. The results are shown in Model 4. The significant association of TTO to female patenting remains positive (equal to 0.022), but becomes non-significant, while the marginal effects of UNIVERSITY PATENT OWNERSHIP and SCIENCE PARK remain sizeable (equal to 0.126 and 0.050 respectively) and significant (at the 1% level). This result is in line with the increasing presence of TTOs over time in universities, which produces an important correlation between priority years and the presence of TTOs. Indeed, in our sample, the average of the TTO variables steadily increases from 0 in 1996, to 0.13 in 2000, 0.50 in 2004 to 0.94 in 2007. Therefore, when we control for the time of the patent, we capture not only the contextual and institutional changes that may affect the participation of women in patenting but also the increasing presence of TTOs in universities.

The effect of some of the control variables is also significant: the level of venture capital investments and the share of women's employment by region are not related to female patenting. Other differences are taken into account by the dummies for geographical areas. Furthermore, female participation tends to be higher in younger teams (the coefficient of the variable AVERAGE TEAM AGE is -0.008 and statistically significant at the 1% level). In unreported regressions, we also find that the presence of an assistant professor on a patent team has a positive significant effect, more sizeable than the effect of the presence of an associate of full professor. As far as university-level characteristics, our results suggest that large universities are more likely to be associated with women's patenting (the coefficient of the variable LARGE UNIVERSITY ranges from 0.066 in Model 4 to 0.096 in Model 2 and it is statistically significant at the 1% level). The regressions also include the dummies for WIPO classes to account for differences in the scientific and technological fields of the patent. The marginal effects of the eight dummies for macro WIPO classes confirm that women patenting is more likely in the baseline class of Human necessities, as compared to all other classes. The marginal effects of all WIPO classes are negative as compared to the baseline dummy. With the exception of Chemistry/Metallurgy and Textile/Paper all marginal effects are highly significant. In unreported estimations, we include a finer grained WIPO classification in 34 classes. The main results remain similar, but given the smaller number of observations in each class, the level of significance of the WIPO dummies is much lower.

Insert Table 4 about here

Robustness check

We carried out a number of alternative estimations to check the robustness of our results.

First, we used the share of female academic inventors in the patent team (SHARE OF FEMALE ACADEMIC INVENTORS) as dependent variable and we employed fractional response estimators, which fit models on continuous 0-1 data. We used the fractional logit model as implemented in Wedderburn (1974) and generalized by McCullagh (1983), where a quasi-likelihood estimation is carried out using iteratively reweighted least squares. Models 5 and 6 of Table 4 exhibit the results of fractional logit estimations on the full model, with and without the control for the priority year of the patent respectively.

The results are qualitatively similar to the probit estimations, as they show a positive and significant effect of our three main explicative variables. In particular, the share of female academics in the patent team increases by 0.916 in case of institutional prestige, by 0.289 in presence of a TTO and by 0.527 when there are links with science parks.

Second, we adopted alternative measures to assess other specific actions supporting technology transfer. The results are shown in Table 5. Specifically, we alternatively included the variables

INCUBATOR, UNIVERSITY PATENT REGULATION and UNIVERSITY TT ENGAGEMENT (which summarizes the presence of a TTO, of an incubator and of patent regulation at the university) in our regressions (Models 1-3). UNIVERSITY PATENT REGULATION and UNIVERSITY TT ENGAGEMENT are positively and significantly associated with FEMALE ACADEMIC INVENTOR, which confirms our main results. The presence of patent regulation at the university increases the probability of women's patenting of 4.7% (significant at the 5% level), while if we consider the overall measure of TT activities through the UNIVERSITY TT ENGAGEMENT variable, the increase is of 3.4% (significant at the 1% level) respectively. Model 4 of Table 5 also confirms that the association to female patenting is captured by the priority year of the patent as it shows results similar to the ones of Table 4 (Model 4), where the marginal effects of UNIVERSITY PATENT OWNERSHIP and SCIENCE PARK remain sizeable (equal to 0.126 and 0.048 respectively) and significant (at the 1% and 5% level respectively).

Finally, we controlled in a smaller sample of observations if the scientific productivity of inventors affect women patenting. We randomly selected 340 patents from the total sample of patents, and for each inventor of these patents we collected data on the number of publications and citations reported in Scopus in the five years preceding the priority year of the patent. We performed the probit estimations of Tables 4 and 5 of this paper on the sample of 340 patents and in additional estimations we included alternatively the logarithm of the total number of publications and the logarithm of the total number of citations of the team of inventors in the five years preceding the patent. We find that results on the explanatory variables of this paper are coherent with the results in the total sample. We also find that scientific publications or citations have a positive effect on the dependent variables, suggesting that women patenting by academics is favored in teams with high scientific productivity and impact.

DISCUSSION AND CONCLUSIONS

In this paper, we have addressed the role of university IP policies and structures on the likelihood of the involvement of women academic researchers in patenting activity. We explored the role of university IPR ownership (comparing university-owned and university-invented patents) and the presence of university TTOs and of steady relationships of universities with science parks in the reduction of gender differences in commercialization activities. For this purpose, we tested a set of hypotheses on a sample of academic patents from Italy in the period 1996-2007. The descriptive part of our study clearly shows that there has been a growing involvement in patenting activity by Italian women academic scientists over the 10-year period of the study. In particular, there has been considerable growth in the share of university-owned patents with at least one female academic inventor on a patent team. Our regression results further highlight the positive impact of university IPR ownership on women's participation in patenting. In addition, they show that the presence of a university TTO as a dedicated unit in support of commercialization has a significant positive role in increasing women's participation in patenting activities. Moreover, they show that the participation of universities in science and technology parks is also associated to a stronger presence of women inventors in academic patents. Such policies can thus be helpful in reducing the gaps and barriers that limit the involvement of women scientists in patenting and commercialization tasks (Rosser, 2009, Rosa & Dawson, 2006).

In terms of contribution, our results are of interest and bear implications at both the scientific and at the policy levels. From a scientific standpoint, our findings contribute to the field of institutional theory by examining how and to what extent the strategic choices made by academic institutions may affect the exploitation of technology knowledge (Baldini et al., 2006; Popp Berman, 2008).

Such literature has largely documented the impact of university policies on academic engagement in technology transfer activities and on university productivity in the commercialization domain (Siegel et al., 2003). However, it has neglected the analysis of the effects that are exerted on the reduction of gender disparities. On this issue, we provide evidence that a better institutional support at the university level could facilitate women's participation in academic patenting, which is considered an important precursor of commercialization activities in general.

Therefore, our findings also provide a contribution to the growing literature on gender differences in science, technology and innovation (Ding et al., 2006; Ding et al., 2013; Meng, 2016; Sugimoto et al., 2015; Whittington & Smith-Doerr, 2005). As suggested by the previous qualitative evidence in this field (Murray & Graham, 2007), our results confirm that women scientists seem to be more responsive to the presence of support structures and policies such as TTOs and science parks because they provide a means of "hand holding" in the process of technology transfer. The positive effect that we highlight may be due to the higher value that is perceived by women scientists in relation advice and assistance in accessing the resources that are critical to define potential venues for commercial exploitation of the research, as well as in the provision of links to external stakeholders (e.g., industry, venture capitalists). Our results also confirm that the under-representation of women in science and engineering fields negatively contributes to female patenting.

At the policy level, our results are of particular relevance in situations of increasing political awareness and concerns about the barriers that lead to a gender gap in science and innovation (Frietsch et al., 2009; Technopolis, 2008). As in many countries, the focus of funding for research has been shifting from basic to applied research and innovation, and the failure to introduce effective measures and mechanisms that are aimed at addressing the gender gap in patenting will lead to reduced competitiveness and innovative growth in the long run. At the individual level, because patents have increasingly become markers of success and peer recognition in some industries, women's low percentages in patenting may significantly reduce their engagement with industries and investors, which could, in turn, further inhibit their professional advancement (Rosser, 2009). Moreover, our results highlight the important role that university TTOs can play in order to enhance the participation of women researchers in commercialization activities. TTO managers should therefore be aware of this opportunity, and encourage the activation of dedicated actions in this respect. For instance, TTOs could undertake dedicated scouting activity to systematically reach out women researchers via direct and face-to-face meetings, in order to advise them in the early steps of the valorization. In a similar way, they could activate training courses on issues related technology commercialization, so to provide women researchers the necessary skills and the opportunity to engage in this area. They could also support the participation of women scientists to innovation awards or prizes, so to generate successful stories and role models.

However, further research is needed to address some of the limitations of this paper and analyze in more detail the specific mechanisms and actions by which a university's technology transfer office may enhance the participation of women academic scientists in patenting. Future qualitative studies are thus required in order to analyze in more depth the dedicated set of actions that TTOs could undertake in this repect, in order to identify best practices and transferable lessons.

An additional important issue that should be further addressed by future research is the involvement of women academic scientists in the actual commercialization of patented inventions, for instance through licensing or spin-off formation. The generation of new patents is indeed only the first step of a long, and often complex, path to bring a new invention into the market. Focusing on patents is extremely important, since it often represents a precondition to establish licensing agreements or create new spinoff at later stages (especially in some sectors, such as the life sciences). Nevertheless, future research should devote more attention in assessing the impact of university policies for technology transfer on women involvement in a broader set of technology transfer activities, including licensing, spinoff formation, research collaborations and consulting.

Finally, we focused our analysis on the experience of a single country. Although Italy represents an ideal context to study our research questions, it also presents a set of institutional specificities (starting from the existence of a "Professor's Privilege" legislative regime on university-generated inventions) which may limit the generalizability of our findings in other contexts. In addition to that, there might be additional cultural factors more generally related to gender equality in society and the reduced participation of women in the workforce (as compared to other Countries where women participation is higher), which could influence some of our findings. In this respect, it would be important, in the future, to conduct multi-country studies to explore the role of university support mechanisms in other national contexts, which are characterized by different socio-cultural and policy environments.

Also, our estimations do not investigate the role of other characteristics of universities, such as its quality, which could have a potential effect on the participation of women in patenting activities. Previous research has, indeed, shown that top ranking universities have a stronger tradition of active participation in technology transfer and this may have impact in terms of attention toward the involvement of women in technology transfer. Finally, future research could also be extended to include the investigation of the effect of other more specific gender equality policy measures to address the valorization of gender diversity in the workplace. Despite such limitations, the results of our research highlight the role of university policies and support the mechanisms that are required to address the gender gap and promote the greater participation of women scientists in knowledge transfer.

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Table 1. Descriptive statistics

Variable	N	mean	sd	min	max
FEMALE_ACADEMIC INVENTOR	2538	0.208	0.406	0	1
SHARE OF FEMALE ACADEMIC INVENTORS	2538	0.075	0.176	0	1
UNIVERSITY PATENT OWNERSHIP	2538	0.199	0.399	0	1
TTO	2538	0.465	0.499	0	1
INCUBATOR	2538	0.216	0.411	0	1
UNIVERSITY PATENT REGULATION	2538	0.675	0.468	0	1
SCIENCE PARK	2538	0.271	0.444	0	1
REGIONAL VC INVESTMENTS	2538	2.642	1.538	0	5.063
REGIONAL FEMALE EMPLOYMENT	2538	48.817	10.235	21.603	63.227
CENTRAL ITALY	2538	0.230	0.421	0	1
ISLANDS	2538	0.078	0.268	0	1
NORTH EASTERN ITALY	2538	0.237	0.425	0	1
NORTH WESTERN ITALY	2538	0.370	0.483	0	1
SOUTHERN ITALY	2538	0.086	0.280	0	1
AVERAGE TEAM AGE	2538	49.932	9.262	27	75
ASSISTANT PROFESSOR	2538	0.326	0.469	0	1
ASSOCIATE PROFESSOR	2538	0.441	0.497	0	1
FULL PROFESSOR	2538	0.620	0.485	0	1
LARGE UNIVERSITY	2538	0.804	0.397	0	1
MEDIUM UNIVERSITY	2538	0.169	0.375	0	1
SMALL UNIVERSITY	2538	0.276	0.164	0	1
PRIORITY YEAR 1996	2538	0.062	0.241	0	1
PRIORITY YEAR 1997	2538	0.067	0.250	0	1
PRIORITY YEAR 1998	2538	0.063	0.243	0	1
PRIORITY YEAR_1999	2538	0.079	0.270	0	1
PRIORITY YEAR_2000	2538	0.082	0.274	0	1
PRIORITY YEAR_2001	2538	0.078	0.268	0	1
PRIORITY YEAR_2002	2538	0.091	0.288	0	1
PRIORITY YEAR_2003	2538	0.086	0.280	0	1
PRIORITY YEAR_2004	2538	0.096	0.295	0	1
PRIORITY YEAR_2005	2538	0.108	0.310	0	1
PRIORITY YEAR_2006	2538	0.113	0.316	0	1
PRIORITY YEAR_2007	2538	0.076	0.264	0	1
HUMAN NECESSITIES	2538	0.391	0.488	0	1
TRANSPORTING	2538	0.115	0.320	0	1
CHEMISTRY AND METALLURGY	2538	0.172	0.378	0	1
TEXTILES AND PAPER	2538	0.006	0.077	0	1
FIXED CONSTRUCTIONS	2538	0.013	0.112	0	1
MECHANICAL ENGINEERING	2538	0.031	0.173	0	1
PHYSICS	2538	0.163	0.370	0	1
ELECTRICITY	2538	0.109	0.311	0	1

Table 2. Number and share of academic patents by type of ownership and with at least a female academic in the patent team

	A	B	C	D	E	F	G
Priority Year	University patents (n)	University invented patents (%)	University owned patents (%)	Patents with female (n)	Patents with female academic (n)	University invented patents with female academic (n)	University owned patents with female academic (n)
1996	157	94,27%	5,73%	44	15	42	2
1997	170	95,29%	4,71%	56	20	52	4
1998	160	92,50%	7,50%	57	20	49	8
1999	201	91,54%	8,46%	74	20	64	10
2000	208	83,17%	16,83%	64	32	47	17
2001	198	80,81%	19,19%	84	37	65	19
2002	231	81,39%	18,61%	100	49	82	18
2003	218	84,40%	15,60%	99	49	80	19
2004	244	76,23%	23,77%	120	59	92	28
2005	273	73,63%	26,37%	126	72	89	37
2006	286	64,69%	35,31%	164	91	97	67
2007	192	59,90%	40,10%	101	64	48	53
Total sample	2,538	80,14%	19,86%	1089	528	807	282

Table 3. Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. UNIVERSITY PATENT OWNERSHIP	1													
2. TTO	0.21*	1												
3. INCUBATOR	0.15*	0.44*	1											
4. UNIVERSITY PATENT REGULATION	0.15*	0.46*	0.34*	1										
5. SCIENCE PARK	0.04*	0.13*	0.09*	0.20*	1									
6. REGIONAL VC INVESTMENTS	0.11*	0.19*	0.27*	0.31*	0.01	1								
7. REGIONAL FEMALE EMPLOYMENT	0.09*	0.14*	0.29*	0.24*	-0.22*	0.56*	1							
8. AVERAGE TEAM AGE	-0.12*	-0.06*	-0.10*	-0.02	0.00	-0.02	0.00	1						
9. ASSISTANT PROFESSOR	0.17*	0.22*	0.12*	0.16*	0.17*	0.02	-0.03	-0.44*	1					
10. ASSOCIATE PROFESSOR	0.05*	0.05*	0.10*	0.06*	-0.04	0.07*	0.08*	-0.16*	-0.14*	1				
11. FULL PROFESSOR	0.08*	-0.04*	-0.10*	-0.03	-0.05*	-0.03	-0.04*	0.33*	-0.15*	-0.42*	1			
12. LARGE UNIVERSITY	-0.01	0.06*	0.15*	0.22*	0.01	0.04*	-0.08*	0.09*	0.02	-0.02	0.02	1		
13. MEDIUM UNIVERSITY	0.03	-0.10*	-0.13*	-0.17*	0.04	-0.07*	0.08*	-0.09*	0.01	0.01	-0.03	-0.91*	1	
14. SMALL UNIVERSITY	0.03	0.08*	-0.07*	-0.14*	0.10*	0.05*	0.02	-0.01*	-0.07	0.02	-0.01	-0.34*	-0.08*	1

Note: * $p < 0.05$.

Table 4. Estimates of female academic involvement in patenting in case of universities with (i) ownership of the patents, (ii) a TTO and (iii) established connections to science parks

	Model 1 Probit	Model 2 Probit	Model 3 Probit	Model 4 Probit	Model 5 Fractional logit	Model 6 Fractional logit
UNIVERSITY PATENT OWNERSHIP	0.153***	0.137***	0.136***	0.126***	0.916***	0.898***
	(0.028)	(0.027)	(0.027)	(0.027)	(0.201)	(0.205)
TTO		0.076***	0.072***	0.022	0.289*	-0.461**
		(0.017)	(0.016)	(0.022)	(0.172)	(0.230)
SCIENCE PARK			0.069***	0.050**	0.527**	0.280
			(0.020)	(0.021)	(0.188)	(0.198)
REGIONAL VC INVESTMENTS	0.009	0.007	0.003	0.001	0.172	0.108
	(0.008)	(0.008)	(0.007)	(0.010)	(0.065)	(0.103)
REGIONAL FEMALE EMPLOYMENT	0.003	0.001	0.001	-0.002	-0.001	-0.051**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.019)	(0.021)
ISLANDS	0.006	-0.048	-0.091**	-0.142**	-0.766	-1.965***
	(0.051)	(0.044)	(0.046)	(0.050)	(0.502)	(0.543)
NORTH EASTERN ITALY	-0.137***	-0.110***	-0.102***	-0.078**	-0.904***	-0.346
	(0.033)	(0.030)	(0.032)	(0.031)	(0.276)	(0.289)
NORTH WESTERN ITALY	-0.040*	-0.033	-0.033	-0.015	0.147	0.585**
	(0.024)	(0.027)	(0.027)	(0.028)	(0.231)	(0.253)
SOUTHERN ITALY	-0.049	-0.074	-0.107**	-0.181***	-0.962**	-2.462***
	(0.060)	(0.054)	(0.049)	(0.052)	(0.456)	(0.505)
AVERAGE TEAM AGE	-0.008***	-0.008***	-0.008***	-0.008***	-0.052***	-0.057***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.009)	(0.009)
LARGE UNIVERSITY	0.082**	0.096**	0.075*	0.066*	0.443	0.244
	(0.040)	(0.046)	(0.043)	(0.040)	(0.480)	(0.486)
MEDIUM UNIVERSITY	0.055	0.076	0.047	0.037	1.103**	0.660
	(0.047)	(0.054)	(0.051)	(0.046)	(0.521)	(0.527)
PRIORITY YEAR 1997				0.016		0.443
				(0.047)		(0.432)
PRIORITY YEAR 1998				0.017		1.028**
				(0.038)		(0.525)
PRIORITY YEAR 1999				-0.024		0.319
				(0.034)		(0.517)
PRIORITY YEAR 2000				0.035		1.399
				(0.046)		(0.551)
PRIORITY YEAR 2001				0.041		1.778***
				(0.036)		(0.533)
PRIORITY YEAR 2002				0.059		1.328
				(0.045)		(0.521)
PRIORITY YEAR 2003				0.080*		1.845***
				(0.046)		(0.534)
PRIORITY YEAR 2004				0.074		1.762***
				(0.046)		(0.529)
PRIORITY YEAR 2005				0.097**		2.272***
				(0.046)		(0.551)
PRIORITY YEAR 2006				0.122*		2.457***
				(0.047)		(0.567)
PRIORITY YEAR 2007				0.139**		2.619***
				(0.051)		(0.604)
TRANSPORTING	-0.206***	-0.206***	-0.209***	-0.205***	-1.383***	-1.332***
	(0.038)	(0.037)	(0.039)	(0.039)	(0.258)	(0.261)
CHEMISTRY AND METALLURGY	-0.013	-0.015	-0.015	-0.015	-0.245	-0.296
	(0.023)	(0.023)	(0.023)	(0.023)	(0.223)	(0.225)
TEXTILES AND PAPER	-0.096	-0.091	-0.091	-0.087	-1.758*	-1.983***
	(0.094)	(0.098)	(0.102)	(0.100)	(1.006)	(1.014)

FIXED CONSTRUCTIONS	-0.341**	-0.341**	-0.343**	-0.350**	-5.042***	-5.195***
	(0.116)	(0.115)	(0.111)	(0.113)	(0.699)	(0.704)
MECHANICAL ENGINEERING	-0.341***	-0.341***	-0.335***	-0.351***	-3.220***	-4.021***
	(0.085)	(0.087)	(0.088)	(0.088)	(0.456)	(0.461)
PHYSICS	-0.234***	-0.234***	-0.235***	-0.234***	-1.946***	-2.135***
	(0.034)	(0.035)	(0.034)	(0.033)	(0.230)	(0.232)
ELECTRICITY	-0.177***	-0.182***	-0.183***	-0.184***	-1.443***	-1.634***
	(0.042)	(0.041)	(0.038)	(0.038)	(0.272)	(0.274)
N	2538	2538	2538	2538	2538	2538

Notes: Marginal effects are shown. Robust standard errors are in parentheses, adjusted for clusters by universities' identifiers. Models 1-4 use the dummy FEMALE ACADEMIC INVENTOR as dependent variable and adopt a probit econometric specification, while Models 5-6 use the 0-1 bounded variable SHARE OF FEMALE ACADEMIC INVENTORS and adopt a fractional logit econometric specification. The baseline category for geographic area dummies is CENTRAL ITALY. The baseline category for the size of the university is the variable SMALL UNIVERSITY. The baseline category for the priority year of the patent is 1996. * $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$

Table 5. Estimates of female academic involvement in patenting in case of universities with (i) ownership of the patents, (ii) an incubator and (iii) patent regulation

	Model 1 Probit	Model 2 Probit	Model 3 Probit	Model 4 Probit
UNIVERSITY PATENT OWNERSHIP	0.148***	0.146***	0.138***	0.126***
	(0.027)	(0.027)	(0.027)	(0.027)
INCUBATOR	0.030			
	(0.021)			
UNIVERSITY PATENT REGULATION		0.047**		
		(0.018)		
UNIVERSITY TT ENGAGEMENT			0.034***	0.008
			(0.010)	(0.012)
SCIENCE PARK	0.072***	0.065***	0.064**	0.048**
	(0.020)	(0.020)	(0.021)	(0.021)
REGIONAL VC INVESTMENTS	0.004	0.001	0.002	-0.001
	(0.006)	(0.006)	(0.007)	(0.010)
REGIONAL FEMALE EMPLOYMENT	0.002	0.002	0.001	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)
ISLANDS	-0.055	-0.058	-0.091*	-0.145**
	(0.045)	(0.045)	(0.040)	(0.048)
NORTH EASTERN ITALY	-0.128***	-0.121***	-0.114***	-0.079**
	(0.031)	(0.031)	(0.029)	(0.032)
NORTH WESTERN ITALY	-0.042*	-0.037	-0.038	-0.015
	(0.024)	(0.026)	(0.024)	(0.028)
SOUTHERN ITALY	-0.097*	-0.097*	-0.118**	-0.190***
	(0.054)	(0.051)	(0.048)	(0.051)
AVERAGE TEAM AGE	-0.008***	-0.008***	-0.008***	-0.008***
	(0.001)	(0.001)	(0.001)	(0.001)
LARGE UNIVERSITY	0.053	0.038	0.043	0.057
	(0.038)	(0.040)	(0.040)	(0.037)
MEDIUM UNIVERSITY	0.022	0.013	0.023	0.031
	(0.045)	(0.046)	(0.048)	(0.044)
PRIORITY YEAR 1997				0.016
				(0.047)
PRIORITY YEAR 1998				0.019
				(0.038)
PRIORITY YEAR 1999				-0.021
				(0.035)
PRIORITY YEAR 2000				0.039
				(0.048)
PRIORITY YEAR 2001				0.046
				(0.038)
PRIORITY YEAR 2002				0.065
				(0.048)
PRIORITY YEAR 2003				0.086*
				(0.051)
PRIORITY YEAR 2004				0.082*
				(0.046)
PRIORITY YEAR 2005				0.107**
				(0.050)
PRIORITY YEAR 2006				0.133**
				(0.047)
PRIORITY YEAR 2007				0.150**
				(0.052)
TRANSPORTING.	-0.213***	-0.209***	-0.212***	-0.206***
	(0.040)	(0.040)	(0.040)	(0.039)
CHEMISTRY AND METALLURGY	-0.015	-0.013	-0.016	-0.015
	(0.023)	(0.023)	(0.023)	(0.023)
TEXTILES AND PAPER	-0.100	-0.095	-0.099	-0.089

	(0.102)	(0.100)	(0.103)	(0.101)
FIXED CONSTRUCTIONS	-0.340**	-0.338**	-0.338**	-0.348**
	(0.112)	(0.112)	(0.111)	(0.113)
MECHANICAL ENGINEERING	-0.339***	-0.339***	-0.344***	-0.353***
	(0.087)	(0.085)	(0.087)	(0.088)
PHYSICS	-0.238***	-0.236***	-0.239***	-0.234***
	(0.034)	(0.032)	(0.033)	(0.034)
ELECTRICITY	-0.183***	-0.179***	-0.185***	-0.185***
	(0.039)	(0.039)	(0.038)	(0.038)
N	2538	2538	2538	2538

Notes: Marginal effects are shown. Robust standard errors are in parentheses, adjusted for clusters by universities' identifiers. All models use the dummy FEMALE ACADEMIC INVENTOR as dependent variable and adopt a probit econometric specification. The baseline category for geographic area dummies is CENTRAL ITALY. The baseline category for the size of the university is the variable SMALL UNIVERSITY. The baseline category for the priority year of the patent is 1996. * p < 0.10. **p < 0.05. ***p < 0.01.

Figure 1. Share of female patenting in university patents, and university-invented and university-owned patents