



Paper to be presented at
DRUID15, Rome, June 15-17, 2015
(Coorganized with LUISS)

THE EFFECT OF UNIVERSITY-LEVEL SUPPORT POLICIES ON FEMALE PARTICIPATION IN ACADEMIC PATENTING

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Abstract

A growing stream of academic literature investigates various factors which impede the participation of women in patenting and commercialization of the patented research; however, limited research has been performed on the ways to address this gender gap. We explore whether the institutional ownership arrangements of university patent, as well as the presence of such university-level support measures as a technology transfer office (TTO) and IP policy has a positive effect on the female involvement in patenting. We test our hypotheses on a sample of 2538 academic patents produced by Italian inventors in the period of 1996-2007. The results of our research highlight a positive role of a university in addressing the gender gap in productivity and in commercial engagement within academia.

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ABSTRACT

A growing stream of academic literature investigates various factors which impede the participation of women in patenting and commercialization of the patented research; however, limited research has been performed on the ways to address this gender gap. We explore whether the institutional ownership arrangements of university patent, as well as the presence of such university-level support measures as a technology transfer office (TTO) and IP policy has a positive effect on the female involvement in patenting. We test our hypotheses on a sample of 2538 academic patents produced by Italian inventors in the period of 1996-2007. The results of our research highlight a positive role of a university in addressing the gender gap in productivity and in commercial engagement within academia.

INTRODUCTION

With the interaction between science and the economy becoming more significant as the basis of sustained economic development, women's growing presence in the science and technology transfer fields in academia makes them important players in the innovation process. Therefore equal participation to the production and diffusion of scientific knowledge has emerged as a major political, economic, and social issue, which calls for research explicitly addressing gender dynamics. Under such circumstances, the issue of under-performance of women and their under-representation in the sectors of high technological impact – e.g. universities, academic research centers, etc. - poses a serious problem for both academic researchers and policy makers.

As underlined by several authors in the recent literature on the matter, current attempts to promote scientific excellence in various countries across the world “can no longer ignore the gender aspects of research organizations, managers, programs, policies and outcomes” (Ranga & Etzkowitz, 2010). Several other studies have further urged that gender-specified metrics and more inclusive analytical perspectives must be applied in order to assess the overall science and technology workforce situation and to introduce related policy decisions and investments in human capital (e.g., McNeely & Schintler, 2010).

For what concerns technology transfer activities from universities to the industry, the ongoing research shows that there exists a clear gender gap at virtually every stage of the innovation

process: women are less likely to disclose inventions than men are, they are less likely to patent, and less likely to engage in entrepreneurial activity, such as starting a company or serving on a scientific advisory board (Ding, Murray, & Stuart, 2006; Ding, Stuart, & Murray, 2012; Giuri et al., 2007; Frietsch, Haller, Funken-Vrohlings, & Gruppa, 2009; Stephan & El-Ganainy, 2007; Technopolis, 2008). The findings from such a wide range of academic and industry studies provide solid evidence that women represent a considerable unexploited source of human capital in Europe, and that their contribution to Europe's potential is not being maximized.

There is a growing stream of academic literature that investigates various factors which impede the participation of women in patenting and commercialization of the patented research (Ding et al., 2006, 2012; Hunt, Garant, Herman, & Munroe, 2012; Murray & Graham, 2007; Tartari & Salter, 2012; Whittington & Smith-Doerr, 2005, 2008). However, to the best of our knowledge, limited research has been performed in what regards the ways to address this gender gap by analyzing the specific measures and policies that could be put in place to foster broader participation of women academics in all stages of commercial exploitation of an invention.

In order to address this gap, we focus on the factors that might facilitate the female involvement in academic patenting. In particular, we explore whether and how the universities and their internal policies and support structures may create a more favourable and engaging environment for women scientists and foster their broader participation in patenting activities. In line with this objective, we first investigate whether the institutional ownership arrangements of university patent affects the level of female participation in patenting, distinguishing between university-owned and university-invented academic patents (Geuna & Nesta 2006; Lissoni, 2012; Lissoni, Pezzoni, Poti, & Romagnosi, 2013). In the former case, patented inventions generated by publicly funded research are owned by the university that employs the academic inventor. In the latter

case, ownership of patents generated by academic inventors remains with these inventors, or a corporation or organization with which they associate, not the university itself. In this respect, we hypothesize a positive effect of university ownership on the share of women academics engaging in patenting activities.

In the second part of our analysis, we investigate the role of university-level mechanisms in support of patenting and knowledge transfer, namely TTO offices and IPR regulations, to see if they facilitate a broader participation of female academics in patenting. We hypothesize that women academic scientists will be more “responsive” than their male counterparts to the presence of such internal structures and regulations that facilitate the participation in patenting and commercialization activities. Such internal support mechanisms may reduce the bias against women, address the high levels of ambiguity in the patenting process, as well as provide legitimacy and visibility to women scientists which they often lack in the traditionally male-dominated working environments as that of academia (Murray & Graham, 2007; Roos & Gatta, 2009; Rosser, 2009; Stephan & El-Ganainy, 2007). Taking into consideration all of the above said, we hypothesize that there will be more patents with female participation at the universities which have an established TTO, as well as those which have adopted explicit IP regulations to govern the IP-related matters, in comparison with the universities that lack such internal support mechanisms.

We test our hypotheses on a sample of 2538 academic patents produced by Italian inventors in the period of 1996-2007, including 504 university-owned and 2034 university-invented patents. In line with the existing studies (Mauleon & Bordons, 2009; Naldi, Luzi, Valente, & Vannini

Parenti, 2004), we measure female participation in patenting by looking whether there was at least one female academic inventor reported on the patent team.

We thus aim to provide a value added in the research on women participation in patenting by conducting an in-depth study of a particular national context with a longitudinal approach. Our contribution is thus to the general literature on the gender gap in science and technology, as well as to the more specific debate on the role of institutional context and, specifically, of various university-level policies and support elements in fostering broader participation of women at different stages of the innovation process.

The rest of the paper presents first a review of the relevant literature, then describes the context of the study, the sources of data, sample and the methods employed. It then presents the results of the regression analyses, and, in conclusion, it discusses the policy implications of our findings.

THEORETICAL BACKGROUND

The gender gap in academic patenting

Even though the number of women academics has significantly grown in recent decades, their involvement in patenting and other forms of knowledge transfer remains quite limited (Murray & Graham, 2007; Rosa & Dawson, 2006; Thursby & Thursby, 2005; Whittington & Smith-Doerr, 2005). Moreover, the positive developments registered by academic women in their institutional status, individual rank or scientific productivity are not equally reflected in their involvement in patenting and commercialization of their research through such technology transfer activities as, for example, licensing or creating spin-offs (Murray & Graham, 2007). As the results of existing studies demonstrate, women faculty engage in patenting at a decreased rate than male scientists

(Morgan, Kruytbosch, & Kannankutty, 2001; Whittington & Smith-Doerr, 2005, 2008; Whittington, 2007); they do not sit on scientific advisory boards at the same rate as men scientists do, as well as they make up a much smaller percentage of company founders (Ding, et al., 2006, 2012; Stuart & Ding, 2006; Murray & Graham, 2007).

Previous studies highlight several types of factors that may prevent women academics from engaging in patenting and technology transfer more actively. One of the most widely cited factors is the limited access to different types of resources, e.g. financial, human or those of social capital (Mosey & Wright, 2008; Rosa & Dawson, 2006; Stephan & El-Ganainy, 2007). Moreover, the previous research distinguishes the factors which are related to the social construction of gender and the stereotypes pertaining thereto manifested in the traditional gender roles which assign to a woman more household chores (Etzkowitz, Kemelgor, & Uzzi, 2000) and lead to the conflict between family life and work (Shaw & Cassell, 2007). These may impact on the women's decision to engage in "extra" activities like, in this case, those of technology transfer. Other arguments rely on the gender profiles that present women as having greater risk aversion, a lower level of interest in money and financial transactions, or different attitudes to competition (Niederle & Vesterlund, 2005; Stephan & El-Ganainy, 2007).

The above classification falls in line with the sociological perspective which offers two groups of explanations to why women, in comparison with their male counterparts, tend to be less productive, and, in this particular case, why they engage to a much lesser extent in different forms of academic activities, starting from publishing, and most recently licensing, founding academic start-ups and other forms of technology transfer. According to the dispositional approach (sometimes referred to as the "difference model") female scientists tend to lag behind

their male colleagues along various professional dimensions because the two genders are “different” in their values and priorities, which lead to different choices and work-related decisions (Sonnert & Holton, 1995). However, there is evidence from a number of studies performed in several professional environments (e.g. entrepreneurship), which demonstrates that women are not that different in their motivations and preferences once such individual-level characteristics as education, professional experience, income etc. are controlled for (e.g., Brush, Carter, Gatewood, Greene, & Hart, 2001). This points to the arguably higher explanatory power of the second, structural, approach to gender gap in professional attainments.

The structural approach (the so-called “deficit model”) argues on the other hand that female scientists are less productive and less involved in commercial activities than male scientists because they have fewer opportunities than men throughout the course of their careers. In other words, there are legal, political, and social structural obstacles that hinder female scientists from attaining the level of career success that male scientists are more likely to achieve (Corley & Gaughan, 2005; Long, 2001).

When looking at a specific context of science, the structural perspective reaffirms the importance of structural sources of gender inequality in science. In particular, researchers adhering to this perspective argue that women and men scientists demonstrate different productivity and engagement levels due to the fact that they are located in different structural positions which results in different access to valuable resources (e.g., Xie & Shauman, 1998; Whittington & Smith-Doerr, 2005). Thus, in relation to research productivity, some authors find a very limited direct effect of gender once structural characteristics are controlled for and the differences in the distribution of resources such as space, equipment, and time are taken into account (Xie &

Shauman, 1998, 2004). The previous research has also found that women academics tend to experience less mentoring and collaboration opportunities during their scientific career (Long & McGinnis, 1985), which, coupled with their argued higher awareness of and sensitivity to the presence of organizational constraints (Fox & Ferri, 1992), largely contribute to their lower involvement in a wide range of job-related activities.

Much of the early research on academia failed to consider how resource distribution and the structure of academic work is gendered (Whittington, 2009). With that, organizational context may likely play an important role in gender equality, as successful scientific work relies on equal access to facilities and funds, available help, and a supportive research environment (Fox 1991, 2001). Based on the previous arguments, the role of the university – as an employer organization - becomes an important issue to consider in the debate on the ways of increasing female participation in the innovation processes. As so much as the policies and measures implemented at the university level may result highly instrumental in addressing the gender gap in academic patenting. In the following section we thus turn to the literature on the general role of university-level measures and structures in support of knowledge transfer, as well as we explain in detail the rationale behind the assumption on the positive impact of such measures on the female participation in patenting activities.

The role of university-level support mechanisms in addressing the gender gap in academic patenting

University setting has been traditionally characterized by a high degree of complexity due to multiple outputs, ambiguous goals, and stakeholders with differing interests (March & Olsen,

1976), and so the role of various mechanisms and policies in support of patenting and knowledge transfer that are designed and implemented at the university level cannot be overestimated.

There exists an extensive body of research on the role and effect of such internal support structures as a TTO (Louis, Jones, Anderson, Blumenthal, & Campbell, 2001; Thursby et al., 2001) or internal policy regulations on patenting or the creation of spinoffs (Baldini, Grimaldi, & Sobrero 2007; Giuri, Munari, & Pasquini, 2013; Lissoni et al., 2013). These studies highlight the importance of TTOs and university policies for successful transfer of academic knowledge to the market place. In particular, the literature argues that through the creation of TTOs and the adoption of internal patent policies, universities can mitigate market inefficiencies, which arise with regard to patenting and commercialization of academic inventions (e.g. information asymmetries, high embedded risk, etc.). However, in addition to being important signalling mechanisms for external third parties and shareholders (Baldini, Fini, Grimaldi, & Sobrero, 2010), such internal policies and mechanisms are designed with the goal of addressing the needs of the internal parties - i.e. academic inventors - by providing professional support and assistance in commercializing their research. In particular, 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 university internal policies and structures may be more instrumental to a particular group of academic inventors, i.e. women scientists.

The existing research offers several explanations for why this may be the case. For instance, the study by Ding et al. (2006) shows that one of the major hurdles for women academics in relation to their commercial engagement is the lack of exposure to the commercial sector. Most women academic scientists tend to have few contacts with industry since they find it harder than men to make such industry contacts (Ding et al., 2006). This may suggest that the role of different

support mechanisms inside the university may play a crucial role in increasing women scientists' participation. It has been found that, lacking industry connections, women find it time-consuming to explore whether an idea is commercially relevant. In contrast, men often describe an industry contact as a "precursor" to patenting. As reported in the interviews, many female faculty members felt deterred from completing a patent filing due to being hampered by their narrow networks and being concerned about the time it would take to "shop" a patent around (Murray & Graham, 2007).

One of the factors reducing the perceived cost of patenting for women is represented by formal institutional sponsorship. In the qualitative part of the study by Ding et al. (2006), many women commented that their TTO provided industry contacts, advice, and encouragement to develop the commercial aspects of their research. In a parallel study by the colleagues, the findings showed the decline of gender differences among junior faculty prompted by the presence of institutional support (e.g., TTOs) (Murray & Graham, 2007).

Another aspect which can make institutional factors more salient for women scientists than for men has to do with the concern expressed by many female faculty members that pursuing commercial opportunities might hinder their university careers. The women academics who were interviewed in the study by Ding et al. (2006) were found to be more likely to describe the challenges associated with balancing multiple career elements: teaching, research, and commercialization. Unlike their male counterparts, who describe their patenting decisions as unproblematic and driven by "translational" interests, female faculty express concern about the potentially negative impact that patenting might have on education, collegiality, and research quality (Ding et al., 2006).

The institutional support mechanisms may address the above mentioned issues by reducing the ambiguity in the perception of patenting and other knowledge transfer activities by women faculty through providing explicit information on the process of commercialization, as well as offering additional support and guidance and facilitating access to financial resources and industry networks.

Based on the theoretical considerations described above, in the following section we put forward the hypotheses related to the effect of university ownership of academic patents (distinguishing between university-owned and university-invented patents) and two types of internal support mechanisms, namely a university technology transfer office (TTO) and the internal IP regulation, on the level of female academics' participation in patenting.

HYPOTHESES

The role of university ownership of patents

A series of legislative reforms implemented around the world, starting with the Bayh-Dole Act in the United States, aimed to strengthen the assignment of patent ownership rights to universities so that to encourage transfers of university research to industry settings (Geuna & Rossi, 2011; Grimaldi, Kenney, Siegel, & Wright, 2011). Such reforms in support of institutional ownership of academic patents sought to provide adequate incentives for universities and PROs to develop technology transfer capabilities and invest in patenting and commercialization structures, because they enjoyed greater ownership certainty (Geuna & Rossi, 2011). Extant literature analyzes legislative changes governing university IPR ownership in different countries (Lissoni et al., 2013; Mowery & Ziedonis, 2002), the distribution of academic scientists' patenting activity in various countries (Baldini et al., 2006; Lissoni, Llerena, McKelvey, Sanditov, 2007), the factors

that might explain the assignment of academic patents to universities rather than corporations or other applicants (Markman, Gianiodis, & Phan, 2008; Thursby, Fuller, & Thursby, 2009), and the effect on commercialization rates (Crespi et al., 2010; Giuri et al., 2013). However, so far no direct attempt has been made in the literature in order to assess the involvement of women academic inventors in university-owned patents, as compared to university-invented ones.

As to this point, based on the above mentioned arguments, one should expect that university IPR ownership should favour a stronger participation of women researchers in patenting activity. Institutional ownership represents a fundamental prerequisite to allow universities and PROs to create technology transfer offices (TTOs) that centralize, professionally manage, and strengthen technology transfer procedures. This step appears instrumental for fostering technology transfer activities in that professors and researchers often lack the expertise, business knowledge, commercial relationships, financial resources, or interest to engage in commercialization. As explained in the previous section, this gap is particularly pronounced for women academic inventors, who could therefore enjoy a greater benefit from the support of such infrastructures and policies.

In addition to that, the existing evidence shows that the participation, as well as the contribution of women in the patenting arena, tends to increase with the number of co-inventors cited on the patent team, which could indicate a better inclination of women to co-operate and to participate in large research groups (Mauleon & Bordons, 2009; Naldi et al., 2004). It has been evidenced that universities and research institutions, according to the results of a large-scale study carried out in 6 major European countries, tend to have a larger share of collaborative patents as compared to firms (Giuri et al., 2007). This difference may be due to the differing nature and

goals of these two types of organizations. Thus, firms by definition are more competition-oriented and, thus, tend to internalize as much as possible the inventive process in order to avoid leakages of proprietary information; while universities, taking into consideration their traditional mission of knowledge diffusion, will be more open to collaborative research efforts, which will ultimately result in a larger percentage of collaborative patented inventions owned by the universities. Following this line of reasoning, university-owned patents should be associated with more collaborative inventive activity, and by that enhance the involvement of women researchers in the team.

Based on the above arguments, we hypothesize that there will be a higher likelihood of academic female participation among university-owned patents as compared to university-invented ones.

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

The role of TTO on women patenting

The institutional ownership, generally, points to the establishment of an active technology transfer office (TTO), which operates as the support mechanism for smoother transition of research from academia to industry. There is an extant stream of literature dedicated to exploring the role of a university's TTO as a mediating institution for improving the link between universities and industry (Markman, Gianiodis, Phan, & Balkin, 2005; Phan & Siegel, 2006; Siegel, Waldman, & Link, 2003). Technology transfer offices act as “brokers” between academia and industry by providing expertise and managing commercialization processes related to patenting, licensing and the creation of start-up companies (Phan & Siegel, 2006; Powers & McDougall, 2005). In present, with the gradual change in the professional norms in academia and

the diffusion of various support mechanisms inside universities, the role of technology transfer offices as “third party brokers” has increased considerably. Typically performing a mediating role and functioning as “boundary spanners”, TTOs bridge cultural and value related barriers between “customers” (entrepreneurs/firms) and “suppliers” (scientists/universities) who operate in distinctly different environments (Siegel et al., 2003).

In particular, TTOs are instrumental in reducing the asymmetry of information between industry and science on the value of inventions as companies are not normally able to assess the quality of inventions ex-ante, and as inventors may have difficulty in assessing the business value of their inventions, particularly when they arise in new technology areas (Markman et al., 2005). Several recent studies have emphasized the role of the technology licensing office as both a locus for organizational learning about technology transfer (Feldman, Feller, Bercovitz, & Burton, 2002), and an important factor in licensing success (Siegel et al., 2003). It has also been argued that the technology transfer office plays a key role with respect to engendering academic entrepreneurship in relation to founding spin-offs (O’Shea, Allen, Chevalier, & Roche, 2005), by creating company formation expertise and synergy-generating networks between academics and venture capitalists, advisors and customers (Chugh, 2004; Munari & Toschi, 2011). Thus, as the prior research shows, it is expected that the presence of a technology transfer office will facilitate the academics’ involvement in knowledge transfer through providing technical support, market expertise, and additional resources to patent and subsequently commercialize their patented inventions.

The evidence from previous exploratory research points to the possible positive effect the presence of a technology transfer office might have on women academics’ involvement in

knowledge transfer (Murray & Graham, 2007). As it is argued in a pair of companion papers (Ding et al. 2006), a lack of connections to members of the business community and industry players is likely to be a determining factor in female scientists' low rates of participation in various knowledge transfer activities. In particular, some studies, looking at the issue of academic engagement in commercial activities from a historical perspective, have suggested that women academics, being considered low-status members of the scientific community, were least committed to the ideals embodied in the "Mertonian norms" and most interested in different sorts of entrepreneurial activity, but nonetheless they encountered difficulties in engaging in such activities because of the lack of the necessary third-party support (Stuart & Ding, 2006).

The research by Murray and Graham (2007) shows that in the presence of a technology transfer office or other internal support structure women academics tend to use such formal institutional mechanisms to obtain resources and to learn about commercial science more often than their male peers. For men the TTO provides more of a "technical" value added in what regards the legal support, identification of lawyers and assistance in managing the licensing process. In exploratory studies, male interviewees viewed such a "third-party broker" as having little additional impact on their ability to establish connections to industry companies, while women academics described the "hand holding" provided by the TTO as "guiding them through an uncertain landscape" (Murray & Graham, 2007).

Coupled with the extensive evidence from previous studies on the lack of access to valuable industry connections and the high perceived time cost of looking for potential "buyers" of the invented technology for female academic scientists, we expect that the presence of a TTO at the respective university will increase the likelihood of female participation in patenting activities:

Hypothesis 2: The presence of a university's technology transfer office will increase the probability of observing a patent with at least one female academic inventor on the patent team.

The role of universities' IP regulations

Existing research on the role of internal support mechanisms has defined flexible and clear university policies related to technology transfer as one of the main organizational and managerial factors to consider in order to facilitate university-industry collaboration (Siegel, Waldman, Atwater, & Link, 2004). At the level of each university, patent policies are intended to rule the commercialization activities of academics and, as argued in the existing studies, have two main goals (Baldini et al., 2010). Firstly, they clearly define the rights of all parties involved in the transaction on both the academic and the industrial side, as well as their remunerations (if applicable). Specifically, the IP policy states to whom the invention must be disclosed and who is entitled to patent. Secondly, the internal IP policies, to the extent that they govern a university's involvement in and support for the technology-transfer activity, provide the basis for the legal, financial and marketing support for the individual academics involved in the process (Baldini et al., 2007).

To the extent that university regulations are destined to provide formalized and thus presumably clear information on the rules and procedures for technology transfer between academia and industry, as well as the support framework for patenting, we assume that for women academics, who have been evidenced to demonstrate generally more ambiguity and lack of information with regard to the patenting and subsequent commercialization process (Murray & Graham, 2007), the presence of such internal regulations may provide a considerable added value and will thus have a positive effect on increasing female participation in knowledge transfer activities.

In line with this reasoning, we put forward the following hypothesis:

Hypothesis 3: The presence of internal IP regulation will increase the probability of observing a patent with at least one female academic inventor on the patent team.

METHODOLOGY

Sample and data sources

Our data come from two main sources. The initial source was the APE-INV dataset which consists of patent applications filed the European Patent Office (EPO), with priority dates comprised between 1996 and 2007 and 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 manner, it constitutes a perfect base to build reliable estimates of academic patenting in Italy throughout the 10-year period (see Lissoni et al., 2013 for a more detailed description of the dataset).

In order to obtain additional information needed for the present research (e.g. the names of the inventors on the patent team), we performed matching of the APE-INV dataset with the patent-level data that were missing. These data were additionally retrieved from PATSTAT. Since the database does not provide the gender of the inventors, our next step was name disambiguation and assigning gender based on the inventor's first name. The dubious cases were double checked by searching the name of the inventor in question in the online directories, to obtain additional information from the references in the publications which could help establish whether the inventor is a male or a female.

For the university-level data, we used both secondary and primary sources. For the dates of introduction of IP regulations we turned to the study performed by Baldini, Grimaldi and Sobrero (2006) on Italian patenting where the authors provide the dates of IP policy adoption. For the missing cases, we contacted the technology transfer offices of the universities directly, by email. In the same manner we obtained the dates for the TTO creation for the universities from our sample.

After matching and cleaning the data, our sample includes information on 2538 Italian academic patents filed between 1996 and 2007. For the purposes of the present research we adopt a definition of an “academic” patent utilized in the existing literature. Thus, we define "academic" a patent that was signed at least by one academic scientist, while working at his/her university, irrespective of whether the patent is 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, Schmoch, Schulze, & Bethke, 2013; Lissoni, 2012; Lissoni et al., 2013). In terms of type of ownership, the sample contains 2034 university-invented academic patents, while 504 academic patents from the sample are university-owned (20% of the sample). In addition to that, 21% of the patents included in our sample have at least one female academic inventor. The main advantage of the sample we used 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, etc.).

Variables

Dependent variable.

In our regressions, we estimate the likelihood of having at least one female academic inventor among the inventors in the patent team. This measurement of female participation is common in the literature on gender gap in patenting activities (for instance, see Naldi et al. 2004; Mauleon & Bordons, 2009). We thus introduce a dummy variable equal “1” if at least one inventor on the patent team is a university-affiliated female, while it is equal “0” if otherwise.

Explanatory variables.

The three main explanatory variables in our estimations are the ownership of the patent, the presence of a TTO, and the presence of an internal IP regulation at the priority date.

Concerning patent ownership, we construct a dummy variable (UNI_OWN) which is equal “1” if the patent is either owned or co-owned by the university (that is, there is at least one university listed as applicant of the patent); “0” if otherwise.

The presence of a TTO is measured by a dummy variable equal “1” if a TTO existed at the priority date of the patent¹; “0” if otherwise. In a similar way, the presence of an internal IP regulation at the university is measured by a dummy variable equal “1” if an IP regulation existed at the priority date of the patent²; “0” if otherwise. Since we take the inventor’s university of affiliation as the reference university for the construction of these two variables, in cases of inventors affiliated with different universities at the time of patenting, we acknowledge the presence of a TTO/IP regulation if at least one of these universities had a TTO/IP regulation in place at the priority date.

¹If there are inventors from more than one university, we take the university with the oldest date of the TTO creation.

²If there are inventors from more than one university, we take the university with the oldest date of the IP regulation.

Control variables.

We included a series of control variables in our estimations, in order to reduce unobserved heterogeneity that might affect the probability to obtain the expected result.

In particular, at the patent level, we control for the technological class (IPC classification) to which the patented invention belongs, since it has been evidenced that women scientists tend to be underrepresented in certain research fields such as, for instance, engineering or physics (e.g. Hunt et al., 2012).

The variable that accounts for the academic position, i.e. seniority, of the inventors on the patent team controls for the fact that there might exist an overt discrimination and bias among the older academic peers with regard to their female colleagues, so that they will tend to avoid having women inventors in their teams. We thus introduce a control variable which proxies for the average age of the inventors on the patent team.

We also control for the presence of a more experienced member on the patent team (full professor); we introduce a dummy variable FULL equal “1” if there is at least one full professor on the patent team, and “0” if there is no any senior member in the team.

Lastly, we control for such university-level variables as the size and region of the university of inventor’s affiliation to proxy for the quality of the university of affiliation of the inventor, as well as for the share of female professors at the parent university (FEMALE_SHARE).

As argued in the literature, more prominent 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). As for the geographic influence, in Italy the northern regions have been

traditionally more endowed with resources as compared to the central and southern regions, so we might expect that universities situated in the north of the country will be better placed to engage more extensively in patenting and commercialization activities. For the university's 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; Small -less than 10.000 students. In line with this classification, we introduce respective dummy variables for each of the category (LARGE, MEDIUM, SMALL), SMALL being the baseline case in our estimations. The dummy variables which control for the university's region (NORTH, CENTER, SOUTH) were constructed based on the accepted classification³. SOUTH dummy variable is the baseline case.

RESULTS

Descriptive statistics

In the results section, we first provide descriptive statistics to account for the temporal trends in the evolution of Italian academic patenting by type of ownership, as well as with regard to the female participation in such academic patents (Table 2 presents the descriptive statistics on the variables included in our sample, whereas Table 3 presents the correlation matrix).

Insert Table A2 about here

Insert Table A3 about here

³ North of Italy includes the following regions: Lombardia, Piemonte, Valle d'Aosta, Trentino Alto Adige, Friuli Venezia Giulia, Liguria, Veneto. Center comprises of: Emilia Romagna, Lazio, Tuscany, Marche, Abruzzo, Sardinia. The South includes: Molise, Basilicata, Sicily, Puglia, Campania.

Figure 1 provides the patent distribution by type of ownership:

Insert Figure A1 about here

As it can be seen from the figure above, university-invented patents considerably prevail over the university-owned, even though there has been a marked increasing trend in Italian university ownership over the years. This is consistent with the existing evidence on a growing control exerted by universities on IP over their scientists' inventions, as a result of their increased autonomy starting in the second half of the 1990s (e.g. Lissoni et al., 2013). In particular, with the advent of autonomy, several Italian universities introduced explicit IP regulations starting from 1995, and by 2008 over 70% of Italian universities had adopted one (Baldini et al., 2010; Lissoni et al., 2013). This evolution is vividly depicted in the Figure 1. However, in spite of the important changes in the autonomy and IP regulation at university level, the share of academic patents with university ownership still remains significantly lower as compared to the share of university-invented academic patents (see Figure A2).

Insert Figure A2 about here

For the purposes of our research, we then specifically look at the distribution of academic patents with female participation. Since not all women on the patent team may be from academia (i.e. they were not university-affiliated at the time of the patent (priority year)), we control for this by

distinguishing between the patents with at least one university-affiliated (academic)⁴female inventor, and investigate whether the share of such academic patents tends to grow over the years.

We further explore whether there are any differences in terms of the effect of the type of ownership, in line with one of our hypotheses regarding the effect of institutional ownership on the share of female participation. As it can be seen in the figure below, the distribution by year of academic patents including at least one female academic inventor reveals the higher participation of female academics in university-invented patents, as compared to the university-owned ones. This could be explained by the higher share of university-invented vs. university-owned patents in the general structure of academic patenting, as depicted in Figure 2. However, after 2003 the growing trend of the university-owned patents with female participation has become much more pronounced, exceeding the share of university-invented patents in 2007 and reaching almost 20% in that same year (see Figure A3).

Insert Figure A3 about here

The growth in the share of university-owned academic patents with at least one university-affiliated female has been uneven, demonstrating a drastic decline in the year 1999, resuming the growth in the years 2000 and 2001. However, after the year 2001 the share of university-owned patents with female participation decreased again, while the percentage of university-invented patents continued to grow. This 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

⁴We use the term “university-affiliated” and “academic” interchangeably to say that an inventor comes from academia.

effect on the general amount of the academic university-owned patents due to a drastic shift from the institutional ownership and the adjustment of the whole system. The previous figures (e.g. Figure 1 for academic patents) do not, however, exhibit such a vivid decline in the year 2002 for university-owned patents in general. The share of university-invented patents with the female academic participation demonstrated, on the contrary, the growing trend which culminated in 2003. 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 right after the introduction of the “professor’s privilege” in Italy, or collaborating more with the inventors from industry when the IP rights for the joint research results would go to the industry. As the graph 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, made by public employees, arising from research financed at least partially by the private sector, or stemming from specific research projects funded by public organizations other than the inventors’ organization(s), by granting IPRs on such inventions to the public employers rather than the 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.

Regression results

Table A4 (see the APPENDIX A) displays the marginal effects of a probit regression where the dependent variable is the probability of having at least one female academic inventor on the

patent team. The first specification includes only control variables, while the second specification includes the type of ownership dummy. In the specifications three and four the variables for the presence of a TTO and IP regulation are introduced respectively, while the last, fifth, specification provides a full model with the whole set of variables. According to the hypothesis put forward in one of the previous sections, we expect that the university ownership will tend to increase the likelihood of having a female academic inventor as 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 technology transfer office and the internal IP regulation – will as well increase the probability of patents with at least one female academic in the inventors’ team. As the results described below demonstrate, two of these hypotheses have been supported in our full model.

Insert Table A4 about here

The results of the respective regressions show that university-owned patents demonstrate a higher probability to have at least one female academic inventor in the patent team, as compared to university-invented patents. Indeed, the coefficient of the dummy variable University-owned is positive and statistically significant (at the 1% level) in both Model 2 and in Model 5. Besides that, also our second hypothesis is confirmed, given that the presence of a TTO has a positive and statistically significant (at the 1% level both in Model 3 and in Model 5) effect on the probability of having female academic presence in the patent team. For what concerns our third hypothesis, it is confirmed only in Model 4, when we separately include the dummy IP regulation in the Model (the coefficient of the variable is positive and statistically significant at the 1% level in this model). However, if we look at the full model (Column 5), the effect of the dummy IP regulation

becomes insignificant. This may suggest that the presence of IP regulations per se does not provide a value added for academic female inventors, in that such policies provide a general framework for patenting and commercialization activities and may not be perceived as bringing an additional value in addressing the specific obstacles encountered by female inventors in academia. In comparison, the effect of other two explanatory variables, i.e. institutional ownership and the presence of a TTO, remains significant in the full model as well. This points to the instrumental role of the university's structured involvement in patenting in general, and of the TTO in particular as the support structure which may add enhanced value for female researchers through acting as a broker between the individual inventor and the internal and external stakeholders.

The effect of some of the control variables is significant as well. Thus, female participation tends to be higher in the younger teams; with that, the presence of a senior member (full professor) on the patent team has a positive significant effect as well. As expected, the higher share of female professorship at the university will lead to a higher probability of female participation in patenting activities. However, in line with the existing evidence and according to our expectations, the involvement by women scientists will be highly dependent on the field of their research. Thus, as our results suggest, it is less likely to observe female participation in the patents corresponding to such technological classes as Mechanical Engineering, Physics, Electricity and Transporting.

In addition to the effect of the above variables, the effect of the dummy variable South remains negative and statistically significant in all models, in line with our expectations that there will be lower level of participation by female academic inventors in less economically developed regions of Southern Italy, where historically the perception of the role of a female in the society has been perceived in a much more traditional way with the family responsibilities being a top priority

activity for women which may have affected the women's career choices. There are therefore important contextual influences which affect this kind of behaviour. We do not find, on the other hand, any statistically significant effect related to the size of the university to which the inventors are affiliated.

DISCUSSION AND CONCLUSIONS

In this paper we have addressed the role of university IP policies and structures on the likelihood to involve women academic researchers in patenting activity. We explored the role of university IPR ownership (comparing university-owned and university-invented patents), the presence of a technology transfer office and the introduction of an IP regulation in the university. We tested a set of hypotheses on such issues on a sample of academic patents from Italy. The descriptive part of our study vividly depicts that there has been a growing trend in participation in patenting activity by Italian female academic scientists over the 10-year period of the study. An important finding of the present research is that there has been considerable growth in the share of university-owned patents with at least one female academic inventor on the patent team, which in 2007 outpaced the share of patents with other types of ownership (e.g. by a firm or an individual). This points to the increasing positive impact of the institutional ownership on female participation in patenting and in other stages of an innovation process within academia.

With our study, we tried to further explore this observation by testing the hypotheses on the university internal policies and mechanisms that might play an instrumental role in fostering broader participation of female inventors. The results of our econometric analysis confirm that the university ownership and the presence of a dedicated unit in support of commercialization have a significant positive role in increasing the female participation in patenting activities. Our findings are in line with the results of the qualitative research previously conducted in another

national setting, the United States (Murray & Graham, 2007), and which evidenced that women academics happen to be more responsive to the presence of such internal support structures as a technology transfer office, as they tend to perceive them as “a hand holding” when engaging in patenting or other knowledge transfer activities. Apparently, as supported by the results of our empirical analysis, the presence of a university’s TTO increases the share of female participation in patenting. The positive effect may take place due to the increased value added for women scientists of the TTO’s services and assistance in accessing the resources critical for defining potential venues for commercial exploitation of the research, as well as providing links to the external stakeholders (e.g. industry, venture capitalists) and “brokering” for the successful commercialization, which is an important prerequisite for patenting. In comparison to men, female academic inventors have been found to be in a much more disadvantaged position (Rosser, 2009, Rosa & Dawson, 2006), and therefore, as the results of our study demonstrate, the effect of the TTO will be positively correlated with this group of academic scientists.

However, further research is needed to analyze in more detail the specific mechanisms by which a university’s technology transfer office may enhance the participation of women academic scientists in patenting. Besides that, an important issue that should be 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. Country-specific studies will also be needed to explore the role of university and its internal support mechanisms in other national contexts which are characterized by different socio-cultural and policy environments. Future research could also be extended to include the investigation of the effect of other policy measures at the university level as, for instance, paternity leave policy or a set of explicit gender policies addressing the valorisation of gender diversity at the workplace.

In terms of the contribution, a particular feature of the present research is that, being placed in a national context, it creates an added value at two levels: organizational (university) and country level, in the form of policy implications for both universities and national governments in the field of gender equality in science and academia respectively. This happens to be of particular relevance in the situation of an ever increasing awareness and sharp concern about the underlying factors behind the gender gap in scientific and, more recently, commercial involvement of academic scientists (Frietsch et al., 2009; Technopolis, 2008). As in many countries the focus for scientific research has been shifting from basic to applied research and innovation, for which one of the primary indicators is patents granted (Rosser, 2009), failure to introduce effective and relevant measures and mechanisms aimed at addressing the gender gap in patenting will lead to reduced competitiveness and innovative growth in the long run. At the organizational level, since patents have recently become a marker of success and peer recognition in some industries, women's low percentages in patenting may significantly reduce their engagement with the industry and will, thus, inhibit considerably their professional advancement (Rosser, 2009). The results of our research highlight the role of a university in addressing this gender gap and in promoting higher participation of women scientists in knowledge transfer through various institution-level mechanisms and instruments. In this manner, with the present study we provide an empirical basis for country- and organization-level policies advancing state-of-the-art understanding of the institutional mechanisms which may reduce the gender gap in productivity and in commercial engagement within academia resulting an important measure of effective utilization of qualified human resources necessary for sustainable growth and development.

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APPENDIX A

Figure A1 - Number of academic patents by type of ownership for the period 1996-2007:

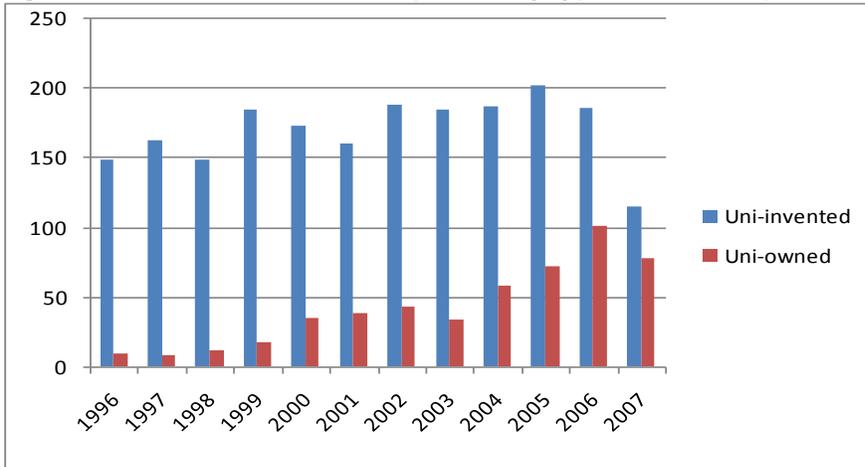


Figure A2 - % of academic patents by type of ownership for the period 1996-2007:

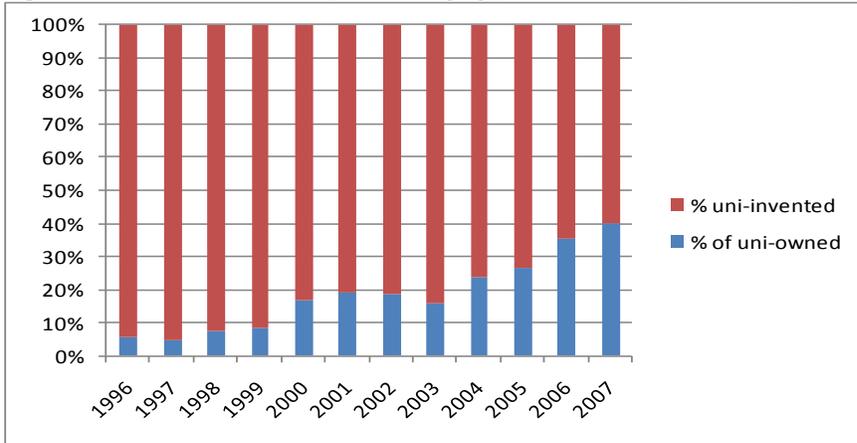


Figure A3- % of patents with at least one academic female, by year and type of ownership

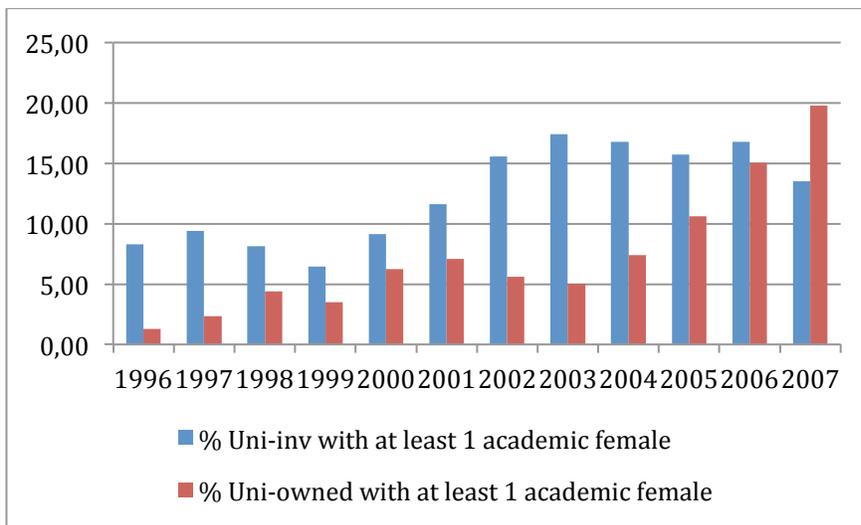


Table A1. Definition and measures of the variables

Variable name	Variable description
Dependent variable:	
FEMALE_UNI	Dummy variable equal “1” if at least one inventor on the patent team is university-affiliated female; “0” if otherwise
Explanatory variables:	
UNI_OWN	Dummy variable equal “1” if the patent is owned/co-owned by university; “0” if otherwise
TTO	Dummy variable equal “1” if a TTO existed at the priority date of the patent ⁵ ; “0” if otherwise
IP	Dummy variable equal “1” if there was an IP regulation in place at the priority date of the patent ⁶ ; “0” if otherwise
Control variables:	
AVERAGE AGE	Average age of the inventors on the patent team
CLASS	Technological class of the patent, according to IPC classification: <ul style="list-style-type: none"> 1 - Human necessities 2 – Performing operations; Transporting 3 – Chemistry; Metallurgy 4- Textiles; Paper 5 – Fixed constructions 6 – Mechanical engineering 7 - Physics 8 – Electricity
FEMALE_SHARE	Continuous variable measuring the share of female professors at the parent university, at priority year of the patent
FULL	Dummy variable equal “1” if there is at least one full professor on the patent team; “0” if otherwise
LARGE	Dummy variable equal “1” if at least one university of affiliation of any inventor on the patent team was large university ⁷ ; “0” if otherwise

⁵If there are inventors from more than one university, we take the university with the oldest date of the TTO creation.

⁶ If there are inventors from more than one university, we take the university with the oldest date of IP policy introduction.

MEDIUM	Dummy variable equal “1” if at least one university of affiliation of any inventor on the patent team was medium university; “0” if otherwise
SMALL	Dummy variable equal “1” if at least one university of affiliation of any inventor on the patent team was small university; “0” if otherwise (baseline)
NORTH	Dummy variable equal “1” if at least one university of affiliation of any inventor on the patent team was from North of Italy ⁸ ; “0” if otherwise
CENTER	Dummy variable equal “1” if at least one university of affiliation of any inventor on the patent team was from Center of Italy; “0” if otherwise
SOUTH	Dummy variable equal “1” if at least one university of affiliation of any inventor on the patent team was from South of Italy; “0” if otherwise (baseline)

⁷ 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; Small -less than 10.000 students.

⁸ North: Lombardia, Piemonte, Valle d’Aosta, Trentino Alto Adige, Friuli Venezia Giulia, Liguria, Veneto ; Center: Emilia Romagna, Lazio, Tuscany, Marche, Abruzzo, Sardinia; South: Molise, Basilicata, Sicily, Puglia, Campania

Table A2.Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
FEMALE_UNI	2538	.2080378	.405984	0	1
UNI_OWN	2538	.1985816	.3990108	0	1
TTO	2538	.464933	.4988671	0	1
IP	2538	.6863672	.4640605	0	1
AVERAGE_AGE	2538	49.9317	9.261807	27	75
FEMALE_SHARE	2538	.2925374	.0546089	0	.4
SOUTH	2538	.1509062	.358028	0	1
NORTH	2538	.4412924	.4966393	0	1
CENTER	2538	.4078014	.4915227	0	1
LARGE	2538	.8037825	.3972132	0	1
MEDIUM	2538	.1686367	.3745045	0	1
SMALL	2538	.0275808	.1638006	0	1
FULL	2538	.6201734	.4854392	0	1

Table A3. Correlation matrix

	1	2	3	4	5	6	7
1 Female_uni	1.00						
2 Uni_own	0.23*	1.00					
3 TTO	0.16*	0.21*	1.00				
4 IP	0.13*	0.16*	0.47*	1.00			
5 Average_age	0.16*	-0.12*	-0.06*	-0.02	1.00		
6 Female_share	0.12*	0.06*	0.13*	0.25*	0.05*	1.00	
7 South	-0.05*	-0.06*	-0.01	-0.04	-0.04*	0.02	1.00
8 North	0.04*	0.04*	0.15*	0.09*	-0.12*	0.07*	-0.06*
9 Center	-0.00	0.00	-0.14*	-0.06*	0.15*	-0.09*	0.09*
10 Large	0.03	-0.01	0.06*	0.23*	0.09*	0.01	0.22*
11 Medium	-0.02	0.03	-0.10*	-0.18*	-0.09*	-0.02	-0.19*
12 Small	-0.01	-0.03	0.09*	-0.15*	-0.01	0.04	-0.09*
13 Full	0.04*	0.08*	-0.05*	-0.02	0.33*	-0.04*	-0.00

	8	9	10	11	12	13	14
8 South	1.00						
9 North	-0.38*	1.00					
10 Center	-0.35*	-0.74*	1.00				
11 Large	0.00	0.09*	-0.09*	1.00			
12 Medium	-0.05	-0.14*	0.14*	-0.91*	1.00		
13 Small	0.00	0.08*	-0.09*	-0.34*	-0.08*	1.00	
14 Full	0.02	-0.09*	0.08*	0.02	-0.03	0.01	1.00

Table A4. Marginal effects, probit estimations of likelihood of having at least one female academic inventor on the patent team

Variable	(1) Controls only	(2) Uni_own	(3) TTO	(4) IP	(5) Full model
Uni_own		0.135*** (0.0164)			0.128*** (0.0166)
TTO			0.0742*** (0.0187)		0.0471** (0.0197)
IP				0.0547*** (0.0199)	0.0301 (0.0206)
Average age	-0.0104*** (0.000911)	-0.00920*** (0.000915)	-0.0103*** (0.000909)	-0.0104*** (0.000910)	-0.00913*** (0.000913)
_Iclass_2	-0.190*** (0.0285)	-0.193*** (0.0286)	-0.190*** (0.0284)	-0.191*** (0.0287)	-0.194*** (0.0286)
_Iclass_3	-0.0136 (0.0195)	-0.0132 (0.0191)	-0.0125 (0.0195)	-0.0123 (0.0195)	-0.0117 (0.0191)
_Iclass_4	-0.0512 (0.0971)	-0.0738 (0.0938)	-0.0498 (0.0969)	-0.0507 (0.0971)	-0.0722 (0.0920)
_Iclass_5	-0.285*** (0.110)	-0.310*** (0.111)	-0.290*** (0.110)	-0.285*** (0.110)	-0.315*** (0.111)
_Iclass_6	-0.343*** (0.0826)	-0.317*** (0.0836)	-0.343*** (0.0836)	-0.348*** (0.0813)	-0.321*** (0.0833)
	-0.207***				

_Iclass_7	(0.0244)	-0.215***	-0.209***	-0.208***	-0.216***
	-0.179***	(0.0244)	(0.0245)	(0.0244)	(0.0245)
_Iclass_8	(0.0278)	-0.158***	-0.182***	-0.177***	-0.160***
	0.280*	(0.0274)	(0.0277)	(0.0277)	(0.0274)
Share_female	(0.155)	0.274*	0.319**	0.249	0.283*
	-0.0525**	(0.154)	(0.154)	(0.155)	(0.153)
South	(0.0238)	-0.0419*	-0.0509**	-0.0503**	-0.0404*
	0.0117	(0.0231)	(0.0236)	(0.0239)	(0.0231)
North	(0.0167)	0.0124	0.00552	0.00855	0.00666
	0.0660	(0.0165)	(0.0169)	(0.0167)	(0.0167)
Large	(0.0468)	0.0521	0.0774*	0.0385	0.0449
	0.0252	(0.0451)	(0.0467)	(0.0476)	(0.0461)
Medium	(0.0497)	0.00826	0.0463	0.00919	0.0138
	0.0781***	(0.0481)	(0.0498)	(0.0498)	(0.0486)
Full	(0.0168)	0.0580***	0.0765***	0.0760***	0.0572***
		(0.0169)	(0.0168)	(0.0168)	(0.0168)
	2,538				
Observations		2,538	2,538	2,538	2,538

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1