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Science **313**, 665 (2006);
DOI: 10.1126/science.1124832

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Gender Differences in Patenting in the Academic Life Sciences

Waverly W. Ding,[1] Fiona Murray,[2] Toby E. Stuart[3]*†

We analyzed longitudinal data on academic careers and conducted interviews with faculty members to determine the scope and causes of the gender gap in patenting among life scientists. Our regressions on a random sample of 4227 life scientists over a 30-year period show that women faculty members patent at about 40% of the rate of men. We found that the gender gap has improved over time but remains large.

The gender gap in academic science is a topic of ongoing policy and scholarly debate. Studies in fields as diverse as engineering and biology have found that women scientists suffer from an attainment gap along at least three important dimensions: productivity, recognition, and reward (*1*–*4*). Fortunately, some recent evidence provides cause for optimism. Especially in fields within the academic life sciences, the gender gap has narrowed (*3*, *5*). Until recently, however, little research has explored an increasingly important source of nonsalary remuneration for faculty: participation in commercial science (*6*). This omission is problematic given the growing opportunities for recognition and reward in the commercialization of scientific research. Although profiting from university research continues to generate controversy (*7*), the reality is that commercial activities including patenting, consulting, and scientific advisory board (SAB) membership have become commonplace (*8*). What limited evidence exists about "academic entrepreneurship" suggests a gender gap of considerable magnitude.

Here, we examine gender differences in one specific commercial activity—patenting. We conducted a longitudinal empirical analysis using a random sample of faculty in the life sciences employed in U.S. academic institutions. The analysis is complemented by interviews with life scientists at one prominent university. Although academic patents do not yield immediate financial returns to their inventors, frequently they serve as an avenue to a variety of rewards, such as royalty-bearing license agreements with established companies or startup formation with substantial equity participation. Although not the only route to commercial engagement, our interviews and previous research suggest that patents are an important precursor to opportunities in industry.

We began the quantitative analysis by drawing a random sample of 12,000 life scientists from the UMI Proquest Dissertations database (*9*). We restricted the sample to those earning Ph.D.'s between 1967 and 1995 in the scientific fields that have most fostered the commercial life sciences. We then used the *Science Citation Index* (*10*) to collect the publications, coauthors, and employers of the individuals in the sample. Because our interest is in academic careers, we retained only the 4227 individuals with at least 5 years of post-Ph.D. publishing experience in academic institutions. We then obtained the patents on which the scientists in the sample are listed as inventors. With this information, we created a data set of scientist-year observations with covariates for the individual's gender, annual publication activity, and annual patent count [supporting online material (SOM) text].

Of the scientists in our sample, 11.5% are listed as inventors on one or more patents. However, the full sample proportion masks a large gender difference: Of the 903 women in the sample, 5.65% held patents as of the last year of the data. By contrast, 13% of the 3324 male scientists in the data are listed on patents. Moreover, the 431 male patenters have amassed a total of 1286 patents in our data set. The 51 women patenters produced only 92 patents.

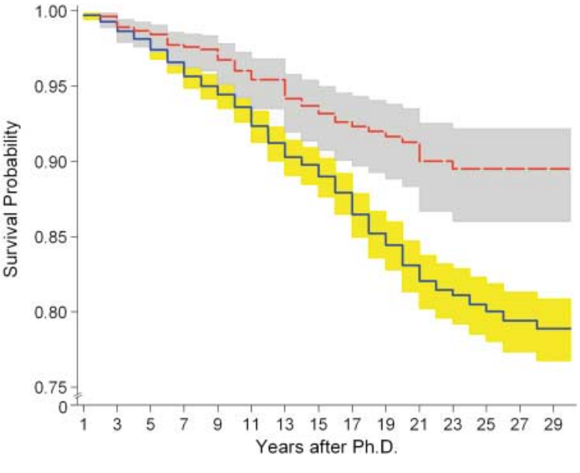
We structured the data archive to enable survival analyses. Figure 1 displays gender-specific nonparametric survivor plots that show the likelihood that a scientist in the data has not patented up to a given year of professional tenure. The plots show that, at all career stages, the curve for male scientists is beneath that for women, and the gender gap in survival probabilities increases over time.

Similar to other areas of scientific attainment, patenting is affected by a range of individual, field, and institutional factors, many of which may differ systematically between the sexes (*11*–*13*). After constructing four mutually exclusive subsamples—male patent holders, female patent holders, men without patents, and women without patents—we observed considerable subsample differences in means (across levels of professional experience) in (i) number of papers, (ii) amount of NIH grants, and (iii) number of papers coauthored with researchers in industry (Fig. 2). Male patenters typically have the highest paper counts, the most NIH grant money, and along with the women patenters, the most coauthorships with industry scientists (table S1 provides significance tests).

Given evidence of these disparities between male and female scientists, it is important to determine the conditional effect of gender on patenting—its net effect after holding constant other measured attributes of scientists. Therefore, we estimated scientist-level regressions of the rate of patenting. Formally, let $\lambda_i(t)$ designate the instantaneous transition rate, where $t = 1,\ldots,35$ years (we assume that 35 years is the maximum time any scientist is at risk). We estimated Cox proportional hazards regressions. Letting $\lambda_0(t)$ indicate the baseline hazard, $X_i(t-1)$ indicate a vector of lagged, time-varying covariates, and V_i indicate a vector of time-independent covariates, we estimated $\lambda_i(t,X,V,\beta,\gamma) = \lambda_0(t) \times \exp[\beta' X_i(t-1) + \gamma' V_i]$.

We included a number of variables in the $X_i(t-1)$ vector. One attribute that influences patenting is a scientist's research productivity. At the extreme, an unpublished scientist probably lacks novel findings to patent. Therefore, we included the number of articles each scientist has published in the previous 5-year period and the square of this variable. Those we interviewed suggested that scientists' employers also influence patenting by providing support

Fig. 1. Gender-specific Kaplan-Meier estimates of the survivorship function of first patenting with confidence intervals. The likelihood that scientists (blue line for male and red dashed line for female) have not patented up to a given year of professional experience is shown. Both the stratified log-rank test and Wilcoxon test ($P < 0.01$) reject the hypothesis that the survival functions are equal.



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for interactions with industry. To proxy for this workplace characteristic, we included the number of patents assigned to the scientist's employing university during the previous 5 years (excluding patents held by the focal scientist). We reasoned that universities with high patent counts will likely have an effective technology transfer office (TTO) and a culture that supports involvement in commercial endeavors.

Interviewees suggested that networks of colleagues influenced their patenting behavior, which is consistent with recent research on entrepreneurship (*8*, *14*). Scientists (particularly male faculty) routinely mentioned consulting with coauthors, colleagues, and industry contacts for advice about the patent process. We captured faculty members' contacts with two variables. First, as a gauge of network reach, we included the average number of coauthors the scientist has had on previously published papers. Second, as a proxy for the richness of scientists' networks with industry, we included a dummy variable equal to one if a scientist has recently coauthored papers with one or more researchers in industry.

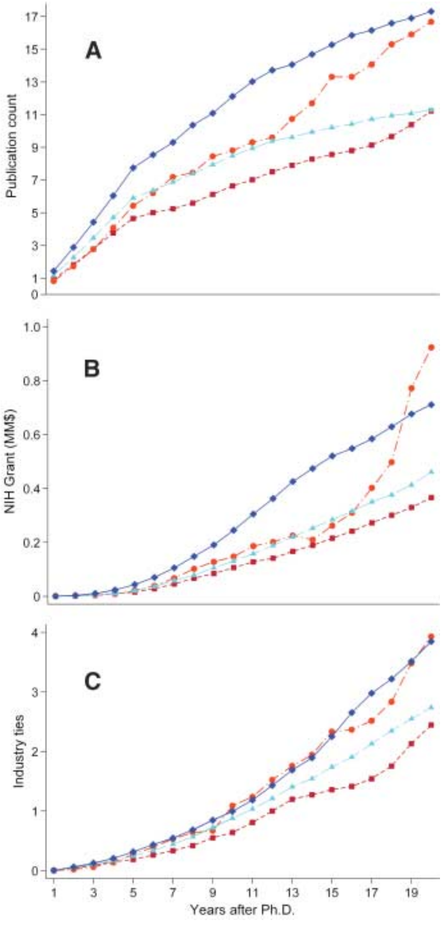

Fig. 2. Mean publication count (**A**), NIH grant totals (**B**), and number of jointly authored papers with industry researchers (**C**) during the first 20 years of scientists' careers. Groups are male patenters (dark blue squares), males without patents (light blue triangles), female patenters (light pink circles), and females without patents (dark pink squares). Although women patenters appear to have a higher mean grant total than male patenters beyond the 18th year of professional experience, this difference is not statistically significant. (Table S1 provides equality of means tests across categories.) MM$, millions of dollars.

Figure 3 shows our regression findings (table S2). The parameter estimates suggest that an increase in the 5-year publication count of one standard deviation of the observed distribution (12.1 papers) multiplies the hazard rate of patenting by a factor of 1.81. Similarly, scientists that average a greater number of coauthors per paper, those that work at universities that promote patenting and those that have collaborative projects with scientists in industry, patent at a greater rate. There also are statistically significant scientific field effects. Relative to the omitted category (genetics) in the regression, molecular biologists, immunologists, and organic chemists patent at a substantially higher rate (Fig. 3 and table S2).

After accounting for the effects of productivity, networks, field, and employer attributes, what is the net effect of gender? There remains a large, statistically significant ($P < 0.001$) effect of being female. The parameter estimate implies that, holding constant productivity, social network, scientific field, and employer characteristics, comparable women life scientists patent at only 0.40 times the rate of equivalent male scientists. This finding leads to the question: What might cause such a large gender difference in patenting?

One possibility is that men and women do qualitatively different kinds of research. In particular, if women are risk averse in their research choices (*15*), there may be a gender difference in research "patentability." We believe such a difference would manifest in the extent of scholarly impact. To explore this possibility, we created a data set of the 23,436 articles published by the women in our sample and matched each paper (by publication year) with a randomly drawn article from the pool of male scientists' papers. This yields a sample of articles with a 1:1 gender ratio. We then examined, by gender and year, the average number of citations and the journal impact factor (JIF) of these papers. We found that the per-article mean citation count for male scientists is very similar to that of women (table S3). Moreover, the gender gap in average JIF actually favors women (average JIF for male: 4.06; average JIF for female: 4.12). Overall, there is no evidence that women do less important work based on standard measures of scientific impact.

If there is no measurable gender difference in the scholarly influence of research, what else might cause such a large gender difference in patenting? For clues, we turned to our faculty interviews, in which two factors loomed large. The first is lack of exposure to the commercial sector. Most (but not all) women had few contacts in industry. Lacking these connections, women found it time-consuming to gauge whether an idea was commercially relevant. In contrast, men often described an industry contact as a precursor to patenting. Hampered by their narrow networks and concerned about the time it would take to "shop" a patent around, several female faculty were deterred from completing a patent filing. Thus, differences in the composition of professional networks meant that the time cost of patenting was higher for many women faculty.

Several women suggested a second hurdle: concern that pursuing commercial opportunities might hinder their university careers. The women we interviewed were more likely to describe the challenges associated with balancing multiple career elements: teaching, research, and commercialization. Unlike their male counterparts, who described their patenting decisions as unproblematic and driven by translational interests, female faculty expressed concern about the potentially negative impact that patenting might have on education, collegiality, and research quality.

Our interviews also uncovered two factors that reduced the perceived costs of patenting for female faculty: collegial support and institutional assistance. Compared with men, female faculty were much more likely to be encouraged in patenting by their (typically male) coauthors, who often drove the patenting process.

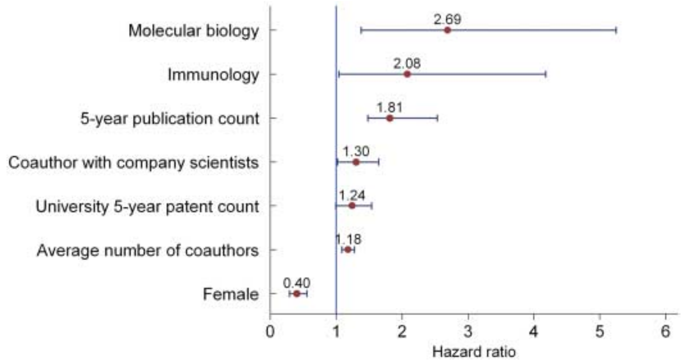

Fig. 3. Hazard ratios and 95% confidence intervals from Cox regression of time until patenting. Hazard ratio *g* implies that the probability of patenting changes by a factor of *g* for a unit (dichotomous variables) or standard deviation (continuous variables) change in the covariate value. Predictors are sorted by effect magnitude and are statistically significant if 1.0 falls outside of the confidence interval. (Full regression results are presented in table S2.)

Whereas men sought advice from their often broad-reaching networks, women frequently depended on close relationships with male collaborators to initiate the patenting process. Formal institutional sponsorship was also particularly important for women. Many women commented that their TTO provided industry contacts, advice, and encouragement to develop the commercial aspects of their research.

Our interviews also exposed differences between older and younger women scientists. Most senior female faculty we met perceived themselves as being excluded from industry relationships and therefore failed to develop an understanding of how commercial science works. Few made the transition to patenting. Some of the younger (but tenured) female life scientists had begun to incorporate patenting into their research strategy. Nonetheless, many still felt at a disadvantage to their male colleagues because of their limited experience at the academic-industry boundary. It is only among junior faculty that we found parity in attitudes, which were shaped by doctoral and postdoctoral experiences. Regardless of gender, those that experienced patenting during training were undaunted by the challenges of combining academic and commercial science.

Because our data spans 35 years, we can determine whether such generational distinctions are evident in the larger sample. For three Ph.D. cohorts (those earning degrees from 1967 to 1975, 1976 to 1985, and 1986 to 1995), we examined gender-specific nonparametric cumulative hazard plots. For each cohort, we also calculated the male-to-female ratio of the cumulative hazards. For example, at the 10th year after scientists earned their Ph.D., the cumulative hazard of patenting for male scientists was 4.4 times as high as women in the 1967–1975 cohort, 2.1 times as high in the 1976–1985 cohort, and 1.8 times as high in the 1986–1995 cohort (fig. S1). Thus, consistent with our interview findings, the archival data indicate that the gender gap in patenting rates has been declining.

Our analyses suggest that patenting has become common in the academic life sciences, particularly for highly productive and networked faculty. Among the most senior faculty, a large gender gap persists, reinforced by women's limited commercial networks and traditional views of academic careers. Younger cohorts widely embrace patenting, although a gender gap remains. Increasingly, however, young female faculty are similar to their male colleagues: They view patents as accomplishments and as a legitimate means to disseminate research. If this trend continues, we may observe further declines in the magnitude of the gender gap in commercializing academic science.

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16. F.M. acknowledges financial support from the Cambridge-MIT Institute. T.E.S. acknowledges financial support from the Center for Entrepreneurial Leadership at the Ewing Marion Kauffman Foundation, Kansas City, MO. This material is partly based on work supported by the NSF under grant No. EEC-0345195 (T.E.S.).

Supporting Online Material

www.sciencemag.org/cgi/content/full/313/5787/665/DC1
Fig. S1
Tables S1 to S4

11 January 2006; accepted 13 June 2006
10.1126/science.1124832

Regulation of Sexual Development of *Plasmodium* by Translational Repression

Gunnar R. Mair,[1] Joanna A. M. Braks,[1] Lindsey S. Garver,[2] Joop C. A. G. Wiegant,[3] Neil Hall,[4] Roeland W. Dirks,[3] Shahid M. Khan,[1] George Dimopoulos,[2] Chris J. Janse,[1] Andrew P. Waters[1]*

Translational repression of messenger RNAs (mRNAs) plays an important role in sexual differentiation and gametogenesis in multicellular eukaryotes. Translational repression and mRNA turnover were shown to influence stage-specific gene expression in the protozoan *Plasmodium*. The DDX6-class RNA helicase, DOZI (development of zygote inhibited), is found in a complex with mRNA species in cytoplasmic bodies of female, blood-stage gametocytes. These translationally repressed complexes are normally stored for translation after fertilization. Genetic disruption of *pbdozi* inhibits the formation of the ribonucleoprotein complexes, and instead, at least 370 transcripts are diverted to a degradation pathway.

Translational repression (TR) of mRNAs in higher eukaryotes controls temporal expression of specific protein cascades or directs the location of translation within a cell, and is important after gamete fertilization (zygote formation) in the early embryo when de novo transcription of mRNA is restricted (*1*–*5*). The hallmark of repression is the assembly of certain mRNAs together with proteins into quiescent messenger ribonucleoprotein particles (mRNPs), where these transcripts are stored for translation at a later time. The DDX6 family of DEAD-box RNA helicases is tightly linked both to storage of mRNAs encoding proteins associated with progression through meiosis into translationally silent mRNPs and with the transport of mRNA to degradation centers in the cell (P-bodies). These helicases are found in organisms as diverse as yeast (e.g., Dhh1p) and humans (e.g., RCK/p54).

Earlier studies in *Saccharomyces cerevisiae* suggested that Dhh1p was localized to cytoplasmic P-bodies that contain both mRNA and enzymes central to the RNA degradation pathway (e.g., the decapping enzyme), implying that P-bodies harbor transcripts destined for degradation (*6*–*8*). More recently, it was proposed that mRNAs also exit P-bodies and re-engage polysomes for translation in a Dhh1p-dependent mechanism (*9*). With the exception of human RCK/p54, homologs of DDX6 helicases in metazoans have been found exclusively localized to mRNPs involved in TR (*2*–*4*).

TR has been described in *Plasmodium* (*10*–*16*) in the female gametocyte, the stable, blood-stream precursor cell of the female gamete, where two abundant transcripts are present but not translated. These mRNAs, *p25* and *p28*, en-

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