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The engagement gap: Exploring gender differences in University – Industry collaboration activities

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ABSTRACT

In recent years, the debate about the marginality of women in academic science has been extended to academics' engagement with industry and their commercial efforts. Analyzing multi-source data for a large sample of UK physical and engineering scientists and employing a matching technique, this study suggests women academics to engage less and in different ways than their male colleagues of similar status in collaboration activities with industry. We then argue – and empirical assess – these differences can be mitigated by the social context in which women scientists operate, including the presence of women in the local work setting and their wider discipline, and the institutional support for women's careers in their organization. We explore the implications of these findings for policies to support women's scientific and technical careers and engagement with industry.

1. Introduction

The participation of women in science and the presence in particular of an "attainment gap" have been topics of both policy and scholarly debate. Several studies in the 1990s provide evidence of a gender gap in science, with women scientists achieving lower scientific productivity, gaining less recognition and fewer rewards, and being awarded promotions at a slower rate than applies to their male colleagues (Long and Fox, 1995). Although there are studies that show that this attainment gap is narrowing (Holden, 2001), there continues to be a disproportionate lack of women in most scientific disciplines, especially at the upper end of the profession (Etzkowitz et al., 2000). In both the private and public sectors, women tend to occupy marginal social positions in scientific and technical careers (DiTomaso et al., 2007; Ceci and Williams, 2011). A recent US study shows that a women's name on a CV identical to that of a man led to fewer offers of employment and lower prospective salaries from university employers, suggesting that gender biases are alive and well in the academic sector (Moss-Racusin et al., 2012).

These gender differences are reflected in a range of features of academic life including teaching evaluations (Basow and Silberg, 1987), career trajectories (Wolfinger et al., 2009) and scientific productivity (Xie and Shauman, 1998; Long, 2001; Brooks et al., 2014). However, increasingly academics are being expected to increase the social and economic benefits of publicly funded research by actively facilitating the transfer of technology from universities to industry (Cohen et al., 2002). Indeed, technology transfer has become a relevant source of non-salary remuneration for faculty and can be an important source of inspiration for future research. A famous example is the collaboration between Professor Giulio Natta from Milan Polytechnic and the Italian chemical company Montecatini, which led to the development of isotactic polypropylene and eventually contributed to Professor Natta winning the Nobel Prize in chemistry in 1963. Engaging with industry often requires academics to bridge between the institutional logics of industry and academia, and to find ways to develop fruitful and productive collaborations with organizations that operate under

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unfamiliar norms and expectations related to knowledge production (Owen-Smith and Powell, 2001; Sauermann and Stephan, 2013). In this context, research shows that gender inequalities are manifested in the formal aspects of technology transfer, such as patents, invention disclosures and licensing (Thursby and Thursby, 2005; Whittington and Smith-Doerr, 2005; DiTomaso et al., 2007; Colyvas et al., 2012; Ding et al., 2013).

Although there is important preliminary evidence on gender differences in technology transfer, more work is needed on this area. First, previous studies focus mainly on formal measures of technology transfer, such as inventions, patenting and licensing, which are relatively rare for all university scientists (Agrawal and Henderson, 2002). Given that few women (or men) engage in these forms of technology transfer, it can be assumed that the results of these studies relate to a small number of individuals working in selected institutions and disciplines. To address this limitation, the present paper focuses on a wide range of academic engagement activities with industry, such as contract research agreements, joint research projects, consultancy, personnel training, etc., (Perkmann et al., 2013). Second, previous studies tend to focus on a single scientific discipline, the life sciences, where the representation of women is higher than in other scientific fields. In this paper, we focus on researchers' behavior in a broad range of engineering and physical sciences, where the asymmetric representation of women is persistent and stark. Third, given the high levels of gender stratification in science, it is likely that past studies compare female and male populations with very different characteristics, such as tenure and quality of the department of affiliation, which potentially can lead to biased estimations of the effects of gender on technology transfer behavior. To address these factors, we employ a matching estimator to create a balanced sample of academic researchers in a range of scientific fields and universities, who may (or may not) engage with industry via a number of different channels, but who are similar with respect to research productivity, rank and discipline.

Our approach goes further than merely establishing that there are differences in the level and type of engagement with industry of women and male scientists and explores how these differences might be mitigated by the social context in which women work. First, drawing on the concept of tokenism (Kanter, 1977a), we suggest that the presence of numbers of women in the local work context help to enable women scientists to engage equally than their male colleagues in engagement with industry. Second, we suggest that the presence of women in their wider discipline also helps to attenuate differences between men and women in academic engagement with industry. Third, we argue that in work environments where active efforts are made to promote diversity, the differences in patterns of engagement with industry are attenuated.

To explore these propositions, we combine data from multiple sources, including a large-scale survey, the records of the largest UK research council, and other public records, such as ISI Web of Science publications data, to build a rich picture of the careers and behavior of several thousand UK academics. We find support our hypotheses and explore the implications for our understanding of women in scientific and technical careers.

2. Gender stratification in science and engineering

It is clear that women face a specific series of gender related barriers to entry and success in scientific and technical careers (Etzkowitz et al., 2000; Gupta et al., 2005). Gupta et al. (2005) observe that women suffer from a triple burden: an unfavorable work environment, disproportionate domestic responsibilities and a social capital deficit. These three elements are interrelated and contribute to gender stratification. First, many women scientists report feeling isolated, which often results in lack of encouragement to realize their career potential. The male-dominated academic and professional cultures have been variously described as the "gentlemen's club", the "barrack yard" and the "locker room" (Maddock and Parkin, 1994), all environments where women are under-represented (if not absent) and tend to occupy low-status positions, subject to potential tokenism (Kanter, 1977b). In addition, gender stereotypes and gender-related barriers mean that women often have to work harder than men to prove themselves (Kanter, 1977a; Gupta et al., 2005).

Second, domestic responsibilities tend to fall disproportionately to women, subjecting them to pressure from two "greedy institutions": academia and the family (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 and Goulden, 2004). They also take on the most challenging childcare tasks, such as getting up during the night and staying at home to care for a sick child (Rhoads and Rhoads, 2012). In addition, the academic career pathway works against women in that the critical early years of performance assessment overlap with women's years of fertility, leaving many women with the choice between bearing children and tenure (Jacobs et al., 2004; Williams and Ceci, 2010). In some academic environments, women are seen as risky employees whose personal commitments are taken into account in hiring and promotion decisions, while they are often largely overlooked for men. In some cases, career gaps due to maternity leave and childcare are not fully considered in tenure decisions (Williams and Ceci, 2010). For instance, the effect of childbirth on a woman's academic productivity has been estimated at two years of lost publications, a figure that is well beyond the maternity arrangements of even the most progressive employers (Hunter and Leahey, 2010). These domestic differences are magnified by the higher tendency among women academics compared to male academics, to marry another academic (Ferber and Loeb, 1997). In these academic partnerships, the women tend to make sacrifices to further their partners' careers, either by locating to places where they are forced to take up less professionally rewarding positions (Kulis et al., 2002) or part-time or lower level employment in the university sector (Wolfinger et al., 2009). Taken together, these pressures are liable to be an important causal factor in the higher rate of withdrawal of women from scientific careers (Ceci and Williams, 2011) or the tendency of women scientists to become trapped in more marginal academic jobs, such as adjunct or sessional lecturers, or administrative roles in universities (Wolfinger et al., 2009).

Third, research shows that women in science have less rich and diverse social capital, and fewer bridging ties outside their local work contexts than their male colleagues (Etzkowitz et al., 2000). In this sense, women tend to be excluded from the "Kula ring of power" the informal gatherings in science where resources, knowledge and reputation are exchanged and developed (Etzkowitz et al., 2000). They also suffer from lack of relevant role models (Etzkowitz et al., 1994). Faulkner (2006) comments that "far fewer alpha females than alpha males are available as role models." Women generally lead smaller labs and draw fewer resources, which, in turn, might provide them with fewer opportunities for career advancement (Murray and Graham, 2007).

3. Industry engagement and women

Working with industry on collaborative activities requires academics to bridge between the "institutional logics" of industrial practice and academic science (Thornton and Ocasio, 2008). These differences in institutional logics are reflected in the norms of knowledge production and distribution, the time scales of research efforts, and career employment patterns (Sauermann and Stephan, 2013). Since academics have a strong tendency to identify with the institutional logic of science, working with industry partners can present significant challenges to their ways of working (Lin and Bozeman, 2006). Academics have to learn how to forge relationships with industry that generate beneficial outcomes for both parties (Owen-Smith and Powell, 2001). Finding appropriate partners and sustaining these relationships often requires the academic to maintain a network of non-academic colleagues (Lam, 2007). Engaging with industry requires time and other investments to build reputation outside academia, for example, attending meetings with industry partners or taking on roles in the wider profession (D'Este and Perkmann, 2011).

For individual researchers, the decision to engage with industry depends mainly on their social context and their perceptions of the potential costs and benefits from engagement (Owen-Smith and Powell, 2001; Tartari and Breschi, 2012). In terms of the social context, research has shown that academic engagement with industry is more common in leading universities, with strong research capabilities. Institutional support for engagement – training, availability of support, and monetary rewards – with industry may also lead to higher level of academic effort at engagement (Perkmann et al., 2013). In addition, academics attitudes to industry engagement may be shaped by the norms of scientific production and exchange that are present in the main discipline of the academic, with some disciplines exhibit a close affinity to practice and others being fairly distant from industry (Perkmann et al., 2013) and also by the local work context (Louis et al., 1989; Stuart and Ding, 2006; Bercovitz and Feldman, 2008; Tartari et al., 2014).

On the question of individual perceptions about the costs and benefits of academic, engagement with industry, research has found that some individuals may be apprehensive that engagement with industry might limit their freedom of inquiry and skew public research agendas toward marketable research at the expenses of basic research (Nelson, 2001; Tartari and Breschi, 2012), or may cause delays in the publication of scientific papers and data (Blumenthal et al., 1996; Campbell et al., 2000). However, engagement with industry appears to have positive benefits such as providing access to additional resources – both financial and in-kind (e.g., equipment, data and materials). It can also be an important source of inspiration for new research projects (Agrawal and Henderson, 2002; D'Este and Perkmann, 2011).

In light of the particular challenges faced by women in science highlighted in Section 2 above, prior research has suggested that women academics' have lower levels of engagement in formal technology transfer – patents and inventions – than their male colleagues. Ding et al. (2006) show that in life sciences women academics tend to patent 40% less than their male colleagues, even controlling for scientific productivity and "patentability" of results, and that their male colleagues are twice as likely to serve on the senior advisory boards of biotechnology companies (Ding et al., 2013). Thursby and Thursby (2005) provide similar results from a sample of over 4500 academics from 11 major US universities, women (who represent just over the 8% of the population) are less likely to disclose inventions than men despite there being no significant differences in publication patterns. Similarly, Whittington and Smith-Doerr (2005), in an investigation of gender disparities in commercial outcomes for scientists in academia and industry, show that female scientists engage in and produce less commercial work than their male counterparts, and that the level of the disparity is constant across time, while the quality and impact of women's commercial work remains the same or becomes even better than that of male scientists. Also, Colyvas et al. (2012) analyzed the technology transfer activities for a sample of US medical school faculty and found no significant differences between men and women in the likelihood of reporting or successfully commercializing inventions, although there were differences in the numbers of inventions.

Despite this evidence for gender differences in formal technology transfer, we still know little about how women differ from men in their wider pattern of academic engagement. Since academic engagement encompasses a wide range of interactions between academics and industry, and formal technology transfer is itself a rare activity, it is unclear whether the gender differences that appear for formal technology transfer are present for other more common forms of interaction.

Building on the wider literature on the role of women in science and engineering and in line with prior research on the role of women in formal technology transfer, we suggest that the challenges of engagement with industry are higher for women than for men, and that women would receive fewer benefits from these efforts. Therefore, we expect women to engage less with industry than their male colleagues for three main reasons. First, since women scientists work in strongly male dominated environments, they are likely to have to spend more time and effort than their male colleagues to engage with industry. Scholars have suggested that the industrial culture in science and technology can be hostile or unreceptive to women (DiTomaso et al., 2007; Jeppesen and Lakhani, 2010). This inauspicious environment is liable to raise the costs for women scientists to negotiate mutually productive exchanges with industry partners. Second, since women scientists tend to have more domestic responsibilities than their male colleagues, they will have less time or attentional resources to devote to industry engagement, such as speaking at industry organized conferences or attending external meetings with industry partners. Therefore, their personal costs (such as balancing schedules, childcare, etc.) for these activities will be higher than for their male colleagues. Third, since women scientists are more likely to have access to fewer resources and social support mechanisms than their male colleagues, they will have to spend more time and energy to identify useful and then exchange resources with industry partners. Thus,

H1. Women academics will have narrower academic engagement with industry than their male colleagues of similar rank, status, age and discipline.

3.1. Social context and gender differences in academic engagement with industry

The discussion above stresses the individual factors that might lead women to engage less than men, but it is clear from the wider literature that academic engagement within industry is profoundly influenced by the social context in which academics work. To better understand how social context moderates the differences between men and women with respect to academic engagement with industry, we focus on three central elements of the work setting. First, drawing from tokenism theory, we explore the effect of the presence of women in the local work place as an important contextual factor, suggesting the low number of women in the workplace may heighten the engagement gap. Second, we explore how the presence of women in the wider discipline, which is a critical reference point for academic behavior, shapes the engagement gap, again suggesting the low representation of women leads to a higher engagement gap. Finally, we argue that the institutional support for women's careers in science and engineering also mitigates the differences in academic engagement with industry between men and women.

3.2. The presence of women in the local work context

In the study of gender differences in the labor market, considerable attention has been paid to the importance of the proportion of women in local work context. In her seminal work, Kanter (1977a) suggested that minorities representing less than 15% of the larger social group may be the subject of tokenism. In this case, there is a tendency for the visibility of these socially marginal individual's behavior to be magnified in the workplace. In addition, the low numbers of women can lead to the differences between them and the dominant group becoming exaggerated, and may increase the risk of role entrapment, with women expected to take up stereotypical roles provided to them by the dominant group (Kanter, 1977b; Yodder, 1991). Although the concept of tokenism was developed outside the academic context, it may have implications for this setting as well. For instance, women academics may be asked to take on ceremonial tasks, such as being the only female member of a committee (Etzkowitz et al., 2000) or additional service responsibilities including pastoral care for students (Wolfinger et al., 2009). In addition, since many women's academic careers do not 'fit' the conventional career pathway and with few women in the local context, there may be a tendency among male-dominated hiring and promotion panels fail to give credit or disregard women's contributions (van den Brink and Benschop, 2014).

The implications of tokenism for academic engagement with industry are, however, less well understood. The low share of women in the local context may make it difficult for women to access the means and resources to enable to effectively exploit industry relationships. In addition, as a result of tokenism, women may be assigned work roles that do not enable them to gain access useful and valuable industrial contacts. In taking up these roles, women may find that they have difficultly obtaining credit for their contributions from internal and external audiences. The lack of women in the local context also means that women are liable to be short of women role models or mentors to help them deal with the challenges associated with industry engagement. Thus, in the lack of women in the local work context may help to amplify the engagement gap between men and women. Thus,

H2a. The differences in academic engagement with industry between women and male academics (of similar rank, status, age and discipline) will be less pronounced in departments where women represent over 15% of the faculty members.

3.3. The presence of women in the disciplinary context

Within academe, individuals often look to others in their discipline as a reference point for their own behavior and attitudes. As Merton (1973) suggested, academic disciplines provide a social context in which academics seek to obtain status and recognition from their peers for their contributions. As a result, academics tend to highly conscious of their relative position in their disciplinary community, and devote considerable time and attention to nurturing and sustaining relationships with other academics at other institutions who are working on similar topic areas, what Crane (1972) referred to as 'invisible colleges'. They may look to these invisible colleges rather than their local colleagues a source of support, advice and norms (Gouldner, 1957). In addition, academic disciplines profoundly differ in their nature of scientific production and exchange, with some fields tied closely to industrial practice, such as engineering, and others more separate and distinct, such as mathematics (Rosenberg and Nelson, 1994). In the formative stage of academics careers, attitudes toward industry engagement are liable to be developed through interactions with other academics working in the same disciplinary context even if they are located at other institutions. As such, the disciplinary context provides both a vehicle to generate status and also a critical reference point about what types of behaviors are valued and accepted by the community.

It is also clear that the degree of representation of women differs considerably across academic fields. In particular, women constitute only a small percentage of engineering and physical sciences faculty but are better represented in the life sciences. While the level of attainment in life sciences has increased significantly for women since the early 1990s, it has remained stubbornly low in the engineering and physical sciences (Faulkner, 2006). In many fields of engineering and physical sciences, the participation of women is extremely modest, and the imbalance increases as one moves up the social hierarchy. For instance, in 2007, only 5% of professors in UK engineering and technology departments were women (McWhinnie and Fox, 2013).

Accordingly, we suggest that these variations in representation across scientific fields have an important impact on the differences in patterns of academic engagement with industry between women and male academics, such that these differences will be more pronounced in fields where women are a significant minority. The idea here is that the lack of women in the wider academic discipline is akin to a situation described by Kanter for the local work context. As such, women in these disciplinary contexts may suffer from tokenism when they engage in their professional communities. In these communities, they may be entrapped in roles that preclude them from accessing to the necessary resources to allow them to succeed in academic engagement with industry. Male members may consider their contributions to these communities to be marginal or 'low-value', claiming opportunities for advancing industry engagement for themselves (van den Brink and Benschop, 2014). Moreover, the lack of women in the wider discipline leaves women scientists with fewer female role models and mentors to draw upon, that might them less willing to take up the challenge of engaging with industry. Thus,

H2b. The differences in academic engagement with industry between women and male academics (of similar rank, status, age and discipline) will be less pronounced in disciplines where women are more prominent.

3.4. The proactive measures of support of women at the institutional level

Organizations can help to overcome the marginality of minority groups by implementing proactive measures (Kalev et al., 2006). These may be formal commitments to reduce the barriers faced by socially excluded groups, or in more extreme cases, employers may operate quota or set-aside programs to help individuals from disadvantaged groups to perform in their job roles (Heilman et al., 1997). Over the past 30 years, the under representation of women in science has seen significant proactive efforts to overcome this inequality. Universities, research funders and scientific and professional associations have developed a range of mechanisms to help early career women scientists as well as those already in post. For example, the European Commission has supported the actions by European Union member states to help overcome the under-representation of women in science and engineering, through its research funding programs.[1] In the UK, the Higher Education Funding Council of England (HEFCE), in its six year periods of research assessment, allows women a one paper reduction in output (three as opposed to four papers over six years) for each maternity leave (HEFCE, 2011). In addition, in 2005, the UK developed a national certification system called Athena SWAN to judge the level of effort being made by universities to advance the representation of women in science, engineering and technology. This certification system requires that the university demonstrate the implementation of practical efforts to support women in the workplace; levels of effort are rewarded according to a three level rating system (bronze, sil-

[1] http://ec.europa.eu/research/science-society/index.cfm?fuseaction=public.topic&id=1297, accessed March 2013.

ver and gold).[2] Alongside these efforts, several UK universities have developed their own programs to encourage women to take up academic leadership positions. This program provides mentorship, collegial support and training.[3] Although the scale of these efforts in the UK itself remains relatively modest, the approach has increasingly become a more important tool for research funders and others to ensure universities are taking steps to encourage women academics to realize their potential in the profession.

Accordingly, we suggest that existence of these measures to promote women's careers in science and engineering in academic can play an important part in shaping women's engagement with industry. By providing resources and support to women at formative and later stages of their career, these programs provide an important institutional mechanism to support women academics in different aspects of their jobs. These efforts may help to enrich and broaden the range of skills of women academics. For example, such efforts might women with specific training programs to increase research funding and help to their exposure to industry practice. In doing so, these programs may provide women academics with greater confidence to engage outside the university with non-academic communities. These programs may provide direct support to enable women returning from childbirth to engage in research, which in turn can facilitate industry engagement. For example, Imperial College London provides funding up to 50% of salary of one year for women returning from maternity breaks to relieve them from all teaching and administrative duties upon their return.[4] This type of support can provide opportunities for women to renew contacts with potential industry partners after a period of absence, or even spur new collaborations. As such, these programs and efforts may encourage women academics – whether as part of a proactive measure or not – take on a boundary spanning roles (Rothbard et al., 2005). In addition, these programs may help to increase the attractiveness of an employer for minority groups, making them more likely to join the organization and less likely to leave academia (DiTomaso et al., 2007). Accordingly, we suggest that in workplaces where proactive measures to help women in academic careers are in place, the differences between women and men in terms of their engagement efforts will diminish. Thus,

H3. The difference in academic engagement with industry between women and male academics (of similar rank, status, age and discipline) will be less pronounced in workplace environments that implement proactive efforts to encourage women in academic careers.

4. Data and methodology

Studying men's and women's performance differences in science is methodologically difficult as there is usually significant gender stratification in the scientific profession (women scientists predominantly occupy junior positions). This makes comparison of female and male academic populations problematic as the characteristics of the two groups are different with regard to tenure, access to resources, and scientific productivity. This imbalance presents an interesting challenge when studying gender differences since its consequences for estimation consistency cannot be solved fully by the introduction of control variables. When performing causal inference researchers need to restrict their analysis to the range of values for which they have observations. However, regression models tend to extrapolate (sometimes too readily) beyond the range of observed data: this is particularly problematic in studies analyzing gender issues, as the presence of imbalances in the range of data available for treatment (women) and control (men) groups may undermine the integrity of regression results (King and Zeng, 2006).

It is therefore necessary to consider approaches, other than standard regression methods to understand the differences between men and women in external engagement with industry. The approach needs to consider a broad range of forms of engagement with industry, and to compare differences across disciplines and institutions. It is important also to find an approach that will reduce the impact of the unbalanced nature of the two populations such that it does not shape the sign and size of the estimations of gender differences with respect to academic engagement. Ho et al. (2007) suggest that reducing the link between the treatment and control variables renders the estimates less dependent on modeling choices and specifications.

To overcome some of these empirical and methodological issues, we draw information from a unique dataset covering a population of 6200 academic researchers in the UK listed as principal investigators or co-investigators on grants awarded by the EPSRC (Engineering and Physical Sciences Research Council), from 1992 to 2006. The EPSRC is the largest funder of research in the UK (£740 million of research funding in 2008) and finances research in all fields of engineering, mathematics, chemistry, and physics. Although all research projects are funded on the basis of peer review, the EPSRC encourages partnerships between researchers and third parties, such as private firms, government agencies, local authorities, non-profit organizations, etc. However, there is no requirement for an industry partner in EPSRC funding and the grant portfolio includes a mix of collaborative (involving industrial or non-industrial partners) and response mode grants.

To understand academics' engagements with industry, we administered a survey questionnaire in 2009 to all EPSRC-funded investigators, focusing on a broad range of collaborative activities with industry, such as contract research agreements[5], joint research projects, consultancy, personnel training, etc. This method was driven by a desire to overcome the tendency in the literature to focus on a limited range of formal technology transfer activities. After considerable efforts, we obtained a total of 2194 completed questionnaires, corresponding to a response rate of 36%. Each respondent then was matched with the population of academics included in the research assessment exercise (RAE) conducted in 2008 (covering the period 2001–2007). The RAE (now the REF) assesses the quality of research in universities and colleges in the UK and is conducted jointly by HEFCE, the Scottish Funding Council, the Higher Education Funding Council for Wales, and the Department for Employment and Learning of Northern Ireland. These bodies use the RAE quality profiles to determine the level of direct research grants given to the institutions. We next matched the universities included in our sample with data collected by HEFCE through the higher education-business and community interaction survey (HE-BCI), for the years 2005–2007. The annual HE-BCI survey examines the wider exchange of knowledge between universities and the society: it collects financial and output data per academic year at university level, for a range of activities from the commercialization of new knowledge, through the delivery of professional training, consultancy, and services, to activities intended to have direct social benefits. Finally, we collected detailed information on the scientific productivity of respondents from the ISI Web of Science: for each researcher in our sample we identified their detailed publication history, including number of co-authors.

[2] http://www.athenaswan.org.uk, accessed March 2013.
[3] http://www.lfhe.ac.uk/en/programmes-events/you/aurora/, accessed September 2014.
[4] http://www3.imperial.ac.uk/hr/procedures/family/elsiewiddowson, accessed September 2014.
[5] This paper builds on a wider research project, which includes the following papers: Clarysse et al., 2011; Tartari et al., 2014; Tartari et al., 2012.

Table 1
Degree of engagement across different types of interaction with industry, at least once, IPGC Survey and Cambridge Survey.

Types of interaction	Cambridge % At least once	IPGC % At least once
Attendance at conferences with industry and university participation	87	78
Attendance at industry sponsored meetings	n.a.	59
A new contract research agreement (original research work done by University alone)	37	54
A new joint research agreement (original research work undertaken by both partners)	42	53
A new consultancy agreement (provision of advice that requires no original research)	43	44
Postgraduate training with a company (e.g., joint supervision of PhDs)	33	44
Training of company employees (through course enrolment or through temporary personnel exchanges)	33	27
Creation of new physical facilities with industry funding (e.g., new laboratory, other buildings on campus)	9	15

In order to ensure the representativeness of our sample, we conducted several tests to check for potential biases. First, Table 1 compares the level of academic engagement of the participants to our survey with the level of academic engagement of a larger population of UK academics, analyzed by a survey conducted in 2009 by the University of Cambridge. This survey targeted all scientific disciplines among UK universities. Results of our survey are consistent with the Cambridge survey, especially taking into consideration that our sample mainly includes scientists and engineers, who tend to engage with industry more frequently than academics in social sciences and humanities.

Second, we used a Wilcoxon–Mann–Whitney test to analyze whether there were differences in the typology of university of affiliation of the respondents compared to the rest of the sample but found no significant differences. Third, we checked the characteristics of early vs. late respondents and found no major differences between the two populations. Fourth, since the survey was administered only to EPSRC grant holders, there was a risk of sample selection bias since non grant-holders may have different behavior patterns in terms of engagement with industry. Although we do not have information on academics that were not in receipt of a grant between 1992 and 2006, we use the group of academics who did not receive a grant between 2000 and 2006 as a proxy for non-grant holders. Since these academics did not win funding over the previous seven years, they are more likely to exhibit similar behaviors to researchers who have never been awarded a research grant by the EPSRC. If we compare the level of industry engagement of non-grant winning academics with that of academics who received a grant in 2000–2006, we find no statistically significant differences.

The UK provides a particularly interesting case to explore differences in the behavior of men and women academics since it has often been suggested that it lags behind other industrialized countries for representation of women in science and engineering faculties (Etzkowitz et al., 2000). Of 5165 full-time professors working in physical sciences (including biology) and engineering in the UK in the academic year 2006/2007, only 335 were women (HESA, 2007). The distribution of women in different academic disciplines reveals that women professors are concentrated in medicine and education (between 24% and 30%), while they are a significant minority in physical sciences and engineering (between 5% and 8% of the total population of UK professors in these fields). For a detailed overview of the distribution of women in UK universities, see Appendix A.

4.1. Dependent variables

Our dependent variables cover a broad range of industry engagement forms: creation of new physical facilities with industry funding, joint research agreements, contract research, consultancy, training of company employees, co-supervision of postgraduate students, attendance at conferences with industry and university participation, and attendance at industry sponsored meetings. This approach allows us to capture more common and more diverse forms of technology transfer activities than are revealed by examining patents or invention disclosures. By examining this range of forms of engaging with industry, we are able to explore differences in the breadth and depth of academic engagement with industry.

In order to capture a synthetic measure of both the variety of forms of engagement and the intensity of collaboration, we build an individual academic engagement index (AEI), as a modified version (Tartari et al., 2014) of the index developed by Bozeman and Gaughan (2007). Our survey data contain information on the types and frequencies of academics' industry engagement, which we used to construct the index (see Table B1, Appendix B). The academic engagement index is constructed as follows. For every type of industry engagement, we identified whether the researcher had collaborated or not ("occurrence", denoted by b_j). For all the items, respondents were asked to indicate frequency: "0 times", "1–2 times", "3–5 times", "6–9 times", "more than 10 times". In order to obtain a continuous variable for the analysis, we assigned a numerical value to each frequency category. We chose to use the mid-values: for example, for the category "3–5 times", we assume the value 4 (D'Este and Patel, 2007). We then computed the frequency for each type of engagement for the whole population:

$$f_j = \frac{\sum_{n=1}^{N} b_j^n}{N} \quad (1)$$

where j is the type of industry engagement, n is the individual and N is the total sample. We constructed the index by multiplying the number of interactions declared by each academic for each channel (T_j) and the frequency of their non-occurrence ($1 - f_j$) and summing all the scores:

$$\text{AEI}_n = \Sigma_{j=1}^{8} T_j \times \left(1 - f_j\right) \quad (2)$$

The index takes account of the "difficulty" and scarcity of certain activities such as the creation of new physical facilities, relative to others such as attending industry sponsored meetings.

Next, in order to understand whether women and men engage with industry using different types of activities, we used the number of occurrences in each channel of interaction by itself (T_j). Our survey includes information on academics' engagement through eight different channels, allowing us to capture the diversity of academics engagement with industry.

4.2. Control variables

Gender stratification in science means that women in academia tend to be concentrated at the bottom of the career pyramid, where they occupy mostly low status positions, such as post-doctoral researchers or assistant professors. The higher up the career ladder, the smaller the presence of women. This phenomenon is attributed to a "leaky pipeline" (Etzkowitz et al., 2000). This means that on average women researchers are likely to have different demographic and productivity characteristics than their male colleagues.

These characteristics in turn are highly likely to influence academics' engagement with industry.

In light of this, we use a range of variables to match women to male academics. Our goal is to create two groups of academics that are similar in many characteristics so that we can compare differences in the engagement patterns of men and women of equal academic standing, experience, resources, productivity, training, and location. First, we control for academic rank (coded as a dummy which identifies the group of professors): several authors have found a positive effect of being tenured, on collaboration activities with industry (Perkmann et al., 2013). Second, we control for training effects (Bercovitz and Feldman, 2008), including the researchers' academic age (defined as their current age minus the age at which they were awarded their PhD), a dummy variable identifying a holder of a British doctoral degree (British PhD) and a proxy for the quality of the institution awarding the PhD (elite PhD), coded as a dummy variable indicating whether the institution is part of the Times Higher Education Supplement (2004) list of worldwide top 100 universities.

Third, we control for the researcher's resources and productivity. We include the total amount of research funds received from EPSRC in the period 2000–2006, and the total number of publications and citations received during the researcher's career up to 2009. Several authors find that faculty with industry support or researchers involved in entrepreneurial activities publish at least as much as or even more than other faculty (Agrawal and Henderson, 2002; Azoulay et al., 2007); others fail to identify a clear relationship between collaboration activities and academic productivity (Blumenthal et al., 1996), or identify an inverse U-shaped relationship indicating that researchers with industrial exposure publish less if their whole career span is taken into account (Agrawal and Henderson, 2002). Also, by matching for scientific productivity, we ensure, we examine scientists with equal scientific status in their disciplinary communities.

Fourth, we account for differences in scientific disciplines between researchers. The researcher's scientific field tends to define the extent of engagement activities with industry: academics in more applied fields of science, such as engineering, are more likely to collaborate with industry (Lin and Bozeman, 2006). It has been observed also that for researchers working within the so-called Pasteur's Quadrant, practical problems provide a powerful stimulus for the development of new ideas (Stokes, 1997). Moreover, as shown above, women's representation varies greatly among disciplines and it is important to take account of these differences in the distribution. In this study, we deal primarily with researchers in the physical sciences (mathematics, physics, chemistry, computer science, materials, and all branches of engineering), and to a lesser extent with researchers in the life sciences (medicine, pharmacy and biology), social sciences, and humanities.

Finally, we control for the research quality of the department of affiliation (measured as the percentage of staff rated 4* and 3* in the RAE 2008). On the one hand, it is clear that collaboration and entrepreneurial activities are enhanced by the presence of a formal support infrastructure and institutional incentive mechanisms (Owen-Smith and Powell, 2001), often with a stronger effect at the department or research group level (Haeussler and Colyvas, 2011). On the other hand, the effect of overall academic quality of the institution on the likelihood to participate in technology transfer and commercialization activities remains unclear. Some authors find a positive relationship between academic excellence and participation in technology transfer (Owen-Smith and Powell, 2001), others find a negative relationship (Krabel and Mueller, 2009).

To test our hypotheses, we employ three additional variables. First, we introduce a dummy variable (minority department) that takes the value 1 if the researcher is employed in a department where women represent less than 15% of the overall faculty members. As discussed previously, minorities representing less than 15% of the larger social group may suffer from tokenism (Kanter, 1977a). Data on the exact gender composition of departments are unfortunately not publicly available in the UK. Instead, we use data from the 2006/2007 extraction of the higher education information database for institutions (HEIDI), which gives the gender breakdown by discipline. We then combine these data with the discipline distribution by university. Five classes of disciplines (see Table B2 Appendix B) can be matched to the respondents in our survey, and we employ the percentage of women in their discipline and in their university to identify minority departments.

Second, we employ a dummy variable (minority discipline) that takes the value 1 if the researcher is employed in a discipline where women faculty members are a minority. As discussed previously, women represent less than half of the faculty in most disciplines; however their presence is especially low in the engineering and technology field (18% of the whole population of researchers and 5% of professors are women). Therefore, we include the following in our definition of minority disciplines: electrical engineering, general engineering, chemical engineering, civil engineering, mechanical engineering, and materials engineering.

Finally, to assess the degree of organizational support for women in academic careers in each university, we use information about universities' membership in the Athena SWAN Charter. As mentioned before, this scheme is designed to certify that efforts of universities help women academic careers, especially in science and engineering. As part of the process of certification, universities are required to submit a dossier describing their efforts support women in science and engineering careers for expert review. This dossier must contain a letter from the head of the university about the organization's action plan for promoting women in academic careers. It should also contain detailed description of university proactive efforts, such as how equity efforts are embedded into university rules, HR practices, and its performance with regards to gender equity, including female and male staff rations and initiatives to address any imbalances. It also requires the university to document what resources, skills and support it offers to its women members of staff, as well as students. These submissions are then reviewed by an independent panel, which decides whether or not to award certification.[6] The adoption of this certification scheme has, however, been mixed. For instance, at the time of the survey (2008), only 34 of 129 higher education institutions in the UK were members. It also lacked a significant profile within the university sector, as funding agencies and the government at the time of our study did not mandate certification and no funding was attached to the scheme. To assess its wider profile, we used Google Trends and found that between 2004 and 2010 there almost no searchers of 'Athena Swan' in Google search, but since then the term has been searched for around 40 times per month. Given the slow uptake of the scheme and its initial low profile, membership provides insight into the level of effort of each university to support women academics at the time of our study. Moreover, each submission is reviewed by the expert panel, ensuring an independent assessment of the measures take, to support women at that organization. Therefore, we employ a dummy variable (Athena), which takes the value 1 if the university was affiliated to the Athena SWAN Charter at any time between 2004 and 2008.

Distribution of individuals by discipline (after the matching), descriptive statistics and correlations are presented in Appendix B, Tables B2 and B3.

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[6] http://www.ecu.ac.uk/equality-charter-marks/athena-swan/join-athena-swan/, accessed September 2014.

4.3. Estimation

To compare women and men directly, we employ a non-parametric matching method. Matching estimators are usually applied to evaluate the effect of a certain treatment (e.g., administration of a drug) on the sub-population of individuals exposed (treated) and the sub-population not exposed to the treatment (non-treated) (Rosenbaum and Rubin, 1983, 1984; Heckman et al., 1998). The idea behind the matching estimator technique is to match each woman with men presenting similar observable characteristics and to compare the average engagement behavior for the two sub-samples of individuals.

The matching estimator is based on the following formulation: let T be the treatment (an indicator of the individual being a woman); let $Y_i(1)$ be the outcome for the treated individual (i.e., the academic engagement index that would be observed were the individual a woman); and let $Y_i(0)$ be the outcome of the non-treated individual (i.e., the academic engagement index that would be observed were the individual a man). What we want to measure is the mean effect on the academic engagement index for a woman (the sample average treatment effect on the treated individual – SATT):

$$\text{SATT} = E[Y\_i(1) - Y\_i(0)|T = 1] = E[Y\_i(1)|T=1] - E[Y\_i(0)|T = 1] \quad (1)$$

Of course, it is not possible to observe the value of $Y_i(1)$ and $Y_i(0)$ for the same individual: the matching estimator approach will use the average outcomes for similar individuals that were not treated. In other words, for each woman, we need to find men with similar observable characteristics. This approach helps to overcome the estimation problems related to the strong gender stratification that exists in science: it has been shown that the use of regression techniques on unbalanced samples can lead to biased estimates of the coefficients (Ho et al., 2007). When the distribution of covariates differs across two groups of observations, regression techniques produce biased estimates, the magnitude of the bias depending on the difference in the covariate distribution (Rubin, 1973). Moreover, in our case there are regions in the covariate space where there are men but no women – this is a frequent occurrence in gender studies (Boyd et al., 2010): parametric model estimations would therefore involve extrapolation beyond what the data support and they would be highly sensitive also to changes in the regression model (Ho et al., 2007).

We test the balance of the sample along several dimensions, which are described in the next section. We employ nearest neighbor matching estimation for average treatment effects across the sample dimensions, which are shown to be unbalanced (Abadie et al., 2004). We choose this method because the control group (men) is significantly large and because this procedure does not require specification and estimation of a model describing the selection mechanism. The algorithm uses pairs observations (in our case female academics) to the closest m matches in the opposite treatment group (male academics) to provide an estimate of the counterfactual treatment outcome. Let N_1 be the number of women, and let $w(i,j)$ be the weight placed on the jth observations of men used to construct the counterfactual for the ith woman. The weight $w(i,j)$ is derived using the distance from the vector of covariates of the ith woman, X_i, to that of the j nearest men. This weight can be set at equal to 1 for a certain set of covariates, meaning that the values for the woman and the matched men will be the same for that particular set of covariates. Following the formalization in Abadie et al. (2004), SATT is computed as:

$$\text{SATT} = \frac{1}{2}\Sigma_{i\epsilon(T_j=1)}\left[Y_i(1) - w(i,j)Y_j(0)\right] \quad (2)$$

For the matching, we utilize the program nnmatch for STATA11 (Abadie et al., 2004), which enables exact matching for a subset of variables (in our case academic position and discipline), bias correction of the treatment effect, and allows for heteroskedastic errors. For every observation, we use two matches to the treatment group. As a robustness check, we ran the same matching procedure with one or three matches to the treatment groups; the results are consistent.

5. Results and discussion

Before reporting the results of the matching procedure, we examine the extent to which women and men differ with respect to the matching variables. It is important to understand the balance of the sample in order to fully appreciate the extent of gender stratification in science. We begin by looking at the balance between the two populations in terms of academic age, academic position, scientific productivity (number of papers and number of citations), research resources, scientific discipline, quality of department of affiliation, type of university awarding the PhD – elite university and British university.

The balance for academic age, scientific productivity, research resources, and quality of the department of affiliation is tested with a Wilcoxon–Mann-Whitney test since the variables are ordinal but not normally distributed (see Table 1). The distribution of these variables for men and women is compared by creating quantile–quantile plots (see Fig. 1). From the tests and the plots, we observe that the sample is balanced along the dimension of quality of the department of affiliation, but unbalanced along all other dimensions. In particular, it is evident that men tend to occupy more senior positions, they publish more, receive more citations to their work, and have been awarded more grants than the women in the sample.

The balance for academic position, discipline, PhD granted from an elite university, and PhD granted from a British university is tested with a chi-square test since the variables are categorical and the expected frequency for every cell is more than 5 (see Table 2). The variables for academic training appear to be balanced in the sample but those relating to academic position and discipline are not. This suggests that women tend to occupy lower status positions in the university and are heavily underrepresented in engineering disciplines; in mathematics, physics and chemistry, the situation appears more balanced.

Table 2
Wilcoxon–Mann–Whitney tests.

	Before the matching		After the matching	
	z	Prob > |z|	z	Prob > |z|
Academic age	7.189	0.0000	1.111	0.2664
Grants from 2000	2.679	0.0074	0.205	0.8373
Publications	5.877	0.0000	0.855	0.3927
Citations	4.364	0.0000	0.508	0.6113
Quality of the department of affiliation	−0.423	0.6723	−0.193	0.8470

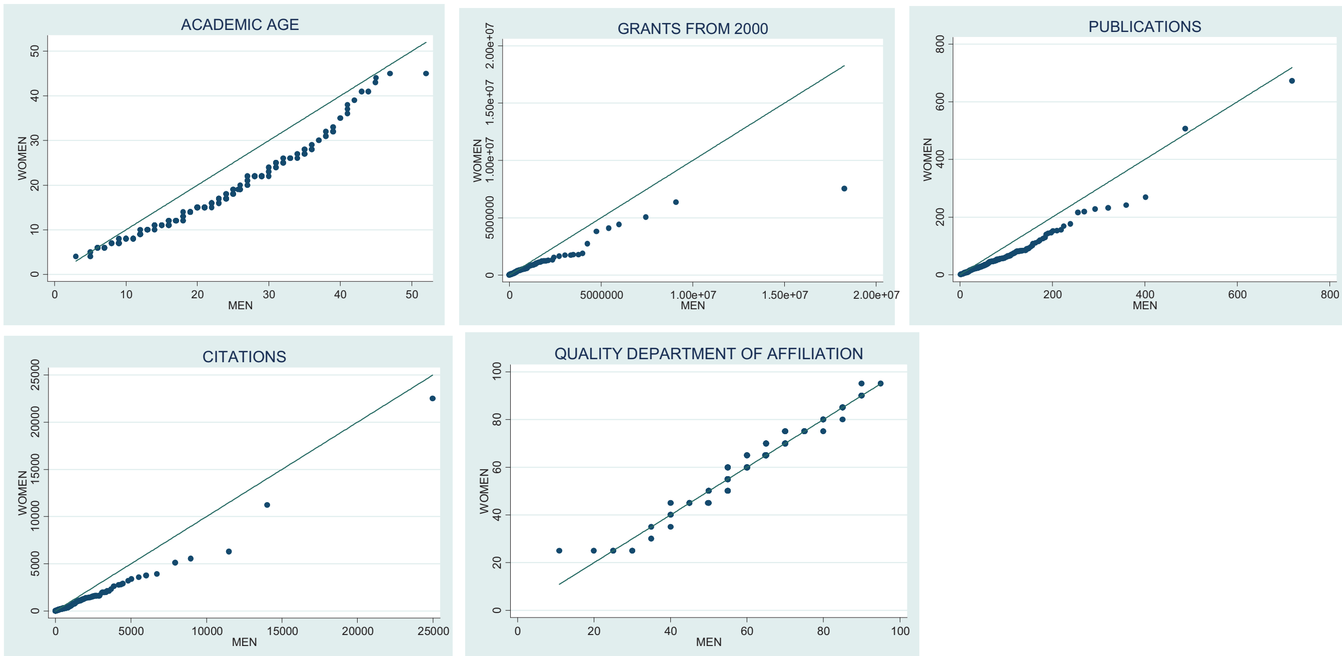

Fig. 1. Quantile–quantile plots, before the matching.

After performing the matching, we check again for imbalances in the sample, across the same dimensions as before. We employ the same techniques as before, and as expected, we find the new sample is correctly balanced (see Tables 2 and 3 and Fig. 2). These results suggest that the matched male academics can be considered sufficiently similar to the women in the sample, and it is therefore possible to estimate the SATT. To be clear, this new balanced sample includes two men of nearly identical academic age, discipline, productivity, resources, and rank to each of the women in our sample.

Table 4 presents the estimates of the SATT of being a woman, on the different industry engagement measures. The results demonstrate that at an aggregate level female researchers collaborate less than their male colleagues (difference = −0.74, p-value < 0.05). We also find that women tend to engage in engagement activities that require a lower commitment in terms of time and resources but may also have lower added-value potential for research (e.g., atten-

Table 3
Chi-square tests.

	Before the matching		After the matching	
	Pearson χ^2	Prob	Pearson χ^2	Prob
Academic rank	29.6200	0.000	0.5016	0.479
UK PhD	1.8960	0.169	0.0001	0.994
Elite PhD	0.0000	0.995	0.0446	0.833
Discipline	39.1255	0.000	3.8612	0.993

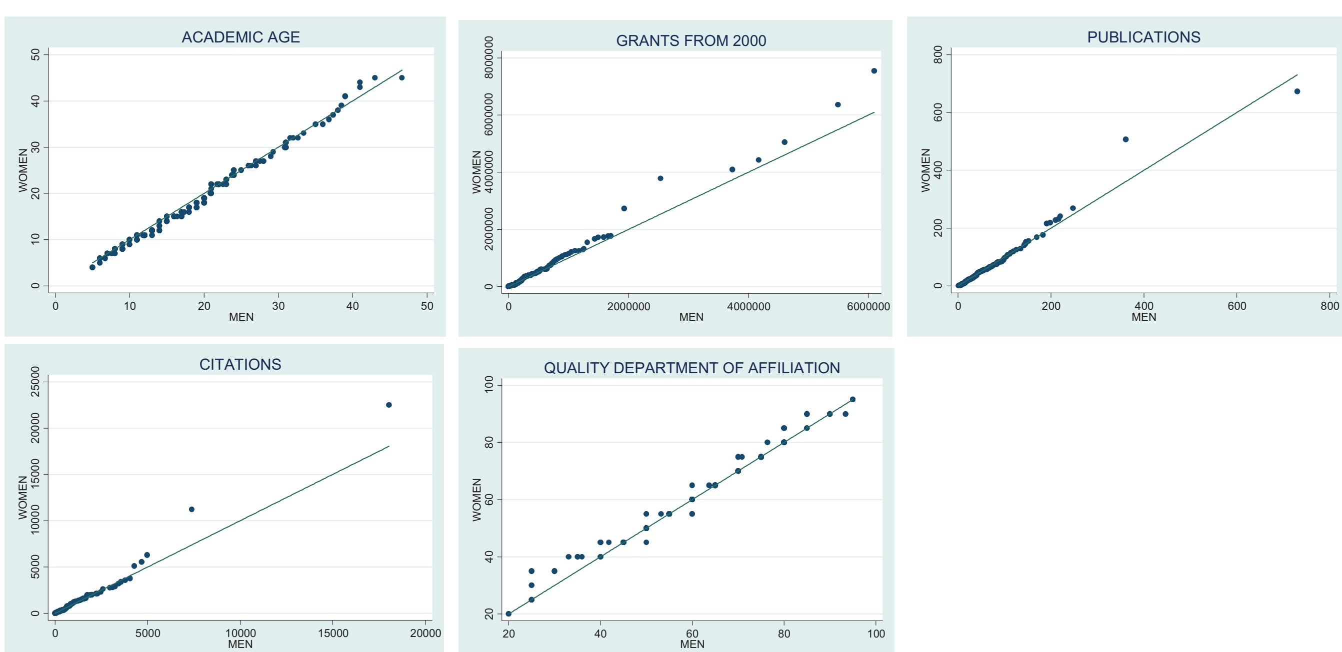

Fig. 2. Quantile–quantile plots, after the matching.

Table 4
Results of neighbor matching procedure.

	Coeff.	Std. error	*P*-value
Academic engagement index	−0.7391	0.3197	0.021
Creation of new physical facilities with industry funding	−0.1790	0.0611	0.003
A new joint research agreement	−0.3460	0.1431	0.016
A new contract research agreement	−0.3324	0.1371	0.015
A new consultancy agreement	−0.2007	0.1310	0.126
Training of company employees	−0.0796	0.1480	0.591
Postgraduate training with a company	−0.0084	0.1373	0.951
Attendance at conferences with ind. and univ. participation	0.0080	0.2191	0.971
Attendance at industry sponsored meetings	−0.3793	0.2157	0.079

Table 5
Test of Hypothesis 2a, 2 independent sample *t*-test (dependent variable = ln(AEI + 1)).

Group	Obs.	Mean	Std. error	Std. dev.
Minority department				
Men	197	1.492	0.057	0.799
Women	118	1.389	0.067	0.724
Difference		0.103	0.09	
H_o: difference = 0		H_a: difference ≠ 0 Pr(*T* > *t*) = 0.2547		
Non-minority department				
Men	141	1.309	0.065	0.773
Women	101	1.246	0.071	0.719
Difference		0.62	0.097	
H_o: difference = 0		H_a: difference ≠ 0 Pr(*T* > *t*) = 0.5239		

dance at conferences with industry participation), while they are less likely to be involved in more intensive channels of interaction such as joint research or contract research agreements. Men in the matched sample on average participated in 1.5 joint research agreements and 1.4 contract research agreements with industry in 2007 and 2008, while women participated on average in just 1.0 joint and contract research agreements in the same period. Therefore, we find support for Hypothesis 1.

Table 5 presents the test for Hypothesis 2a. Using the matched sample of academics, we split the sample into two groups: researchers in departments where women represent less than 15% of the faculty (47% of the sample, corresponding to 263 researchers), and researchers in departments where women represent at least 15% of the faculty (53% of the sample, corresponding to 290 researchers). We cannot assign this variable to four researchers as there were no data available regarding the composition of their departments. We then estimate the average academic engagement of women and men in the two groups: Table 5 shows that there is no difference between men and women engagement in the two groups, which runs contrary to our expectations in H2a.

Table 6 presents the test for Hypothesis 2b. Using the matched sample of academics, we split the sample into two groups: researchers affiliated with disciplines where women represent a significant minority (33% of the sample, corresponding to 183 researchers), and researchers affiliated with disciplines where the presence of women is more pronounced (67% of the sample, corresponding to 374 researchers). We then estimate the average academic engagement of women and men in the two groups: Table 6 shows that the difference in engagement is significant in the minority discipline group but not significant in the comparison group. These results support Hypothesis 2b, suggesting the presence of women in the wider discipline reduces the difference between men and women in terms of industry engagement.

Table 6
Test of Hypothesis 2b, 2 independent sample *t*-test (dependent variable = ln(AEI + 1)).

Group	Obs.	Mean	Std. error	Std. dev.
Minority discipline				
Men	111	1.854	0.059	0.617
Women	72	1.656	0.082	0.695
Difference		0.198	0.098	
H_o: difference = 0		H_a: difference ≠ 0 Pr(*T* > *t*) = 0.0449 H_a: difference > 0 Pr(*T* > *t*) = 0.0225		
Non-minority discipline				
Men	227	1.20	0.052	0.781
Women	147	1.16	0.056	0.682
Difference		0.04	0.079	
H_o: difference = 0		H_a: difference ≠ 0 Pr(*T* > *t*) = 0.6072		

To make sense of these results, we perform an additional test. We separate our population in four groups. The first group (*N* = 243) is composed of researchers who are employed in departments where women represent at least 15% of the faculty and are also affiliated with a non-minority discipline. The second group (*N* = 47) is composed of researchers who are employed in departments where women represent at least 15% of the faculty but are affiliated with a minority discipline. The third group (*N* = 128) is composed of researchers who are employed in departments where women represent less than 15% of the faculty but are affiliated with a non-minority discipline. Finally, the fourth group represents the more marginalized situation for female researchers. Academics in this group (*N* = 135) are employed in departments where women represent less than 15% of the faculty and are also affiliated with a minority discipline. By running the same analysis as before, we can see that the difference in engagement between men and women persists only for researchers in the fourth group (Table 7). A possible reason for finding no differences when we take into account departments rather than discipline is that our measure of gender representation in departments is still too cursory (as the exact data are not publicly available), and the tokenism effect described by Kanter operates at a closer level to the individual. However, we think it is interesting to note that women representation in the wider scientific discipline appears to have an effect on industry engagement, suggesting the macro-level rather than micro-level plays a more prominent role in shaping the engagement gap.

Table 8 presents an analogous test for Hypothesis 3. Here, we split the sample into two groups according to university signature of the Athena SWAN Charter. At the time of the survey, 69% of the researchers in the matched sample were affiliated to an institution that is a member of the Charter. Based on Charter affiliation, we

Table 7
Groups of representation, 2 independent sample *t*-test (dependent variable = ln(AEI + 1)).

Group	Obs.	Difference	Std. error
Group 1: non-minority dept., non-minority discipline H_o: difference = 0	243	0.065 H_a: difference ≠ 0 Pr(*T* > *t*) = 0.5001	0.097
Group 2: non-minority dept., minority discipline H_o: difference = 0	47	0.237 H_a: difference ≠ 0 Pr(*T* > *t*) = 0.2016	0.183
Group 3: minority dept., non-minority discipline H_o: difference = 0	128	0.002 H_a: difference ≠ 0 Pr(*T* > *t*) = 0.9899	0.139
Group 4: minority dept., minority discipline H_o: difference = 0	135	0.188 H_a: difference ≠ 0 Pr(*T* > *t*) = 0.1147 H_a: difference > 0 Pr(*T* > *t*) = 0.0574	0.118

Table 8
Test of Hypothesis 3, 2 independent sample *t*-test (dependent variable = ln(AEI + 1)).

Group	Obs.	Mean	Std. error	Std. dev.
Athena SWAN–affiliated institution				
Men	237	1.382	0.05	0.777
Women	145	1.371	0.06	0.726
Difference		0.012	0.08	
H_o: difference = 0		H_a: difference $\neq$ 0 Pr($T > t$) = 0.8810		
Athena SWAN–non-affiliated institution				
Men	101	1.492	0.082	0.826
Women	74	1.231	0.083	0.713
Difference		0.262	0.119	
H_o: difference = 0		H_a: difference $\neq$ 0 Pr($T > t$) = 0.0297		
	H_a: difference > 0 Pr($T > t$) = 0.01748			
Athena SWAN–silver or gold prize winner institution				
Men	62	1.398	0.107	0.844
Women	48	1.369	0.112	0.782
Difference		0.027	0.157	
H_o: difference = 0		H_a: difference $\neq$ 0 Pr($T > t$) = 0.8662		
Athena SWAN–non-affiliated institution and affiliated institution without prize				
Men	276	1.42	0.047	0.782
Women	171	1.31	0.054	0.708
Difference		0.109	0.073	
H_o: difference = 0		H_a: difference $\neq$ 0 Pr($T > t$) = 0.1368		
		H_a: difference > 0 Pr($T > t$) = 0.0684		

observe that the difference in academic engagement between men and women researchers in Athena SWAN institutions is no longer significant but remains significant for women in non-Athena SWAN organizations. We repeated the analysis splitting the sample into two groups – one group included institutions awarded silver or gold by the Athena SWAN Charter (20% of the matched sample), the other group included the rest of the sample. To qualify for a silver or gold award, the institution must demonstrate that its diversity efforts have improved working conditions for women scientists. Our analysis of this selected group of institutions is consistent with the prior analysis. This supports Hypothesis 3 and points clearly to the importance of proactive policies for nurturing women academics' activities.

5.1. Robustness checks

In this section, we examine a range of alternative explanations for these results, drawing on the literature on the structural disadvantages for women in science. First, several authors observe that women lack exposure to the commercial sector and the composition of their professional networks is different to those participated in by men (Ding et al., 2006; Murray and Graham, 2007). To begin with, we run a regression on the matched subsample with the AEI as a dependent variable. In particular, we interact gender with a variable measuring the years the researchers may have spent as an employee in industry. The results of this econometric analysis show no effect of work experience in industry on mitigating gender differences.[7] We also explore differences between women and men in the matched sample with respect to their experience in entrepreneurship during their careers. Our survey asked academics whether they had been involved in starting a new firm during their professional career, and if so the year the firm was founded. When we compare the balanced population of men and women academics with respect to lifetime entrepreneurship, we find no statistically significant differences (chi-square test, Pearson $\chi^2(1) = 0.0302$, Pr = 0.862).

Second, women scientists and engineers may have less well-developed social networks than their male counterparts (Ibarra, 1993). To capture this effect, we compute the number of different co-authors with whom the academic has worked over her/his career. Analogous to how we examined industry experience, we test whether this social capital measure reduces the effect of gender on academic engagement. Again, we find no statistically significant effect. These results seem to indicate that the matching procedure takes account of the differences in researchers' social capital.

Third, the disproportionate burden of domestic responsibilities on women may contribute to explain differences in industry engagement. While the researchers in our matched sample had similar levels of productivity and similar seniority in institutions of comparable quality, academic engagement remains a partly a discretionary activity (Tartari and Breschi, 2012). Since domestic responsibilities tend to fall primarily on women, we expect that women will have less time available for engagement with industry and that this effect will be more pronounced for women academics with young children (Rhoads and Rhoads, 2012). Since we lack information on the presence of children or the domestic activities of the women and men in our sample, we use researchers' age as a proxy for the presence of young children in the home. For the reasons outlined above, we expect that younger women will have less time left to engage with industry compared to their male colleagues in the same age group. We therefore split the matched sample into two groups: junior academics (born after 1963) and senior academics (born before 1963). This should help to ensure that the chances for the group of senior academics of having young children are relatively low.[8] We then compare the difference in academic engagement of women and men in each the two groups. While the difference in engagement between senior female and male researchers is no longer significant, significant differences persist between women and men in the junior group, with men engaging more than their female colleagues (two-sample *t*-test with equal variances, diff = 0.133, Ha: diff > 0 Pr($T > t$) = 0.0926). As an additional robustness check, we lower the age cut off for male and women academics to those born after 1958; the results are consistent. This suggests that the lack of available time due to domestic responsibilities may be a significant barrier to academic engagement for younger women academics, although this finding requires further corroboration.

Fourth, the literature points to the importance of collegial support and institutional assistance for women academics, and although these efforts do not usually concern facilitating women's engagement with industry, they might serve to free up time and space for these efforts within their broader portfolio of work. This is highlighted in our analysis by the strong moderating effect of institutional affiliation with the Athena SWAN Charter. To investigate this further, we explore whether the moderating effect of institutional support persists if we consider only the group of junior academics where the difference in engagement between women and men is more pronounced. We repeat the same test used for Hypothesis 2a and b on the subgroup of junior academics, and again find a strong and positive effect of Athena SWAN affiliation. Indeed, for those academics working in an Athena-affiliated university, the difference in engagement activities between men and women is no longer significant (two-sample *t* test with equal variances, diff = −0.01, Ha: diff $\neq$ 0 Pr($|T| > |t|$) = 0.5477) but remains significant for those junior academics in institutions not affiliated to Athena (two-sample *t* test with equal variances, diff = 0.453, Ha: diff > 0 Pr($T > t$) = 0.0026). These results highlight that mechanisms to support the early careers of women in science may help to free time and resources to enable engagement with industry partners.

Fifth, we explore the possibility that differences in engagement with industry might be driven by differences in the importance

[7] Regression results are available from the authors upon request.

[8] Since there were some missing values for year of birth, we repeated the analysis with academic age (years elapsed since granting of PhD); the results were consistent.

women and men attribute to different motivations in their professional careers. Motivational factors can be categorized as extrinsic or intrinsic (Amabile, 1996; Ryan and Deci, 2000). Individuals are intrinsically motivated if they seek benefits that originate within themselves and the tasks they are performing; they are extrinsically motivated if they value the benefits provided by an external entity. Both categories of motives have been employed in analyses of scientists' activities (Giuri et al., 2007; Sauermann and Cohen, 2010). Although intrinsic motives have been long associated with scientific work (Hall and Mansfield, 1975), extrinsic benefits such as financial rewards and prestige are also powerful drivers of scientists' activities (Stephan, 1996). While we have no theoretical expectation that would lead us to believe that women and men differ in their personal evaluations of extrinsic and intrinsic benefits of professional careers, we recognize that gender differences in this area may affect our results. We therefore compare women and men in the matched sample according to the importance they attribute to extrinsic vs. intrinsic motivations in their professional careers. Career motivations are measured by a question that asked researchers to rate the importance (on a 5-point Likert scale) of a set of benefits deriving from their profession as researchers, ranging from salary to intellectual challenge. Following the approach in Sauermann and Cohen (2010), we draw on a question about career motivations in the NSF Survey of Doctorate Recipients.[9] Factor analysis (principal component-factor, orthogonal Varimax rotation) identifies two factors each comprised of four items (extrinsic: salary, benefits, job security, opportunities for career advancement; intrinsic: intellectual challenge, level of responsibility, degree of independence, contribution to society). We performed an independent sample *t*-test for both variables (which are normally distributed) and found no significant differences between women and men.

Finally, we explore the possibility that results are driven by the structure of our dependent variable, which is based on an index of different engagement types. We have ran the same analysis by using reduced versions of the index (including only the first three or four most common types of engagement) and the simple sum of all engagement activities (not weighted). The results remain unchanged.

6. Conclusions

Our study suggests that women engage in less with industry than their male counterparts with industry. Although these results are consistent with prior work on the differences between men and women academics in relation to formal technology transfer, they enrich our understanding of where and how these differences are manifested. In particular, by using a matching estimator, we are able to develop a potentially more reliable way of comparing two populations that are characterized by different structural properties (Boyd et al., 2010). In doing so, we are able to show that men and women of equal scientific, institutional and professional status do differ with regards to academic engagement with industry, with women appearing to take up joint research projects and consulting agreements than their men. Although we are unable to identify the exact causal mechanisms that give rise to these differences, our study helps advance understanding of the presence and nature of these gender differences. In doing so, it helps to provide new evidence about how gender differences are manifest in academic engagement with industry across a range of disciplines and universities.

Our analysis focused on three different contextual factors that may attenuate gender differences with regards to academic engagement with industry. First, we found that the presence of women in the wider discipline reduces gender disparities, with the corollary that these differences are magnified in fields with very few women. This suggests that diversity at field or reference level – in our setting the wider scientific discipline – can play an important role in shaping the choices of women academics about when and how to engage with industry partners. Critically, where women are operating in a skewed group, there is a danger that they will avoid engagement activities with industry that require efforts beyond their formal job requirements. Thus, the level of diversity in the wider field may help women to identify role models, find mentors and other forms of social support that will promote their engagement with industry (Etzkowitz et al., 2000). This result is consistent with the idea that increasing diversity across the wider field can help members of minority groups achieve their personal goals in their specific workplaces (DiTomaso et al., 2007). Second, contrary to our initial expectations, we found little evidence that the presence of women in the local work context helps to attenuate differences between men and women with respect to academic engagement with industry. This result may be due to the fact that we unable to obtain precise, granular measures of the presence of women in each local work context. It may also be due to the lack of importance of women in the immediate work context in shaping patterns of academic engagement. One suggestion that emerges from our findings is that macro-level rather than micro-level context matters more for explaining the engagement gap between men and women. However, this statement is only tentative and future research should give more attention to the role of other women in the local work context.

Third, our findings point to the critical importance of organizational-level commitment to women's scientific and engineering careers in shaping women's industry engagement efforts. We found that the difference between men and women in engagement efforts was present only in organizations with no significant formal commitment to supporting women in science and engineering academic careers. Moreover, the stark differences between younger women and male academics in industry engagement are attenuated in universities that are committed to promoting women in science and engineering. This suggests that policies designed to help women in science may be an effective means to enable women to engage with industry as a critical element in their academic careers. Since our approach focused on organizational membership in broad certification institutional-level programs, we are unable to comment on the specific content of different universities policies and their effectiveness (Kalev et al., 2006). Future research could investigate what types of policies most benefit women academics in the various aspects of their job roles (Williams and Ceci, 2010). It would also be useful to know how these policies play out at more local levels, such as the department or research team.

Although not directly addressed in this paper, the experience of women academics in engineering and physical sciences fields may be magnified by the male-dominated nature of industry. Indeed, it could be argued that women academics in these disciplines are trapped within a "double ghetto" (Armstrong and Armstrong, 1984). They work in male-dominated environments within their universities and their disciplines, and when they try to collaborate with industry, they face barriers to the more rewarding types of industry engagement in part because they are again trying to enter a male-dominated environment. Therefore, the possibilities of career development for women researchers are hampered not only by a dearth of role models in academia, but also by a lack of female peers in industry. Future research could explore how patterns of gender stratification in academia may be amplified within the widespread gender stratification in science and engineering professions more in general. In this context, efforts to enable women academics to achieve success in these skewed environments may also require

[9] http://www.nsf.gov/statistics/srvydoctoratework.

changes to help ameliorate the underrepresentation of women in industry.

This research has some policy implications. As government budgets come under increasing pressure, there is a stronger emphasis in policy to ensure that public investments in research generate social and economic benefits. Increasingly governments are attempting to target funding toward those academics that are successful at engaging with industry, placing "impact" alongside "quality" in the allocation of funding to researchers. For example, the UK research councils require academics to submit a "pathway to impact" to accompany their grant proposals and where two proposals are weighted evenly for academic merit, the one claiming higher potential impact will be awarded the funding.[10] The pathways to impact submissions often rest on the ability of the grant applicant to secure letters of support or other institutional commitment to the research, prior to its funding. This system could have unintended consequences for women in academia. Women may appear less able to secure funding, although the granting agencies are making active efforts to monitor gender bias. More likely, the effect of these requirements will be to shape the decision of women academics to apply for funding because they lack the necessary contacts with industry to present a compelling case related to the future impact of their work. Moreover, university managers may look for evidence of engagement with industry in addition to traditional measures of academic achievement, which may further exacerbate the challenge that women academics face in the formative stages of their careers.

As our study suggests, it is crucial that policy makers and university administrators implement effective measures to reduce the gender gap in academic science and also to encourage women to participate more actively in academic engagement with industry. This process needs to be handled carefully. In the US, the system of quotas for minorities (either women or members of different ethnic groups) has been accused to create stigma for the beneficiaries, making them appear less worthy than their peers (Heilman et al., 1997; Etzkowitz et al., 2000). It should be remembered also that much of the process through which disadvantages are created and reinforced occurs at the level of the department or research laboratory. It is important to design policies applicable to both the university and the department level. These policies could include bottom-up initiatives aimed at celebrating women role models, creating time and space for research and therefore industry engagement, and dedicating resources for supporting young women scientists to build and broaden their professional network so that they can access to the so-called "Kula ring of power." Note also that many of the approaches to support women in science will benefit male academics equally.

Our paper has some important limitations. While we believe our matching procedure helps to ensure more precise estimation of gender differences in academic engagement activities, we cannot fully test potential explanations for why these differences persist. This is because we rely on information from a limited number of women which however reflects the actual composition of UK departments in science and engineering disciplines. Like prior studies in this area of research, we also lack information on male and female academics' domestic responsibilities such as childcare, and career breaks due to those responsibilities. Although we control for productivity and resource differences (the primary areas impacted by these domestic responsibilities for women academics), information about children and career breaks might explain some of the differences observed in industry engagement patterns (Williams and Ceci, 2010). There are also other areas of academic engagement, such as pressures for secrecy or publication delays from industry, which might present additional challenges for women scientists. Since we lack information on how academic engagement with industry varies over time and how women (and men) build capacity to successfully engage with industry, we are unable to draw any inferences about how engagement differences shape academic career pathways. Finally, our research attempts to compare men and women at working in similar institutional settings, but it may be other features of the institutional context shape the engagement gap. In particular, future research could explore differences between men and women are magnified (or not) across disciplines; national contexts; and university types.

More insights into the challenges and opportunities that women academics face in their work, especially when they engage with non-academics, might ensure that the full potential of these talented and dedicated individuals is realized at both personal and societal level.

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Appendix A.

Distribution of women scientists across role and disciplines, UK universities, 2006/2007.

Source: HESA data, Staff Collection 2006/2007.

	Medicine, dentistry & health		Agriculture, forestry & veterinary science		Biological, mathematical & physical sciences		Engineering & technology		Architecture & planning		Administrative, business & social studies		Humanities & language based studies & archaeology		Design, creative & performing arts		Education	
	Professor	Other	Professor	Other	Professor	Other	Professor	Other	Professor	Other	Professor	Other	Professor	Other	Professor	Other	Professor	Other
Women	885	18975	15	750	240	6105	95	3080	20	675	690	8770	375	4515	60	4155	165	5400
Men	2855	12950	145	940	2860	12545	1970	12775	240	1655	3000	12140	1445	4725	340	5350	380	4465
Total (by role)	3740	31925	160	1690	3100	18650	2065	15855	260	2330	3690	20910	1820	9240	*400*	*9505*	*545*	*9865*
Total (all roles)	35665		1850		21750		17920		2590		24600		11060		9905		10410	
% women (all roles)	56%		41%		29%		18%		27%		38%		44%		43%		53%	
% women (by role)	24%	59%	9%	44%	8%	33%	5%	19%	8%	29%	19%	42%	21%	49%	15%	44%	30%	55%

Notes:

1. **Professor** includes heads of departments, professors, researchers (former UAP scale grade IV), and clinical professors

[10] http://www.rcuk.ac.uk/kei/impacts/Pages/home.aspx, accessed March 2013.

2. **Other** includes principal lecturers, senior lecturers (former UAP/CSCFC scales), researchers (former UAP scale grade III), clinical senior lecturers, lecturers, senior lecturers (former PCEF scale), clinical lecturers, and all research grades (former PCEF/CSCFC/UAP scale) not listed above.

Appendix B.

Table B1
Types of researchers' interaction with industry.

Type of interaction (j)	Frequency %, men ($b_j = 1$)	Frequency %, women ($b_j = 1$)
Attendance at conferences with industry and university participation	83	88
Attendance at industry sponsored meetings	64	63
A new contract research agreement (original research work done by University alone)	58	54
A new joint research agreement (original research work undertaken by both partners)	58	51
Postgraduate training with a company (e.g., joint supervision of PhDs)	49	44
A new consultancy agreement (provision of advice that requires no original research)	48	41
Training of company employees	31	27
Creation of new physical facilities with industry funding	18	9

Table B2
Discipline distribution.

Discipline	Minority	N	Mean AEI	Std. dev.
Medicine	0	23	1.55	0.59
Biological, mathematical and physical sciences	0	297	1.12	0.74
Engineering and technology	1	183	1.77	0.65
Social studies	0	45	1.36	0.75
Humanities	0	9	1.24	0.71

Table B3
Descriptive statistics and correlation matrix (observations included in the main model specification).

		Mean	Std. dev.	Min	Max	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]
[1]	AEI	1.371	0.773	0	3.527	1.00																	
[2]	Women	0.398	0.49	0	1	−0.07	1.00																
[3]	Minority discipline	0.326	0.469	0	1	0.37	0.04	1.00															
[4]	Athena	0.702	0.458	0	1	0.01	−0.07	−0.01	1.00														
[5]	Industry experience	3.247	5.986	0	40	0.04	0.03	0.02	−0.03	1.00													
[6]	Junior	0.435	0.496	0	1	0.02	0.04	0.01	−0.02	−0.19	1.00												
[7]	Co-authors	79.747	83.431	0	637	−0.05	0.03	0.03	0.09	0.01	−0.12	1.00											
[8]	Entrepreneur	0.292	0.455	0	1	0.00	0.03	0.06	0.01	0.20	−0.14	0.04	1.00										
[9]	Grants from 2000	448947	840178	0	7549490	0.17	0.03	0.04	-0.04	−0.02	−0.01	−0.03	−0.02	1.00									
[10]	Publications	51.127	72.5	1	734	0.15	0.00	−0.01	-0.09	−0.04	−0.02	0.05	−0.01	0.36	1.00								
[11]	Citations	731.924	1800	0	22493	0.07	0.01	−0.10	-0.09	−0.02	−0.02	0.10	0.00	0.32	0.93	1.00							
[12]	Academic age	17.057	8.511	4	48	0.11	−0.04	0.08	0.01	0.00	−0.01	0.04	0.03	0.28	0.34	0.32	1.00						
[13]	Professor	0.384	0.487	0	1	0.20	−0.05	0.06	0.00	−0.03	−0.06	−0.04	0.01	0.30	0.33	0.25	0.54	1.00					
[14]	UK PhD	0.84	0.367	0	1	−0.01	0.01	0.04	0.00	0.13	−0.08	0.07	0.03	−0.01	−0.08	−0.09	−0.06	−0.08	1.00				
[15]	Elite PhD	0.409	0.492	0	1	−0.05	−0.01	−0.04	0.15	−0.02	0.01	−0.01	0.00	−0.01	0.03	0.04	0.01	−0.01	0.14	1.00			
[16]	Department quality	62.31	15.287	20	95	0.04	0.03	0.03	0.28	−0.01	0.05	0.06	0.07	0.02	0.02	0.03	0.09	−0.01	−0.05	0.15	1.00		
[17]	Department income from ind.	583439	849962	0	4643718	−0.02	0.04	0.06	0.04	0.08	−0.06	−0.02	0.04	0.04	−0.03	−0.02	−0.03	−0.02	0.03	0.08	0.24	1.00	
[18]	University quality	2.676	0.2	1.85	3.15	0.02	−0.04	0.06	0.45	−0.10	0.06	0.14	0.04	0.01	0.01	0.02	0.08	−0.03	−0.09	0.29	0.62	0.15	1.00

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