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# Buying science and selling science: gender differences in the market for commercial science

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Growing opportunities for academic scientists to commercialize their science has led to a new commercial marketplace. Recent evidence suggests that “commercial science” participation is characterized by gender stratification. Using interviews with life science faculty at one high-status university we examine the mechanisms that instituted, reinforced, and reduced the gender gap in commercial science between 1975 and 2005. We find gender differences from processes on both the demand—(opportunity) and supply—(interest) sides; of deeper significance are the intersections between these sides of the market. Specifically, explicit early exclusion of women left them with fewer opportunities in the marketplace, weakening their socialization and skills in commercial science. This uneven opportunity structure left senior/mid-career women with fewer chances to confront the ambiguities of this new practice, resulting in their greater ambivalence. Gender differences remain significant among junior faculty but we find their decline prompted by greater gender-equality in advisor mentoring and the presence of institutional support which together have started to reshape the supply-side of commercial science.

## 1. The gender gap in commercial science

### 1.1 *The rise of commercial science*

Many academic research projects are characterized by the production of dual-purpose knowledge—knowledge that is simultaneously valuable as a scientific discovery and as a useful, inventive construct (Stokes, 1997; Biagioli, 2000; Murray, 2002; Murray and Stern, 2006). Such knowledge offers opportunities in two distinct markets. The first is the traditional academic science marketplace in which individuals use their knowledge to garner priority and prestige through publication, peer-review and participation in scientific conferences (Merton, 1973; Dasgupta and David, 1994). The second is the pursuit of the practical and commercial aspects of their knowledge in the “*commercial science*” marketplace. While these dual options

have been available to scientists since the Enlightenment (Biagioli, 2000; Mokyr, 2004), this activity has burgeoned in the past three decades and become potentially highly financially rewarding (Kenney, 1986; Holgate and Edwards, 2006; Stephan *et al.*, 2006). Initially highly controversial and widely contested, since the 1970s, commercial science has experienced a tremendous increase in academic faculty participation along many dimensions: i.e. invention disclosure, patenting, licensing, and consulting, Scientific Advisory Board (SAB) membership and firm founding.

Participation has been particularly striking for faculty of modern biotechnology (i.e. the *life sciences*<sup>1</sup>) with their research emerging as critical sources of valuable academic *and* commercial science (Kenney, 1986; Etzkowitz, 1998).<sup>2</sup> This phenomenon of “dual knowledge–dual markets” in the life sciences reflects at least three related forces: first, the dramatic rise in dual knowledge is traced back to the 1970s (Morange, 1998), when discoveries such as the techniques of recombinant DNA came to exemplify dual knowledge (Cohen *et al.*, 1973), forming the basis of many biotechnology firms and allowing an elite group of academics to participate in dual markets. Second, policy shifts, especially the 1980 Bayh-Dole Act, encouraged academics to claim intellectual property over their dual knowledge, and to work with universities to license these rights to firms. Third, investors became increasingly willing to fund speculative academic ideas that might serve as the basis of a commercial product. Nonetheless, traditional suspicion over the mingling of science and money and questions of conflict of interest persist at the academic-commercial boundary (Etzkowitz, 1998; Heller and Eisenberg, 1998; Rai, 1999; Schissel *et al.*, 1999; Campbell *et al.*, 2002; Krimsky, 2003; Cockburn, 2005).

### *1.2 Gendered faculty participation in commercial science*

Understanding participation in commercial science remains an important puzzle for those studying the academic-commercial boundary, including policymakers intent on increasing rates of technology transfer. A series of studies have identified characteristics of those academic scientists most likely to engage in commercial science marketplace. Overall, the evidence suggests that this marketplace looks strongly towards the norms of academic science—individual publication productivity and quality, institutional status and support, career stage and size of co-authorship networks—as a driver of participation.

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<sup>1</sup>E.g. molecular biology, biochemistry, organic chemistry, medical science, biochemical engineering, and bioengineering.

<sup>2</sup>Indeed, between 1989 and 1999 universities classified by the Carnegie Classification of Institutions of Higher Education as US Research I Universities received over 6000 life science patents (Blumenthal, 2003) and commercial science became increasingly widespread. This classification was used prior to 2000 to identify those universities in the United States, which received the highest amounts of Federal science research funding. The classification is now obsolete.

The status of actors is important when ideas are uncertain (Stuart, 1998); it is thus not surprising to find that highly accomplished scientists are most likely to participate in commercial ventures (Audretsch and Stephan, 1996; Zucker *et al.*, 1998). Examining the earliest stages of venture formation Shane and Khurana (2003) show that for a sample of university-invented ideas, the likelihood of a start-up venture is strongly predicted by prior entrepreneurial experience of the inventor and by the inventor's university rank. Early descriptions of the "business of science" highlight the role of a handful of faculty from top ranking academic institutions in the establishment of many of the earliest biotech firms including Genentech, Biogen, Amgen, and Genzyme (Kenney, 1986; Stuart and Ding, 2006). With regard to invention disclosure and patenting, the patterns are similar, being closely correlated to individual scientific productivity (i.e. publication rates), scientific quality (citation rates), institutional reputation, and institutional support (i.e. the presence of a technology transfer office, TTO) (Thursby *et al.*, 2001; Agrawal and Henderson, 2002; Thursby and Thursby, 2003; Fabrizio and DiMinin, 2005; Azoulay *et al.*, 2006; Stephan *et al.*, 2006).

Yet wide variation in participation exists even amongst "high profile" faculty. Unexplained and only recently documented is that from its inception, faculty participation in commercial science has been particularly highly stratified by *gender*. Recent quantitative studies suggest that over the past 35 years, female life science faculty have lagged dramatically behind their male colleagues in commercial science dimensions of their careers (Ding *et al.*, 2005, 2006; Bunker Whittington and Smith-Doerr, 2005). As men parlayed their research into commercial networks, patents, start-up companies and, occasionally, millions, female faculty did not. A wide gender gap persists even today, after accounting for variations in institutional status, individual rank and productivity.

Evidence suggests that gender stratification in commercial science is highest at the most prestigious institutions (Azoulay *et al.*, 2006; Ding *et al.*, 2005). Women underperform relative to their male colleagues along multiple commercial dimensions. A study of SAB membership of public biotech companies identified 190 academic founders and 771 SAB members. Only 6% (59) of these academics were women (compared to ~20% of women in a random matched sample of academic scientists, controlling for PhD year and subject) (Ding *et al.*, 2005). Among over 4000 US life science academics, male faculty were found to patent at more than 2.5 times the rate of their female counterparts, after accounting for differences in institutional prestige and individual scientific productivity (Ding *et al.*, 2006). Another sample of 1000 recipients of NIH graduate training grants in cellular and molecular biology shows a gender difference of 30% of men compared to 14% of women patenting, with little change over time (Bunker Whittington and Smith-Doerr, 2005). Furthermore, in a sample of over 4500 faculty at 11 major universities, women (6.74%) are less likely to disclose inventions than men (8.67%) despite the fact that there are no significant differences in publication

patterns (Thursby and Thursby, 2005). Finally, Corley and Gaughan (2005) find that female faculty engage in less outside consulting. Taken together, these studies present compelling evidence for the emergence and maintenance of a gender gap in commercial science. However, as with other arenas of gender stratification, scholarship has yet to uncover the mechanisms through which such patterns emerge.

### 1.3 Research objectives

This article explores (i) the mechanisms behind the gender-based participation gap in commercial science and (ii) the processes that impact this gap over time. We build off the well-developed literature on women in science, entrepreneurship, and other professions to question current commercialization theories that tend to assume no differences in participation by gender, and offer limited insights into widespread variation in faculty participation, particularly among highly productive, high prestige individuals. *Gender is thus our conceptual lens for establishing greater theoretical and analytical leverage on the dynamics of the commercial science marketplace.*

This is a qualitative interview-based study of 56 life sciences faculty at one high prestige academic institution who received their PhDs between 1960 and 2001—before and during which commercial science emerged on university campuses. We separate faculty into four cohorts based on year of PhD receipt to probe the role of early career context, experience and status on attitudes towards commercial science (see Goldin, 2004 for the recent use of cohort-based analysis in gender and education). Our interviews and analysis use a supply and demand framework; i.e. we investigate how the gender-based participation gap arises from differences in selling science and/or buying science. This perspective builds on the literature that identifies gender-based variations in interests, resources, human capital, etc. (“supply-side”) and discrimination, bias, and gender-based variations in opportunities (“demand-side”). We also examine *interdependencies* that arise between the two sides of the market for commercial science, and explore how they contributed to the emergence of the participation gap in the 1970s and the changes in that gap in the following three decades.

We find that complex social processes, contoured by gender, operate on both the supply and demand sides of the market. Moreover, it is the intersections of these two market processes that drive the perpetuation and reduction of the gender gap. Our research finds three interdependencies that are particularly salient: first, initial exclusion from opportunities in commercial science led to women’s lower levels of professional socialization and skills in selling science. Second, exclusion and the limited activation of women’s scientific networks for commercial opportunities meant that women were less able to resolve the ambiguities felt by *all* scientists in the early days of commercial science. Their willingness and ability to sell was thus more limited. Third, much greater rates of male participation in the early days

of commercial science caused the commercial role to be constructed as male, leaving women less skilled, disaffected and more likely to self-assess as low competence in commercial science than their male colleagues.

We also elaborate on those mechanisms that have reduced gender inequity in commercial science over time. These include the recent equal treatment of junior women by commercially-oriented advisors, the appointment of senior women to high level administrative positions and the concomitant challenge to stereotypic beliefs related to gender and commercial science, thus increasing the visibility of senior female commercial role models. Meanwhile, the role of the TTO in making commercial science more transparent has normative implications for *all* faculty, but particularly for women. Taken together, these structural and institutional factors have come into play to countervail the strong systemic aspects of the gender gap. Nonetheless, the gap remains and the long-term balance of these various factors cannot easily be predicted. Among today's junior women, our data suggest the continued existence of gender differences; in our sample only 11% of junior women, versus 44% of junior men, have patented (mirroring findings from larger-scale studies). These data, and junior women's depictions of emerging opportunity constraints, imply that gender problems remain salient for today's female scientists and should remain a cause for concern for policy makers.

Our findings are limited to experiences at one elite US institution. Nonetheless, the stability of factors shaping gender inequality in academia suggests that our understanding of commercial science should be relevant to faculty in other US research-oriented academic institutions. Policy implications call for greater attention to (i) the social dynamics of commercialization, (ii) processes that overcome bias in the market, and (iii) the role of brokers such as TTOs in shaping commercial science. These interventions should reduce the likelihood that faculty with good ideas are overlooked and instead have the opportunity to participate in the market for commercial science.

The remainder of this article is structured as follows: Section 2 outlines our analytical framework for exploring the gender gap in commercial science, building on current gender scholarship in occupations. After outlining our methods in Section 3, Sections 4, 5 and 6 present our findings. We conclude in Section 7 with a brief discussion of the limitations of our analysis, and its implications for scholarship and policymakers.

## 2. Analytical framework

### 2.1 *Supply and demand-side sources of gender stratification*

While studies of commercial science have greatly improved our knowledge of this emerging activity, they do not elucidate the mechanisms through which inequity has arisen and evolved in a relatively new type of work. Literature on gender inequality

in occupations—especially from academic science and entrepreneurship—provides clues and a frame for our analysis: it explicitly recognizes “demand” (opportunity structure) and “supply” (expertise and interest) factors that affect gender inequality (Ridgeway, 2006).

Demand-side factors include gender-based expectations of competence by employers or colleagues, sex-typing of particular jobs, and other forms of discrimination (Reskin and Roos, 1990; Petersen, 2004; Fernandez and Sosa, 2005). For example, in the overall cross-sectional data on gender stratification in entrepreneurship, men are more than twice as active in entrepreneurship as women (Reynolds *et al.*, 2001, 2004; Minniti and Arenius, 2003). With regard to venture funding, there is evidence of under-representation of women in investments (Carter and Rosa, 1998; Greene *et al.*, 2001, see Marlow and Patton, 2005 for a discussion of mechanisms). Studies reveal that those who fund early-stage firms hold gender-based stereotypes (Ducheneaut, 1997), particularly credit-based lenders (Buttner and Rosen, 1988). While these studies show no evidence of gender differences in rates of bank lending (Buttner and Rosen, 1989) or in the line-of-credit made available to women (Haynes and Haynes, 1999), women are subject to higher collateral and interest rate requirements than men (Coleman, 2000).

In science and medicine, demand-side driven participation gaps have also been measured. A recent study of academic medicine found that among cohorts of graduates from all US medical schools (1979–1993), women were significantly less likely to be promoted than men based on their cohort representation. Furthermore, women’s under representation was greater in tenure track positions (Nonnemaker, 2000). Ginther and Hayes (2003) illustrate the enduring gender gaps in salaries and promotion for cohorts in the humanities between 1977 and 1995, even after controlling for productivity and demographic factors. They observe a slight decline in the promotion gap among the most recent cohort. In most of these studies, demand-side factors are considered of particular importance and there is evidence of discrimination in the critical career processes of peer-review, hiring and other selection decisions (Fox, 1991; Barinaga, 1992; Wenneras and Wold, 1997).

On the other side of the market are supply networks, i.e. those individuals who signal interest in a job or activity. While supply-side factors are difficult to measure given the insights required into individual choices, they have been shown to shape gender segregation in recruitment networks (Granovetter and Tilly, 1988). This is particularly striking in the choice of degree subject (major) chosen by men and women in university (Jacobs, 1995). Core supply-side mechanisms include biases in individuals’ expectations for their own competence in certain roles (Correll, 2001). This can lead to less assertiveness, less demand for rewards (Major, 1989), and lower actual performance independent of ability (Spencer *et al.*, 2001). For instance, in decisions by high school students to participate in advanced-level mathematics and science classes, Correll (2001) shows that males who test at the same ability level as females have higher self-assessments of their own mathematical competence

than females. This pattern did not arise in self assessment of verbal tasks. This self assessment was significant in individuals' decisions to participate in quantitative college degree subjects.

Studies based on so-called “nascent entrepreneurs”—those who are “at risk” of engaging in entrepreneurial activity—also reveal that a key driver of the two-fold difference in rates of entrepreneurship is the gender-based fear of failure (after holding resource endowments constant) (Wagner, 2004) or negative self-perception (Shragg *et al.*, 1992). Fear of failure has a smaller negative influence on men than women in their decision to participate in entrepreneurial activities, a finding in line with other studies of gender and risk (Eckel and Grossman, 2003). Likewise, Treichel and Scott (2006) find that women apply for smaller bank loans while their refusal rates are equivalent to men. More concrete obstacles to female business success include women's lower levels of training and preparation to operate a business, and limited access to resources, such as networks and financial capital (Carter *et al.*, 2001).

This cumulative evidence suggests that our proposed supply- and demand-side framing of the gender gap in commercial science is appropriate. Commercial science is a labor market, albeit one with some specific characteristics: on the supply-side participation does not mean relinquishing an existing faculty position, and on the demand-side buyers are heterogeneous and diffuse (including investors, firms, and licensing officers). Yet, the search for *either* a supply *or* a demand-side explanation of the gender gap is too limited. Instead, we examine the intersections between these two sides. As Fernandez and Sosa (2005) noted in the hiring arena, the various supply- and demand-side processes “potentially feedback on one another” and have “complex interdependencies.” An analysis of such interdependencies in commercial science will provide a window into the mechanisms through which the gender gap emerges and evolves for “work that occurs at the cutting edge of economic, technological, and social organizational change” (Ridgeway, 2006).

With this framing in mind, our fieldwork was guided by four key questions:

- What are the supply- and demand-side factors shaping faculty commercial science participation throughout their careers and how do they vary by gender?
- How do these supply and demand side factors interact and depend on one another?
- Which of these factors and interdependencies are most powerfully at work in the early development of commercial science, leading to the initial gender gap in participation?
- How have these factors and interdependencies shifted over time to reinforce or reduce the gender gap in participation?

Commercial science is a powerful setting for such an analysis. Unlike academic science, it has not been dominated by men since the 17th century (Keller, 1985, 1988), but is a

new opportunity for academic scientists to reshape their careers. Its emergence in the mid-1970s allows us to explore the initial conditions under which interests (supply), opportunities (demand) and gender (West and Zimmerman, 1987) were initiated, interacted and contributed to stratification in the market that then took hold throughout the system. Many early protagonists remain as senior faculty. In examining their early experience and recent attitudes versus those of younger faculty we can observe the changing nature of the commercial marketplace. Finally, we have a number of measures of scientific productivity, attainment, status, etc., which allow us to “control” for some of the key drivers of participation identified by prior quantitative studies.

### 3. Methods

Quantitative studies provide limited insights into the complex mechanisms at work in the commercial science marketplace. It is only through in-depth qualitative analysis that we can reveal insights into decisions to participate in commercial science, including both opportunities and faculty responses to them. (Bruni *et al.*, 2005). Therefore, we chose an inductive, qualitative approach to generate theory on the mechanisms of gender inequity in commercial science, its origins and transformation. Our research is based on semi-structured interviews of 1–3 h, with 56 of a possible 148 life science faculty members from one institution (38% of the population). Our sample included 34 male (29%) and 22 female (73%) interviewees.

#### 3.1 Sampling strategy

Key decisions regarding sample design were (i) choice of institution(s) and (ii) faculty participants. With limited guidance from current literature regarding possible sources of institutional variation we followed Agrawal and Henderson (2002) and focused on one institution that we refer to as “*Big School*.”<sup>3</sup> This design allows us to hold the “organization” constant in observing the experiences of male and female faculty under similar organizational conditions. This approach challenges the generalizability of our findings; we discuss these limitations in our conclusions.

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<sup>3</sup>While the institution itself has placed us under no strictures about confidentiality, we have guaranteed all our interview subjects anonymity. Given the relatively small numbers of individuals (particularly women) involved—due to the absolute numbers of female faculty rather than response rates—it would be extremely easy to identify specific individuals from the information and comments disclosed in interviews. We have therefore decided to disguise the names of both the institution and the individuals.

Big School is considered “high status” by most metrics of academic prestige, including program rankings and receipt of research funding.<sup>4</sup> It is among the leading recipients of university patents and its history reveals a tradition of active participation in technology transfer. Like a number of its US counterparts, it established a TTO in the 1980s. Big School has contributed many life science patents and numerous biotechnology firms since 1975. The choice of such a highly prestigious institution has several advantages. First, its representative setting of universities most active in technology transfer demonstrates the significant number of commercial science opportunities for faculty. Second, its prestige allows us to control for faculty variation in productivity, human capital, and positional resources that are important determinants of commercial science.

Our starting faculty population of 148 individuals included all those listed as current faculty during 2004–2005 active in the disciplines that underlie modern biotechnology.<sup>5</sup> They are tenure-track or tenured faculty engaged in research and teaching. All have active laboratories training graduate students, and are recipients of research funding from a range of sources. We included faculty of all rank and experience (in terms of years since PhD receipt) for generational comparison (see Xie and Shauman, 1998 for cohort designs in quantitative studies of gender). To narrow down our sample, we planned to interview the entire female faculty ( $n=30$ ) and then follow with a matched male sample (generated by asking female interviewees to identify one or more of their male peers within Big School). The match was verified using PhD date and department assignment. This follows recent literature in the field (Ding *et al.*, 2006) and attempts to remove confounding factors such as career stage, status etc.

### 3.2 Data gathering

Prior to our interviews we completed simple quantitative bibliometric analyses to measure individual faculty productivity. We tabulated publication and patent data including total publication counts, publication weighted citation counts and percentage of industry co-authored papers, and patent counts. We then began our qualitative study by contacting all 30 female faculty, relying upon the prestige of a

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<sup>4</sup>Big School ranks highly among the recipients of National Institutes of Health (NIH) funding for biomedical research (the largest source of biomedical research funding in the US). Many of its departments and PhD programs are ranked among the top five by *US News and World Report* and *The Gorman Report*.

<sup>5</sup>Like in most institutions, life science faculty at Big School are spread across a number of departments. We therefore included the five departments that might be construed broadly as encompassing the life sciences: biology, chemistry, medical sciences, and chemical and biological engineering. However, due to the idiosyncrasies associated with departmental naming and boundaries, most major institutions are easily identified from their departmental names. We have excluded these precise departmental labels from our study.

senior faculty member in science to introduce our study. We followed up with non-respondents 2 weeks later. Our response rate was 73% (22 women).<sup>6</sup>

Our interviews were semi-structured; we asked faculty to trace their career trajectories from graduate school to the present and to describe their commercial science experiences throughout their careers, i.e. their career “pipeline” (see Xie and Shauman, 1998; Levin and Stephan, 1998 for a more detailed description of the pipeline approach). We gathered in-depth descriptions of research, lab operations (funding, size, projects, etc.), research communities, “extra-curricular” professional activity (e.g. administrative), and personal characteristics (marital status, family size, etc.). Our protocol then probed their commercial activity along multiple dimensions: patenting, licensing, start-up formation, consulting and advising. We were interested in perceptions of their commercial environments as graduates and faculty and their overall philosophies of academic and commercial science. We then explored specific opportunities to engage in commercial science, cases of initiating commercial participation, and their perceptions of gender bias in the workplace and with regards to commercial science.

In March 2005, we began interviewing male faculty following the “matched” approach. The response rate among men was 95%. We interviewed the matched group of 22 men then added an additional 12, selected from the cohort who received their PhDs before 1986, for a total of 34 male interviews.<sup>7</sup> These additional interviews allowed us to further probe the early period for which we found the most stark gender differences. Given the small number of female faculty of this generation (11; we interviewed nine), we wanted to increase our male sample to be certain that we were observing between, rather than within, gender differences. For faculty trained after 1986, our gender ratio was 1:1.<sup>8</sup>

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<sup>6</sup>One of the eight women we did not interview, one had left “Big School” when we made our request for an interview. For the sake of completeness, we compared the characteristics of all eight non-respondents to the 22 women we interviewed. The only differences that are significant at a 10% level are a) year of first patent grant—non-respondents patent later, and b) the average number of patent assignees—non-respondents have fewer.

<sup>7</sup>When we compared the interviewed and non-interviewed male faculty (34 versus 84) we found only one statistically significant difference in the mean of the two samples (at the 10% level); non-interviewed men took longer to patent—14 years versus 10 years for interviewees.

<sup>8</sup>We supported our qualitative data with bibliometric data downloaded from ISI Web of Science (WoS) and Thomson’s Delphion Intellectual Property Network (publications and patents, respectively). This gave us the entire publication and patenting history of all 148 faculty over the period 1973–2005 (the starting data is constrained by the coverage of WoS). Comparing WoS output to faculty résumés shows that the former undercounts publications, but we believe this measurement error is consistent across our sample.

### 3.3 *Data analysis*

#### 3.3.1 Qualitative analysis

Our initial qualitative analysis focused on the reading and coding of interview transcripts, guided by our initial themes of supply and demand side drivers of commercial science activities and their interdependencies. As our interviews progressed, a series of themes emerged around narratives of exclusion and inclusion, and generational differences. Given we wanted to examine the dynamics of gender issues in commercial science, we refined our study design, putting faculty respondents into cohorts and analyzing the interviews of each group separately. This allowed us to more systematically understand the processes through which scientists construct their participation in commercial science.

#### 3.3.2 Cohort analysis

Following Goldin (2004) we divided faculty into four cohorts based on year of PhD award. The first generation, which we refer to as the “distinguished” generation, trained prior to the emergence of commercial science (PhD receipt pre-1975). The last “junior” generation (PhDs granted 1995–2001) was made up almost exclusively of untenured faculty. For faculty trained between 1975 and 1995 the appropriate generational cut-off was more difficult to establish. We use 1985, following other scholars who have identified this as a critical point in the biotechnology industry, when commercial science became widely established and normative (Kaplan *et al.*, 2003). This allows us to consider the experiences of a “senior” generation trained between 1976 and 1985, and a “mid-career” generation trained from 1986 to 1994. We tabulated descriptive statistics by generation although we interpret these data with caution given that each cohort is small in size.

## 4. Structuring the market for commercial science at big school

In this section, we describe evidence for the gender gap at Big School and provide insights into the supply and demand dynamics of commercial science. In Section 5, we present the data and narratives of by generation. Section 6 explores the interdependencies between the two sides of the market.

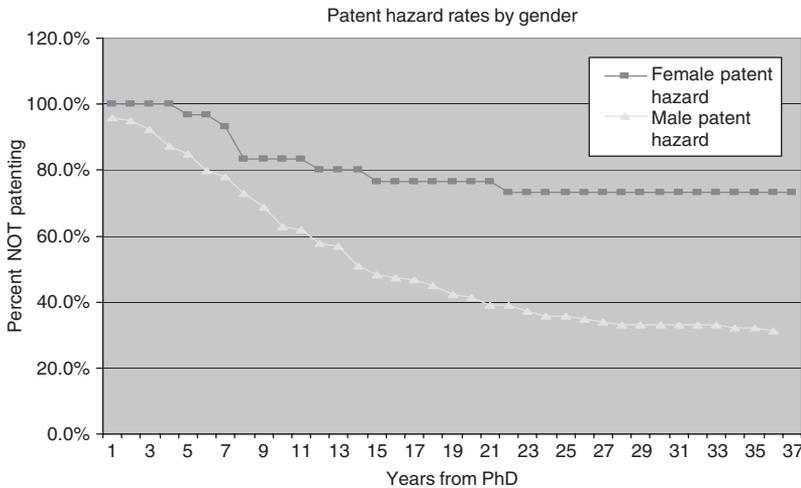
### 4.1 *Gender gap at big school*

Comparative statistics for the male and female faculty in our interview sample (Table 1) confirm the results of prior large-scale statistical studies: while men and women have similar overall academic records, there remain important, statistically significant (10% level) disparities in commercial activities. Female faculty had a lower percentage of industry publications, industry collaborations, and patents than their male colleagues and a smaller percentage of women engage in any patenting.

**Table 1** Descriptive statistics for faculty interview sample—Means by Gender

	Male (34)	Female (22)
PhD year	1981	1986
Total publication count	82	55
Publication count per year	3.7	2.6
Citation count per paper	42	41
Number of co-authors	128	91
Number of collaborating Institutions	31	23
<i>Pct. joint industry publications*</i>	16%	6%
<i>Number of industry collaborators*</i>	4.7	2.0
<i>% Faculty with patents*</i>	74%	23%
<i>Patent count*</i>	7.8	1.3
<i>Patent count (patenting faculty only)*</i>	10.6	5.8
<i>% With Children*</i>	68%	50%

\*Represents those values which are significantly different between the male and female interviewed population at a 0.01 confidence level.



**Figure 1** Patenting hazard rates by gender (time in career to first patent)—full population of 148 faculty members.

Patent data for the entire population (148 scientists) confirms this trend: the hazard rate in the transition to patenting over time (Figure 1) illustrates that at Big School, as in the broader population of US life science faculty, men transition to patenting at a higher rate throughout their careers.

These analyses provide strong support for the proposition that the gender gap in participation in commercial science is salient at Big School and that Big School (at least statistically) is broadly representative of academic life sciences. However, it also conceals some within- gender variations in participation; e.g. only 23% of women faculty have patented, while 74% of male faculty hold at least one patent. Building on these quantitative analyses, our interviews provide insights into the demand and supply-side processes of commercial science. As summarized subsequently, our initial qualitative analyses probe both within gender and across gender sources of variation, but again we found the most striking differences arising across genders.

#### 4.2 Demand side—buying science

Faculty receive opportunities to participate in the commercial marketplace from a wide variety of sources: “cold-calls,” referrals, or direct from, colleagues, academic collaborators, or former students. They assume that cold-calls—most commonly used for consulting—result from their publications one senior man explained, “I think they probably read about my work in the literature. But I have also received a lot of press because the project has had a very high impact. . .” In contrast, referrals were the most common source of SAB membership and licensing opportunities. Consistent with previous research on the role of social networks in facilitating matches between workers and jobs (Granovetter, 1973; Fernandez *et al.*, 2000) faculty describe the importance of a broad contact network to identify and refer individuals who would be strong candidates to provide expertise. This search is described as a highly relational process shaped not only by referrals from the invisible colleges of science (Crane, 1969), but also well beyond these traditional boundaries to incorporate referrals from commercially-oriented networks.

Collegial networks are rich in opportunities for many faculty (Murray, 2004), including consulting, invitations to join SABs and licensees for patents. However, colleagues were most salient in start-up founding. With few exceptions the opportunity to start-up a biotech company came from colleagues with whom faculty had close prior working relationships as a student, peer or senior colleague.

Faculty at Big School experienced the range of opportunity sources; however, gender differences sharply contour the occurrence and relative importance of these opportunities. Women reported fewer invitations than their male colleagues and their balance of sources differed. They received few, if any approaches from industry until late in their careers. The opportunities for female faculty came predominantly (and at lower rates) from peer colleagues and former students. A core message from women was that while their more *senior* male colleagues were generally collegial and supportive of their scientific work, they nonetheless disregarded them as potential collaborators in their commercial activities. We did not hear this

message from male interviewees. For women, participation in patenting, founding and SABs was dominated by opportunities generated by male *peers* with whom they shared common research projects. For equivalent men, opportunities came from advisors, peers and senior faculty.

Among male faculty with little or no participation in commercial science, most had opportunities which they chose to decline. None felt excluded from the opportunity structure and felt that they could insert themselves into the opportunity stream when they so desired. They described any paucity of opportunities in terms of the lack of relevance of their research. In declining commercial opportunities male faculty used terms that emphasized the high demand for their ideas and expertise:

If I wanted to be involved I know that I could be. I've always believed that I could solve any financial problems by just getting consulting or starting a company. I do know how hard it is. I have been there once but right now I am not interested. I just want to do my work which is really exciting and important. When the phone rings I make sure not to seem ambivalent because, you know, these investors are relentless and won't leave you alone unless you make it very clear to them that now is not the time.

In contrast, a dominant narrative among many of the women was the limited number of opportunities, a perception that their equivalent male colleagues were more sought after by industry, and a sense of exclusion. Several wondered whether there was a “boys club” at work. Some noted that their research was “simply too basic and not relevant” as an explanation for their lack of opportunities, but this was the exception.

#### 4.3 *Supply side – selling science*

Scientists we interviewed found themselves selling their science in many settings: filing invention disclosures, initiating patenting without solicitation from industry, and interacting with the TTO all signal their willingness to sell in the commercial marketplace. These commitments were often structured via licensing agreements, consulting arrangements, SAB membership, or sponsored research in the academic laboratory. Scientists described themselves as selling their science at conferences which provided a venue for industry to observe expertise in action.

Our interviews suggest two aspects of the selling process: (i) the skills and resources needed to sell, and (ii) interest in the selling role. We found baseline gender differences in selling skills as well as differential access to the resources needed to learn such skills. The key gender difference was the way in which women “talked about” their science (not limited to commercial issues). They described their science in “smaller” terms—focusing on the “details” and specifics of their projects and contributions. The impression from male faculty was of a grand research agenda with

more “sweeping” potential. While difficult to document, such stylistic differences may impact women’s ability to sell science in the commercial market.

Faculty draw on a range of resources to learn the selling process: PhD mentors, collegial networks, and institutional mechanisms. Women overall felt excluded from commercial “resources” by their PhD mentors (notably senior women). This supports prior evidence that the PhD mentoring relationship can be the source of gender stratification (Long, 1990) and underscores the importance of mentors in shaping expertise (Ibarra, 1999). Women also made differential use of collegial networks to learn the art of selling. Both sexes commented on the importance of senior mentors in the commercial science process, but many women felt that their senior colleagues were sometimes unwilling to show them the ropes. In contrast, men freely approached senior faculty for advice. Women were more likely to learn from close collegial peers, to use formal institutional mechanisms such as the TTO to provide resources and to learn about commercial science. Men who interacted with the TTO used the office for legal support, to identify lawyers and to manage the licensing process. Most of our male interviewees, felt that this third-party broker had little additional impact on their ability to link to established companies. Women described the “hand holding” provided by the TTO as guiding them through an uncertain landscape.

In spite of different resources to learn about commercial science, women seemed as interested as their male colleagues in commercialization and actually declined opportunities at a lower rate than their male colleagues. Both sexes also described initial ambiguity regarding their role in the commercial market, particularly in the 1970s when commercialization was highly contested and controversial (Colyvas and Powell, 2006). However, while women continued to exhibit greater ambivalence in whether to actively sell their science among male faculty we found few voices still expressing reservations about commercial practices—most described their personal choices in terms of their own interests. Men described resolving ambiguity through conversations with senior colleagues and in pragmatic terms, recognizing that commercial science was an imperative in moving their ideas from bench to bedside. The few men with high levels of commercial relevance and low levels of participation described their (lack of) selling unambiguous terms—they had made a calculation that patents and licenses were ineffective tools of commercialization in their specific research area. Women had a distinctive attitude towards selling that was typically shaped around ambivalence and ambiguity. While a few found commercial science unproblematic (including some who did not participate), most—those actively involved and those with no commercial activity—expressed concerns and reservations with the practice.

Overall, our preliminary qualitative and quantitative analyses support the notion that there exist salient gender differences in both the supply and demand dynamics of commercial science. While acknowledging the existence of some within gender distinctions, the gender variations that we documented seem to be more substantial.

Moreover, we found these gender differences to be even more salient when we analyzed our interviews by generation. Section 5 lays out narratives on commercial science by generation as a means to further contour our understanding of the role of gender and age (and the role of within gender variation) in commercial participation.

## 5. Generational narratives on the market for commercial science

Women currently comprise 20% of Big School life science faculty, their representation having risen over generations; 8%, 21%, 26%, and 33% for distinguished, senior, mid-career and junior respectively. Our analysis of the academic performance by generation (Table 2)—confirms the objectives of our research design—to use generational cohorts to further match male and female faculty by publication records, (citation) impact on the scientific community, and collaborative scientific networks. Nonetheless, within generations we find that patent rates vary significantly by gender, a pattern consistent with recent large scale quantitative evidence (Ding *et al.*, 2006) illustrating a persistent gender difference in commercial science, even for junior faculty. By organizing our interview data by generational narratives we further deeper our perspective on the gender variations in patenting and other aspects of commercial science.

### 5.1 *Distinguished and senior faculty*

The dominant narrative of commercial science for these women is of a *lack of opportunities* and *exclusion by buyers*. Our interviews support prior work (Ding *et al.*, 2005) suggesting that in the 1970s and 1980s entrepreneurs and investors almost exclusively approached male scientists when building legitimacy for controversial biotechnology firms. Women felt explicitly excluded on the basis of their gender, and rapidly fell behind in commercial science, which seemed to operate as “some sort of club” behind the scenes. One interviewee noted, “Businessmen came and recruited [male faculty]” and wondered “why didn’t they ask me?” She was told by a male colleague that women could never be involved because businessmen would never recruit them. It seems that in the early days of commercial science, evaluators (such as investors) invoked stereotypic beliefs associated with gender to inform their judgment about the potential to perform commercial science (Festing, 1954). As women built their scientific reputations alongside men, they failed to gain commercial experience and were, at most, peripheral in commercial science networks. Few had more than passing SAB experience compared to some of their male colleagues, who typically served on three or more SABs. One commented that a close male colleague was often approached at conferences by industry scientists and other academics for his opinion on a subject much more central to her research agenda and expertise. Many women said they are not listened to like men: one

**Table 2** Academic science and commercial science characteristics for the entire population of 148 faculty at “Big School”

Cohorts by by PhD Year	Pre-1975 “Distinguished”		1976–1985 “Senior”		1986–1994 “Mid-career”		1995–Present “Junior”	
	M (46)	W (4)	M (26)	W (7)	M (28)	W (10)	M (18)	W (9)
Mean [range] <i>n</i> publications per year	6 [0.5–19.9]	3.1* [2.2–4.8]	4.8 [1.5–9.6]	3.1 [1.4–4.7]	3.6 [0.8–7.3]	3.1 [0.6–6.3]	2 [0.7–2.8]	1.7 [0.6–5.1]
Mean [range] <i>n</i> citations per publication	58.1 [0–640]	53.6 [0–387]	54.5 [0–690]	55.6 [0–515]	52.1 [0–432]	52.1 [0–274]	30.8 [0–175]	23.3 [0–116]
Publications with Industry (%)	15.5%	2.4%	20.6%	2.9%	11.7%	5.9%	9.6%	7.5%
Faculty with one or more granted patents (% <i>, n</i> )	73.9% (34)	0%	88.5% (23)	28.6% (2)	60.7% (17)	50% (5)	44.4% (8)	11.1% (1)
For patenting faculty only, Mean [range] <i>n</i> granted patents	15.0 [0–158]	Na	9.3 [0–31]	3 [0–5]	4 [0–25]	7.8 [0–17]	5.1 [0–13]	1 na

\*It should be noted that while there are differences in the number of publications between male and female faculty in this generation, in general the four women in the generation are “younger” than their male counterparts, which skews the publication data (the average PhD award year is 1972 for female faculty compared to 1968 for male faculty in this generation).

remarked “what I say doesn’t count . . . if [male colleague] got up and said it, it might count.” Revealing a deep understanding of the inherent gender biases that can be activated in our society when new areas of practice emerge (Ridgeway and Correll, 2004; Ridgeway, 2006; Swidler, 1986), senior women noted that “below the surface” there exists a different “comfort level” where men interact.

We heard nothing about exclusion from male faculty in these generations. Men did not share women’s discomfort, but saw their own non-participation as a choice versus a matter of constraint. While commercially-oriented faculty faced criticism within the academy and both sexes voiced concern over the encroachment of commercial practices into their traditional world, only male faculty participated in early commercialization. In doing so, they built on a series of “male” traits—the ability to sell grandiose, visionary, and large scale science (Fox Keller, 1985, 1988). This rapidly established commercial science as an activity undertaken by men in the “male science” image (see Ridgeway, 2006 for a discussion of how gendered interpretations of new practices and norms become institutionalized in emerging work environments).

Their lack of experience and this male “vision” left some women uncomfortable with the emerging role for faculty in commercial science. Several expressed disinterest, ambivalence, and negative or skeptical attitudes towards the commercialization process. One interviewee remarked that her collaborator of seven years is “driven by money” and she avoids his company, seeing it as a conflict of interest. She has not filed any patents because—in addition to the “unethical” aspect of commercial science—she quips, “I don’t even balance my checkbook.” She believes that the integration of commercial science into academia has sent quality control “down the drain.” When she interacts with companies she is “shocked” by how little they know, and she does not really enjoy it because one “pompous” person follows another.

Other senior women remained more open to commercial opportunities but found them late in coming. They felt relatively disadvantaged and uneasy in selling science. One who had recently accepted an invitation from a colleague to found a firm felt uncomfortable with the professional norms and social behaviors of commercial science. The ease with which her male colleague participated in this very different world surprised her.

## 5.2 *Mid-career faculty*

The dominant narrative of commercial science for these women is of *ambivalence over participation* in commercial science and a *narrow opportunity structure*. They received their PhDs as biotechnology became a stable and legitimate part of the organizational landscape (Murray and Kaplan, 2003; Colyvas and Powell, 2006), generating a significant rise in faculty commercial participation (Owen-Smith and Powell, 2002). Yet, like prior generations, few had PhD advisors who were engaged

in commercial science and their participation rates are much lower than their male colleagues.

Among Big School's mid-career faculty, men experience greater participation, a broader network of opportunities, and no ambivalence over the appropriateness of the role or the time it takes away from family, laboratory or teaching. Women are less likely to participate, do so ambivalently, and at a lower scale of involvement. Many of the men we interviewed rapidly observed their senior colleagues, initiated discussions around the nature of commercial science and found role models. The only man in this interview cohort who did not participate based his decision on a strong philosophical perspective associated with his particular research outputs and their availability as research tools.

Women found a disproportionate number of buyers among close colleagues, were rarely approached by outsiders, and had few referrals. In explaining what she saw as a pattern of discrimination, one woman observed the "natural tendency" to go to a man remarking "there's a powerful mindset against asking women to sit on company SABs." Another remarked that people are reluctant to nominate women for commercial opportunities through a combination of "overt prejudice" and "hidden bias." Other colleagues concurred on the existence of cognitive bias against supporting or collaborating with women: "unfortunately the default thing is still gender bias". When they accepted commercial opportunities most women became subordinate partners to male colleagues—the commercial role seeming to be a poor fit and taken on with some reluctance. There were exceptions—one woman had great success in transforming early opportunities into broad referral networks and acquired well-honed selling skills.

### 5.3 Junior faculty

The dominant narrative of commercial science for these women is *conflict between a) perceptions of equal opportunity and b) indicators of emerging constraints*. Research on scientific productivity and career accomplishments in the life sciences demonstrates parity among the junior generation along traditional aspects of scientific careers (Xie and Shauman, 1998). This generation was trained in a milieu that acknowledged and promoted the benefits of commercial science. They observed extensive participation in both academic and commercial science by advisors and mentors. A larger number had the opportunity to file patents. A few had already even achieved the unusual status that brings invitations to advise or found companies. Nonetheless, our evidence still highlights a striking gap in commercial participation rates.

Both faculty share professional concerns: winning grants, publishing, and gaining tenure. For most, commercial activities are something they anticipate later in their careers. Attitudes towards commercial participation also show some parity. Across the gender divide, the attitude towards (and practice of) combining

commercial activities with academic science is strongly shaped by the PhD experience; mentoring by commercially active (male) advisors gave junior faculty a sense of the role of commercially-oriented academia. Our interviews suggest that this is the first generation in which faculty mentors have engaged their male and female students equally in patenting. This generation thus provides useful insights into the formative period of socialization when role models are critical in shaping perceptions of selling science and offering opportunities to enter networks initiated by potential “buyers” (Clark and Corcoran, 1986).

It seems that early and equal mentoring in commercial science might ameliorate women’s disadvantage in attitudes. However, patenting statistics do not support this: The lone female patent holder holds only one patent. Of 18 junior male faculty, eight had granted patents and one holds 13. Only one woman (of nine) has founded a firm, chairs its SAB and has plans to start other firms hoping to “become independently wealthy.” There is some limited evidence that only male rookies have been invited to serve on SABs at this early stage in their career. Junior men are disproportionately likely to engage in actions to aggressively shape their position in commercial (and academic) networks and strategize to sell their science. Conversely, only among junior women, particularly those with female faculty mentors, was there concern over “managing money” and their ability to balance commercial, academic and personal priorities. Again the theme of exclusion arose: one junior woman commented that she has the CV of a “respectable scientist,” but lacks “the look” of one. She described presenting at an industrial conference where male colleagues failed to realize she was the professor overseeing the research. The seeds of gender stratification are thus emerging in this generation, though its extent *remains to be seen*.

## **6. Demand and supply intersections in the commercial science marketplace**

We find, like other scholars, that it is the interdependencies between supply and demand dynamics that illuminate the emergence and change in gender stratification. However, few studies have explored these intersections in detail, and none have used rich qualitative analysis. Interviews reveal a wealth of rich social processes in which positive and negative individual experiences shape faculty views of commercial science and in turn lead to different opportunity structures. We find (i) three key intersections underpinning the initial gender gap in commercial science, and (ii) a series of mechanisms that have reinforced and undermined the gender gap in the past thirty years.

The *first intersection* is that, given their exclusion from commercial activity, women had fewer opportunities to participate and gain experience in commercial science. Distinguished and senior women found themselves excluded from

commercial science by investors, entrepreneurs, and senior colleagues and their accomplishments viewed with a gender-discount (for recent evidence in academic science see NAS, 2006); their productivity has not done as much “work” for them as for their male colleagues (Ibarra, 1992; Renzulli *et al.*, 2000). As a result, women rapidly fell behind in their skills in selling science and became less socialized into the practices of commercial science. The industrial collaborations of senior women bear this out with the percentage of their publications co-authored with industry at only 2–3% compared with 15–20% for their male colleagues (Table 2). This was exacerbated by their exclusion from traditional scientific networks, which, at least in the early days of commercial science, were not “activated” for women by their male colleagues. Under these circumstances the male mentors and colleagues to whom women traditionally turned were not available to them for socialization and learning. Such a peripheral position in commercial networks left women unable and unsure of their abilities to sell science and their language, often in direct conflict with their professional skills and practices, acknowledged this insecurity.

A potentially more important *second intersection* is that, having been excluded from early commercial opportunities, women have fewer opportunities to learn, discuss, and resolve the ambiguities that commercial science caused among all scientists. As a result, across all generations they appear more ambivalent (Merton, 1976; Smelser, 1998) than their male colleagues about participation in commercial science. Women are less likely to actively sell their science and seem more ambivalent (and thus less effective) when they do.

This was particularly notable among mid-career women: some had received but declined SAB invitations. These women constructed commercialization as a complex tradeoff bounded by their commitment to lab work, students and teaching. Several described the activities as posing a serious conflict of interest with administrative duties. In contrast, men felt that their students gained by their participation in commercial science which represented a legitimate aspect of their education. Most incorporated their students into patent writing, sought out their support in start-up formation and generally responded to student curiosity.

One man’s experience demonstrates how early involvement in commercial networks, and early willingness of male mentors to discuss commercial science, lead to a gender difference in resolving ambiguity. He commented that when he joined Big School he addressed the question of the scientific-commercial divide explicitly. His senior male mentors told him to manage the conflict of commercial science, not ignore it, and that he had an obligation to bridge the gap. We heard no similar stories from the women we interviewed:

I was quite intrigued by the potential for commercial activity – my advisor had had some involvement with commercializing his software and several of us had become involved in testing software and using it as consultants to this start-up . . . but I was still unsure how this could

be integrated into my academic research without problems or conflicts... when I came to [Big School] I raised it with my mentors who assured me it was a conflict I had to manage as was essential to further my science and really make an impact.

A *third intersection* that shapes the relationship between interest and opportunities is that the early activities of commercial science were constructed as an essentially male practice. Therefore women are inherently disadvantaged, being less skilled at “male-style” selling. They responded by being more likely to be disaffected with selling science and in later generations, self-assess as less adept in this male activity (Correll, 2001). Many women noted that commercial science was inherently associated with men. One senior female scientist said the “general perception is that women are not entrepreneurial” and “men are in control of... money.”

Among some senior women their experience of watching male colleagues selling science generated skeptical attitudes towards commercial science: “not fun” and “too contentious”. One who turned down a SAB opportunity explained “It was very male and too much like the other [relatively unpleasant] male-dominated aspects of my scientific career.” Only two of these senior women adopted the equanimity we observed in their non-commercially involved male colleagues—a senior biologist summed it up “I am probably the control in your study – I really have no involvement in anything commercial... I understand why some people do but I am simply not interested.” Senior women were the only group to describe being turned off by the practice; for younger generations the male construction of commercial science was revealed in their greater discomfort with the “selling” role.

Demonstrating how rapidly this gendering of roles can take place, none of the men interviewed expressed any discomfort with the selling process. In contrast, some women expressed reservations in their willingness to sell their science, and felt less effective in doing so than their male counterparts. The most self-aware were those in mid-career who noted that their male colleagues were much more effective at “selling” themselves and in gaining industry recognition for their research. Echoing the views of the broader gender literature that women “don’t ask” (Babcock and Laschever, 2003) and are poor at selling themselves, one interviewee remarked that to succeed in commercial science, “one has to be willing to argue” and that the “start-up mentality is of self-promotion and hyperbole.” She described a potential male co-founder for a company as “[drumming] up the work” while she “[celebrated] the technology” because she had a “harder time selling herself” than she believed men did. One commercially active man we interviewed felt “women don’t self-promote well. They’re much more tentative about their vision.” Their attitude toward commercialization was “hesitant,” even when women were advised by prolific founders they were less comfortable with their ability in commercial science. In contrast, a junior faculty member described himself as aggressively pursuing commercial projects and opportunities alongside his PhD advisor,

describing how on his third day in the lab he wrote a disclosure, even though he “didn’t know what it was at the time, just related to an invention.” He learned from his advisor about not being “just commercial but being commercially savvy.”

These *three interactions* together lead women to have less commercial expertise, to be less socialized into commercial science, and to become more ambivalent about the practice, and thus more likely to self-assess their commercial competency as weak. Across generations, the cumulative impact leads to varying degrees of disaffection with the commercial role, a lack of confidence in selling science and at times a decision to rather vigorously defend their decision to “opt out” of commercial science and focus on teaching (Smelser, 1998; Blair-Loy, 2005). However, we also identify a series of factors that have further stratified each generation and some factors that have diminished the gender gap.

### 6.1 Reinforcing intersections

The first factor reinforcing gender stratification across the generations is that in science, as in other professional settings, women are more likely to be mentored by women. Thus they are more likely to learn from individuals with less commercial experience, limited access to commercial networks and some degree of disaffection over commercial practices. This reinforces some of the disadvantages suffered by women in commercial science. Women themselves pointed to the role that “homophilous” networks had in reinforcing their lack of opportunities: When asked if she had been invited to join a SAB or offered consulting opportunities by senior colleagues, one woman replied: “no, first of all I work on X and second of all I am a women and so that would never happen to me...I am not bitter about it...it never happens to any of my female colleagues...its just a fact of life. Maybe I have more female friends in science than male friends and so they ask their friends not me.”

Second, the broader societal perspective on women in commerce reinforces cultural stereotypes against women and money (West and Zimmerman, 1987) and therefore reinforces the ambiguity of women around their role as commercially-oriented scientists. Numerous mid-career women asked male colleagues to lead a commercial activity; they followed with less confidence and with the recognition that they were uncomfortable in the commercial role. One mid-career woman started a company alone but asked her graduate student to become CEO and to lead the fund raising effort because of her expectations about attitudes towards female CEOs: “if I had taken on the CEO role...it would have been more difficult... Venture capitalists are male and the industries I work with are old school male institutions”. They “don’t want to deal with me all the time.” Her CEO, a former student, “[fits] into the social groove right away” whereas she’s “more independent.” Contrasting womens’ tendency to follow behind male colleagues, one junior man

described a commercial collaboration with a senior man as a “combination” of “both their ideas.”

While the commentary was subtle, we heard similar language from a few junior women indicating emerging ambivalence over commercial science even today, verbalized as a “fear of money,” “[incompetence] with money and finance.” Akin to her mentor—the senior woman who does not balance her checkbook—one rookie (who builds complex mathematical models on a daily basis) commented that she would certainly be interested in trying to patent but that “someone would have to push her,” “hold her hand.” She added that money and business are “really scary” to her; “she can barely manage her own grants.” It is particularly striking that this attitude comes from a junior woman with a female PhD advisor who had limited commercial experience; her views are in sharp contrast to junior women with commercial active advisors.

A third reinforcing mechanism is the complex, gendered role of balancing work and family. Surprisingly, none of the faculty we interviewed explicitly mentioned family as a rationale for non-participation in commercial science. However, mid-career women were the first at Big School to try and maintain their careers while pursuing a family. This balancing act led them to consider pursuing commercial science later in their career, with the result that they were less socialized and adept at selling science than their counterparts. Moreover, even when these women had male mentors willing to shepherd them through the commercial process, such mentors could provide limited insights into striking a balance between work and family. As a result, several pulled back from working with commercial men because they were worried about the balancing act required. For all these women, one consequence was that in the early years when networks were being activated and formed, they were sidelined with potential consequences for later commercial opportunities.

## *6.2 Reducing intersections*

Strong mechanisms work to reinforce gender stratification in commercial science. Nonetheless, we found three intersections reducing gender differences: mentoring, institutional support and the role of “signal shocks” to investors.

Mentoring plays a critical role in academic training (Fox, 1998); the same is true for commercial science (see Bercowitz and Feldman, 2003 on mentoring and invention disclosure). Explicit mentors or role models are particularly salient in shaping women’s attitudes and in overcoming broader gender stereotypes. For instance, one mid-career woman noted that the tendency of women to hold themselves back in pursuing commercial science was something a good mentor could not “reverse.” Particularly among junior faculty, PhD advisors seem to be critical to normalizing commercial science, making it appear accessible and normative, and thus to re-shaping supply-side attitudes of female faculty.

We spoke to several “pairs” of junior faculty with the same commercially active PhD advisor and found considerable parity in the degree to which these junior men and women had been included by the advisor in commercial science. Parity also followed in their overall attitudes toward participation in commercial activities, though such parity is not born out in current junior faculty patenting rates at Big School where a gender gap remains (a finding consistent with the quantitative work of Ding *et al.*, 2006; Bunker Whittington and Smith-Doerr, 2005). We also found some, albeit limited, evidence that industry was becoming more accessible to women, with rates of industry collaboration starting to approach parity for junior faculty (Table 2), aided in large part by collaborative experiences in graduate school.

Institutional support and clear metrics for participation and success from Big School were also salient in shaping faculty attitudes toward commercial science, especially for the women we interviewed. Such institutional “rules” helped reduce ambiguity and ambivalence among women. This helps to restructure the supply-side of commercial science by providing information about the role of commercial science in the promotion process and making support for activities less “hidden” and not perceived as a “male club.” Of course, to the extent that the TTO itself has gender bias, or provides a roadmap to commercialization at too high a level of sophistication, it too can reinforce instead of undermine the gender gap. Overall, however, the TTO and related institutional supports seemed to be of more significance to women than to their male colleagues. This perspective is supported by the rise in patenting rates among mid-career female faculty, where patenting participation has reached 50% (compared to 60% for mid-career men).

A final observation is the degree to which “signal shocks” (as we call them) increase opportunities for women in commercial science. Among a number of senior women (but not senior men) we interviewed, appointment to high profile administrative positions—a signal of competence—was followed by a bewildering increase in the number of commercial opportunities. It seems that the signal served as a more readily observable record of commercial interest or other external endorsement to elevate the reputation of these women. A clear illustration was given by one senior professor who described receiving more than 20 invitations to sit on Advisory Boards following her arrival at Big School to take up a senior administrative position: “even though my science had not changed at all, suddenly people thought I was more useful to them and they wanted to involve me in commercial activities.” All the women we interviewed who had taken high profile positions had had similar experiences. Another woman described an avalanche of invitations that arrived after she was invited to serve as a co-founder of a start-up by her prominent former advisor. Once she had been endorsed by a central actor in commercial science, her visibility was dramatically increased and a new opportunity structure followed.

While this does not suggest a significant overall shift in the supply-side, it does imply some flexibility. As Fiske and Taylor (1984) have suggested, social cognition

theory offers a plausible explanation for the importance of such visible accomplishments in creating opportunities for those generally seen as disadvantaged or less adept (in this case women scientists). This underscores our perspective that, particularly in the early days of commercial science, gender was used as a proxy in the assessment of ability. Visible signals of attainment help overcome these proxies and remain of great significance to women faculty. While the few women promoted in commercial science as a result of these “shocks” have started to serve as mentors and role models to other younger women, the impact of their mentoring on junior women’s participation remains to be seen and is not yet evident in our data.

## 7. Conclusions

Overall, the gender gap in commercial science has by no means disappeared at Big School; in the entire population of junior faculty, 44% of men have granted patents compared to only 11% women. More importantly, initial evidence, described earlier, indicates that the opportunity structure for junior women is more stratified than their perceptions allow. Despite the progressive gains made towards parity in their graduate training, as young professors they confront an opportunity structure in which gendered work-family conflicts and cultural stereotypes of women and finance persist. While this structure is undoubtedly more flexible than in prior generations, our qualitative and quantitative evidence indicates that systemic gender stratification endures and requires more than convergence in cognitive attitudes among buyers and sellers of commercial science.

Overall, our research elucidates key determinants of gender stratification in commercial science that lie at the supply and demand intersection of the commercial marketplace. These intersections were initiated when early buyers in the market activated traditional cultural stereotypes of women in science and business, and showed an initial gender bias in the opportunities available to women life scientists. The gender gap in opportunity structure appears to have had a powerful impact on the commercial participation of senior female faculty in at least three ways. First, particularly when the activities are behind the scenes, women had few opportunities to be socialized into commercial science, fell behind in their mastery of the role, and were increasingly less likely to be invited to participate over their male colleagues. Second, women had fewer chances to resolve the ambiguity that most life scientists felt regarding commercial science, leading them to be more ambivalent about their selling skills and lack enthusiasm for commercial participation. Third, the practices of commercial science came to be constructed as male, with some women becoming disaffected and taking a negative attitude towards the newly forming commercial marketplace, and later generations self-assessing that they were less adept than their male counterparts.

These intersections were reinforced across generations by homophily in mentoring and networks, work-family issues, and broader societal stereotypes towards women in commercial roles. However, our evidence also suggests some mechanisms that serve to undermine the enduring disadvantages accumulated by female faculty. These include “signal shocks,” the powerful role of gender-neutral PhD mentoring for young faculty from commercially active advisors, and the rise in visible institutional support for commercial science.

Encouraging research and institutional policies that redress inequities in faculty participation in commercial science is an important next step within this shifting context. Our findings suggest several policy interventions to facilitate the female participation in commercial science and to therefore ensure that those scientific ideas with important commercial relevance are not squandered. First, women’s commercial participation rates can be raised by mentors who (i) encourage *all* their students to look behind the scenes into the world of commercial science, (ii) provide them with ties to those who want to “buy” their ideas, and (iii) show women how to sell their science without corrupting their scientific integrity. Second, the TTO can be asked play an important role in brokering faculty participation in the commercial science marketplace, specifically by providing legitimacy and support for female faculty navigating the commercial market. The TTO can also broker contacts to industry “buyers” who might otherwise overlook good ideas generated by female faculty. Third, the industrial and investment community can be confronted with data such as ours and prompted to look beyond their traditional male networks to assess and “demand” ideas from female as well as male scientists.

The primary limitation of this study is the generalizability of our findings. This elite, insular sample of scientists operates in a commercial environment that is still relatively rare in academia. This experience probably exists only at leading institutions in the life sciences situated in regions with strong commercial institutions. Such limitations beset any single “case study” and speak to the external validity of the findings. Yet, in other aspects of technology transfer, recent qualitative findings suggest considerable similarity in experiences at the institutional level, even if striking regional variations persist. In future work, we intend to probe the degree to which other elite research institutions in similar commercial settings exhibit similar dynamics, especially given the critical role of “initial conditions” in the early experience of female academics in shaping the interactions between supply and demand for commercial science at Big School. It will be essential to establish whether, in a case where the initial participants in commercial science were more gender balanced (if indeed such a case exists), the same intersections would pertain or if the dynamics would lead to a quite distinctive set of (more positive) intersections. Nonetheless, we believe that our findings bring deeper insights into (and encouragement for) the changing role of women in academia and the dynamics of the commercial science marketplace.

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