Is it a man's world? Gender differences in university – industry collaboration activities[1]

Valentina Tartari[2]

Ammon Salter

Innovation and Entrepreneurship Group
Imperial College Business School
Imperial College London
South Kensington Campus
London, United Kingdom
SW7 2AZ

The participation of women in science and in particular the presence of an 'attainment gap' has been for long a topic of both policy and scholarly debate. Several studies in the 1990s showed that there is a gender gap in science, with women scientists exhibiting lower scientific productivity, gaining fewer recognitions and rewards, and attaining promotion more slowly than their male colleagues (Long & Fox, 1995). Numerous explanations have been put forward in the literature for this gap. Gupta and colleagues (2005) observe that women suffer from a triple burden: unfavourable work environment, disproportionate domestic responsibilities and a social capital deficit. The male-dominated academic and professional cultures have been often referred as the "gentlemen's club", the "barrack yard" and the "locker room": in these environments women are under-represented (if not absent at all) and often occupy low-status positions. Moreover, women in science have less rich and diverse social capital and fewer bridging ties than their male colleagues: women tend to be excluded from the "Kula ring of power", the informal gatherings in science where resources, knowledge and reputation is exchanged and developed (Etzkowitz, Kemelgor, & Uzzi, 2000). There is also a lack of relevant role models (Etzkowitz, Kemelgor, Neuschatz, Uzzi, & Alonzo, 1994): "far fewer alpha females than alpha males are available as role models" (Faulkner, 2006). Women generally lead smaller labs, have less resources and therefore less opportunities (Murray & Graham, 2007). Although some studies have shown that this attainment gap is narrowing (Holden, 2001), women still appear to be significantly less likely than their male colleagues to be engaged in formal technology transfer (Ding, Murray, &

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[2] Corresponding author. Email: v.tartari@imperial.ac.uk

Stuart, 2006), which has become a relevant source of non-salary remuneration for faculty and may provide an important source of inspiration for future research.

Our current understanding of gender differences in university-industry collaboration activities leaves something to be desired. Past studies have focused on a single measure of technology transfer, academic patenting, which is relatively rare for all university scientists (Agrawal & Henderson, 2002). In addition, these studies have also only explored a single scientific discipline, namely life sciences, in which women are more likely to be represented than other scientific fields. Given that there are few women (and men) that are engaged in this form of technology transfer, there is a significant danger that the results of these studies are dependent on a small number of individuals working in selected institutions and disciplines. Moreover, studies of performance differences between the sexes in science face some important methodological challenges, as the gender stratification in science is still very much present (women scientists are to be found predominantly in junior positions). This means that past studies are likely to have compared female and male populations with very different characteristics, such as tenure and scientific productivity, potentially leading to biased estimation of the effects of gender on technology transfer behaviour. To overcome these methodological issues, we draw information from a unique dataset, covering a population of 6,200 academic researchers in the UK listed as principal investigators or co-investigators in grants awarded by the EPSRC (Engineering and Physical Sciences Research Council) from 1992 to 2006. We addressed a survey questionnaire to these academics, focussing on a wide range of collaborative activities with industry, such as contract research agreements, joint research projects, consultancy, personnel training etc, and thus overcoming the tendency in the preceding literature to focus on a limited range of formal technology transfer activities. We obtained a total of 2,194 completed questionnaires, corresponding to a response rate of 36%. Each respondent has been linked to information gathered from additional datasets: Research Assessment Exercises (RAE) 2008 scores; data on universities' funding sources collected by the Higher Education Funding Council for England (HEFCE) and publication records.

As far as the dependent variable is concerned, we cover a broad range of industry engagement forms, from attending conferences with industry participants to joint research agreements to venture creation: our approach allows us to capture more common and diverse forms of technology transfer activities, enabling us to explore the differences in both the depth and the width of engagement between women academics and their male colleagues. We use two different approaches to analyse these differences. First of all, in order to capture in a synthetic measure both the variety of forms of engagement and the intensity of collaboration, we build an individual *industrial involvement index* (III), as a modified version of the index developed by Bozeman and Gaughan in 2007 (Bozeman & Gaughan, 2007). Our survey data contains information on the types and frequencies of academics' industry engagement which we used for constructing the index (see Table 1). The industrial involvement scale is constructed as follows. For every type of industry engagement, we established whether a researcher had collaborated or not ('occurrence', denoted by b_j) (see Table 2 for how we coded response items). We then computed the frequency for each type of engagement for the whole population:

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

where j is the type of industry engagement, n is the individual and N is the total sample (N=1,895). We then constructed the index by multiplying the actual number of interactions declared by each academic for each channel (*Tj*) and the frequency of its non-occurrence (1 - f_j) and summing all the scores together:

$$III^n = \sum_{j=1}^{8} T_j^n \cdot (1 - f_j) \qquad (2)$$

The index takes into account the "difficulty" and rareness of certain activities, such as the creation of new physical facilities, relative to others, such as attending industry sponsored meetings. We extend the measure proposed by Bozeman and Gaughan (2007) as we use more granular information taking into account the actual volume of occurrence of the different types of engagement for every individual, as opposed to the simple occurrence. Second, in order to understand if women and men engage in different types of collaborative activities, we use the volume of each channel of interaction by itself (T_j).

We tested the balance of the sample along several dimensions: academic age, academic position, scientific productivity (number of papers and number of citations), amount of grants received from 2000, scientific discipline, quality of the department of affiliation, PhD granted from an elite university (ranked in the Times Higher Education 200 best universities list), PhD granted from a British university. The balance for academic age, scientific productivity, amount of grants received, and quality of the department of affiliation has been tested with a Wilcoxon-Mann-Whitney test as the variables are ordinal but cannot be assumed to be normally distributed. The distribution of these variables for males and females has also been compared through the creation of quantile-quantile plots (see Table 3 and Figure 1). The balance for academic position, discipline, PhD granted from an elite university and PhD granted from a British university has been tested with a chi-square test as the variables are categorical and the expected frequency for every cell is larger than five (see Table 4). A balancing approach helps to overcome the estimation problems related to the strong gender stratification that exists in science. Furthermore, it has indeed been shown that the use of regression techniques on unbalanced samples lead to biased estimates of the coefficients (Ho, Imai, King, & Stuart, 2007). To solve these problems we employ a nearest neighbor matching estimation for average treatment effects across the dimensions which showed to be unbalanced in the sample: academic age, academic position, scientific productivity, amount of grants received from 2000 and scientific discipline. The algorithm used 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. To perform the matching, we utilize the program *nnmatch* for STATA11 (Abadie, Drukker, Leber Herr, & Imbens, 2004), which allows exact matching for a subset of variables (in our case academic position and discipline), bias correction of the treatment effect and also allows for heteroskedastic errors. For every observation, we use two matches in the treatment group.

The results of analysis demonstrate that female researchers collaborate less than their male colleagues (difference = -0.74, *p-value* < 0.05). We also find that women tend to engage in collaboration activities (such as attending conferences with industry participations) that have lower added-value potential for research, while they are less likely to be involved in more rewarding channels of interaction, such as joint research or contract research agreements (respectively, difference = -0.35, *p-value*<0.05; difference = -0.33, *p-value*<0.05). The full results are presented in Table 5.

Several explanations have been put forward in the literature to explain these differences. First of all, it has been claimed that women exhibit a lack of exposure to the commercial sector and that the composition of their professional networks is different from those of men. We have explored this explanation by looking at the differences in the number of years of work experience in the private sector (Two-sample Wilcoxon rank-sum test, Prob > |z| = 0.5042) and the experience as entrepreneurs (Chi-square test, Pearson chi2(1) = 0.0302, Pr = 0.862): neither of these variables are statistically different between women and men in the matched sample. From this analysis, female academics seem to have similar work experiences outside academia than men; however, the results of the matching procedure show that women are less likely to attend industry-sponsored meetings than their men counterparts and therefore they may have fewer occasions to build a professional network including people working in industry. Another possible explanation present in the literature highlights the importance of collegial support and institutional assistance given by women who want to be involved in collaborative activities with industry. Looking at our matched sample, we can see that women are more likely to perceive their department as an obstacle to their engagement activities (Fisher's exact = 0.073) and this may lower their willingness to participate in these activities. We have also explored if there are any differences between junior and senior female scientists and we found that the difference in engagement activities is not significant (Two-sample Wilcoxon rank-sum test, Prob > |z| = 0.1589). There are two mechanisms at play regarding seniority that may lead to a confounding overall effect: younger women may have higher constraints from family (for example children) and therefore have less time to pursue commercial activities. On the other hand, younger women have been trained in a period in which commercial activities inside universities are seen as more legitimate and in which women participation in science has increased across all disciplines. To try to separate these two effects, we examine if there are any differences in the shape of the distributions of the dependent variable for junior women vs. junior men, and senior women vs. senior men. For the junior group, men have a higher value of skewness of the distribution, while for the senior group it is the other way around. Moreover, engaging in less rewarding collaborative activities can engender a vicious circle for women: low value engagement leads to fewer possibilities for publications in scientific outlets from their external engagement, and as a result, women end up being less productive and therefore less likely to be promoted, delaying opportunities to obtain higher autonomy and greater responsibility in their careers. In this sense, women academics appear to be to be trapped in a “double ghetto” (Armstrong & Armstrong, 1984) - they work in male-dominated environments within their universities and their disciplines (especially in physical sciences) and, when they seek to collaborate with industry, they lack access to rewarding sources of industry engagement, in part because they are again faced with male-dominated environment. It is therefore not only the lack of role models in academic life which hinders the possibilities of career development for women researchers, but is also the lack of peers of the same gender in industry. Finally, from a methodological perspective, we think that our matching procedure ensures a more precise estimation of this gender differences in academic technology transfer activities, helping to more clearly identify the challenges and constraints women academics face in working in the predominately ‘man’s world’ of science.

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Tables and Figures

Table 1: 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 (through course enrolment or through temporary personnel exchanges)	31	27
Creation of new physical facilities with industry funding (e.g. new laboratory, other buildings in campus)	18	9

Table 2: Coding of occurrences of researchers' engagement with industry

Questionnaire answer (category)	0	1-2	3-5	6-9	>10
Occurrence (b_j)	0	1	1	1	1
Volume of interaction (T_j)	0	1.5	4	7.5	10

Table 3: Wilcoxon-Mann-Whitney tests

	z	**Prob > $\lvert z \rvert$**
Academic age	7.189	0.0000
Grants from 2000	2.679	0.0074
Publications	5.877	0.0000
Citations	4.364	0.0000
Quality of the department of affiliation	-0.423	0.6723

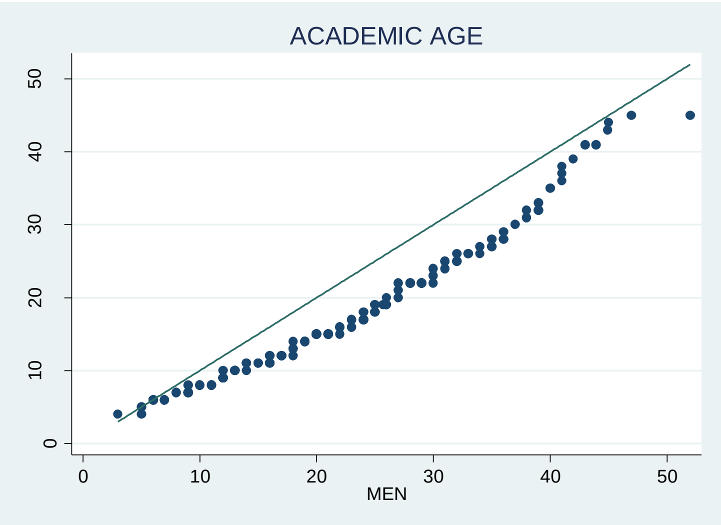
Table 4: Chi-square tests

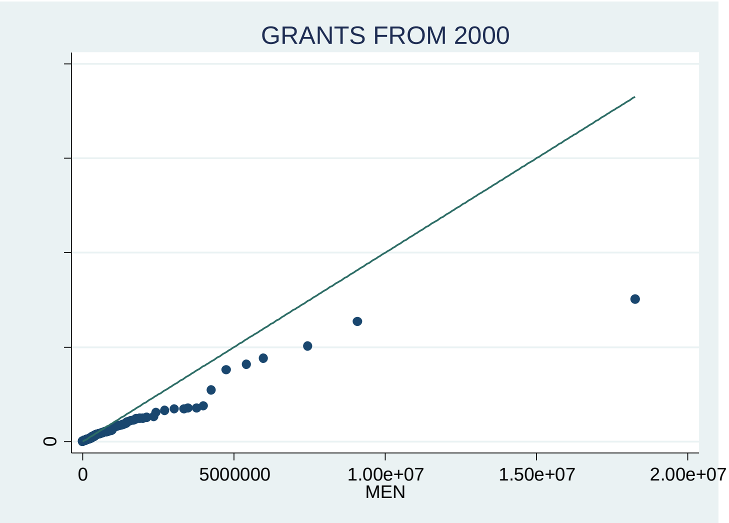
	Pearson χ^2	Prob
Academic rank	29.6200	0.000
UK PhD	1.8960	0.169
Elite PhD	0.0000	0.995
Discipline	39.1255	0.000

Table 5: results of neighbour matching procedure

	Coeff.	Std. Error	P-value
Industrial Involvement 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 industry and university participation	0.0080	0.2191	0.971
Attendance at industry sponsored meetings	-0.3793	0.2157	0.079

Figure 1: Quantile-Quantile plots

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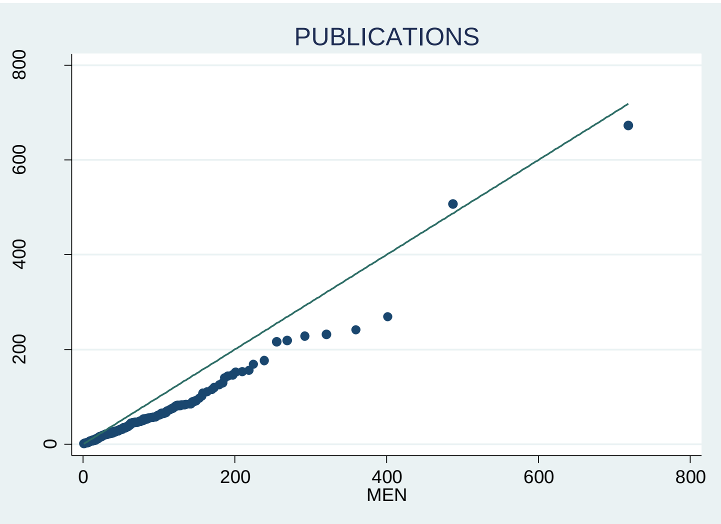
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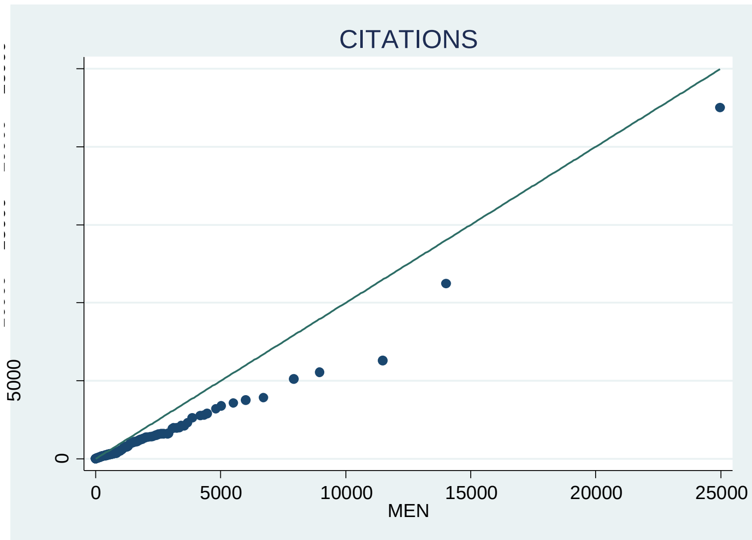
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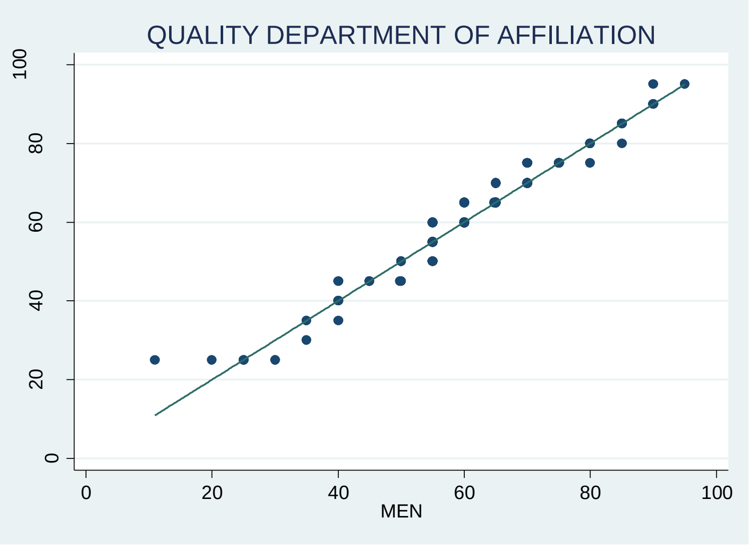
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