Gender Differences in the Relationships between Research Impact and Compensation and Promotion: A Case Study among PhD/PharmD Medical/Dental School Faculty

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Abstract

We examine whether the effects of research impact on faculty compensation and promotion to full professor differ for male and female associate and full professors in the Faculty of Medicine & Dentistry at the University of Alberta. We exclude faculty with MDs and DDSs and proxy for research impact using the faculty member's *h*-index, where *h* represents the number of publications that have been cited at least *h* times. We find that while the compensation of male faculty members increases by 0.6% for every one-unit increase in the *h*-index, the compensation of female faculty is essentially uncorrelated with their *h*-indices. We likewise find that for female faculty to be promoted to full professor they have to have higher research impact proxies than their male peers. Our findings highlight the urgent need for more research on the gendered relationships between research impact and career rewards among faculty.

Keywords: gender pay gap, productivity, promotion, academic medicine

Résumé

Nous avons évalué l'impact de la recherche sur la rémunération du corps professoral et la promotion au rang de professeur titulaire, entre les professeurs agrégés et titulaires hommes et femmes de la Faculté de médecine et de dentisterie de l'Université de l'Alberta. Nous avons exclu les professeurs cliniciens ayant un doctorat en médecine (MD) ou un doctorat en médecine dentaire (DDSs). L'impact de la recherche a été évalué à l'aide de l'indice *h* de chaque membre du corps professoral, où *h* représente le nombre de publications qui ont été citées au moins *h* fois. Nous constatons ainsi que tandis que la rémunération des hommes augmente en moyenne de 0,6 % pour chaque augmentation d'une unité de l'indice *h*, la rémunération des femmes est essentiellement non corrélée avec leurs indices *h*. Nous constatons également que les professeures atteignent la parité pour la promotion au poste de professeur titulaire avec les professeurs masculins équivalents à des indicateurs d'impact de la recherche considérablement supérieurs aux valeurs médianes normalement attendues pour une promotion au poste de professeur titulaire. Nos résultats mettent en évidence le besoin urgent de plus de recherches sur les relations entre le genre et l'impact de la recherche sur l'avancement de la carrière chez les professeurs-chercheurs.

Mots-clés : écart de rémunération entre les genres, productivité, promotion, médecine universitaire

Introduction

A number of Canadian universities including Acadia University, McMaster University, Simon Fraser University, University of Calgary, University of Alberta, University of Guelph, University of Toronto, and University of British Columbia have undertaken reviews of faculty compensation in the last decade to determine whether gender[1] inequities in compensation exist. These studies have documented gender-based pay gaps ranging between \$1,496 and \$3,515 (e.g., Abramson & Rippeyoung, 2012; Bakker et al., 2010; Kaufmann, 2017; Kessler & Pendakur, 2015; McMaster University, 2015), even after controlling for rank, discipline, and years at the university. In percent terms, Benjamin et al. (2019) found that female faculty at the University of Toronto earned 1.3% less than their male peers after controlling for faculty characteristics. Consistent with these findings from individual universities, Momani et al. (2019) use publicly available compensation data for all Ontario universities to document that male university teaching staff earn 2% more than female teaching staff even after controlling for rank, years with the employer, and the university of employment.

One potential explanation for these gender pay gaps is that male faculty may be more productive than female faculty (Doucet et al., 2012). Indeed, Momani et al. (2019) urge in their study that subsequent analysis explicitly accounts for labour productivity. Measuring academic productivity, however, is challenging for at least two reasons. First, what constitutes output varies dramatically across fields of study (Kyvik, 2003). Books, exhibitions, and performances represent important outputs in the humanities and fine arts, while refereed journal publications are the prevailing form of research output in the sciences and many other disciplines. Second, even among disciplines in which refereed journal articles represent the standard form of research output, the average number of articles published over a career varies widely by discipline (Millar & Barker, 2020). As a consequence, citations—a measure of research impact and a potential alternative to publication counts—also vary substantially across disciplines.

The difficulty in measuring research productivity in a uniform fashion across academic disciplines has meant that the individual university studies have largely been unable to assess the impact of research productivity on gender gaps in academic career outcomes. In this study, we address this gap by examining the contribution of research productivity to gender pay gaps and gender differences in promotion to full professor using a sample of academics at the same university in closely related fields where the unit of research output—refereed journal publications—is clear.[2] Specifically, we investigate the role of research impact in compensation and promotion to full professor in a subset of associate and full professors in the Faculty of Medicine & Dentistry at the University of Alberta.

Estimating linear regressions of log-compensation from publicly disclosed compensation data on faculty characteristics, we find that female faculty in the Faculty of Medicine & Dentistry earn 15.0% less than their male peers. Controlling for rank, years since receiving a PhD, years at the university, and years in rank, female faculty earn only 3.2% less than similar male peers—a difference which is no longer statistically significant. Given that annual increases in compensation are determined through a competitive, merit-based process, we then examine the relationship between compensation and research impact proxied for using a faculty member's *h*-index, where *h* represents the number of the individual's publications that have been cited at least *h* times. We find that each one-unit increase in the *h*-index is associated with a statistically significant 0.6% increase in compensation for male faculty members. By contrast, the compensation of female faculty is essentially invariant to changes in the *h*-index. The lower return to research impact among female faculty is remarkably robust to the use of alternative sets of controls and measures of research impact.

The gender gap in compensation conditioning on rank may understate the extent to which female faculty are paid less than their male peers if biases result in lower promotion rates for female faculty. Female faculty in our Faculty of Medicine & Dentistry sample have indeed been promoted more slowly than their male peers. Among faculty who are 15 years past the receipt of their terminal degree, for instance, just 56.4% of female faculty in the Faculty of Medicine & Dentistry have been promoted to full professor, compared to 73.5% of their male peers; comparably large gender gaps exist at all career stages.

The lower probability of promotion to full professors among faculty at Canadian universities has been documented by Stewart et al. (2009) and others. Because promotion to full professor represents one of the most significant career rewards for productivity, we estimate discrete time proportional hazard models examining the relationship between gender, research productivity, and their interaction on the probability of promotion. Specifically, we reconstruct the longitudinal history of research productivity for each faculty member to create a panel data set of years at-risk of promotion using the number of publications, the *h*-index, and citations for publications observed in the year at-risk as our proxies for research productivity. The estimates imply that female faculty are essentially playing catch-up, as female faculty have a lower predicted likelihood of being promoted than otherwise similar men until they have at least 58 publications, an *h*-index of 28, or 5,464 citations—thresholds considerably above the median values (39, 22, and 1,954, respectively) for associate professors in our sample. The small number of women promoted to full professor in our sample means that these estimates should be viewed with caution, but the fact that research productivity has a gendered relationship to promotion probabilities suggests a need for further research in this area.

Section 11 of the *Canadian Human Rights Act* (Government of Canada, 1985) protects pay equality as a human right: "It is a discriminatory practice for an employer to establish or maintain differences in wages between male and female employees employed in the same establishment who are performing work of equal value." Our findings suggest that the university may fail to reward female faculty in the Faculty of Medicine & Dentistry for their research contributions in the same way as their male peers. Given the similarities in compensation practices and collective bargaining agreements across Canadian universities, our study highlights the need for further investigation into whether the research contributions of female faculty are under-rewarded in terms of compensation and promotion relative to their male peers. Our sample is both small and unrepresentative of the population of faculty at Canadian universities, but the finding that female academic compensation is insensitive to research impact measured by the *h*-index is sufficiently concerning as to require further scrutiny to determine its generalizability.

Our findings also have practical implications for how universities and faculty associations work together through collective bargaining agreements to resolve gender inequities in compensation. In most instances where evidence of inequities have been found, the parties have sought to compensate female faculty through either one-time, lump sum payments or adjustments to female faculty placements on salary scales (e.g., Bradshaw, 2013; Hassan, 2019; University of Toronto, 2019). Our results suggest that such remediation may result in gender inequities simply re-emerging over time as the research of female faculty is assessed in the merit review process (e.g., the re-emergence of gender pay gaps at the University of Waterloo following prior remediation; see Loriggio, 2016). Only comprehensive reforms to the processes by which faculty are evaluated and promoted that root out systemic biases that result in the undervaluation of the research impact of female faculty will be sufficient to ensure gender equity. In the Discussion section, we discuss potential sources of the undervaluation of female research and offer some thoughts on how the process of merit evaluation might be improved. Finally, as a practical matter, our findings also highlight the need for faculty associations to reserve the right to collectively bargain over gender inequities even after the parties agree to remediation.

Related Literature

Gender gaps in compensation among faculty in Canadian universities have been documented going back at least half a century. Warman et al. (2010), for instance, used the Full-Time University Teaching Staff Data of Statistics Canada to demonstrate the existence of gender pay gaps among faculty in all Canadian universities over the period of 1970 through 2001, even after controlling for faculty characteristics and institutional fixed effects. While Warman et al. show that these gaps were declining among cohorts over their sample period, the findings of Momani et al. (2019) and the individual university studies mentioned in the introduction indicate that these gender gaps persist.

The persistence of gender pay gaps despite institutional efforts to eliminate them suggests the need for studies that go beyond examining the contributions of gender differences in disciplines, years of experience, and rank to examine gender differences in performance. The analyses at McMaster University, Simon Fraser University, and the Universities of British Columbia and Toronto as well as the study by Doucet et al. (2012) adjusted for high profile recognitions like an endowed Chair or a Canada Research Chair (CRC). While a clear indication of research excellence, the small number of such awards means that they are unlikely to explain much of the substantial variation in faculty compensation. More importantly, the Canada Research Chairs program has itself been under scrutiny for inequity problems (Halliday, 2019; Side & Robbins, 2007). Controlling for the receipt of these high-profile awards may, in fact, lead to biased estimates of gender pay gaps.

The analyses for the Universities of Guelph, Waterloo, and Western Ontario included measures of academic achievement like merit increments. None of the analyses looked at a metric like the *h*-index (University of Western Ontario, 2009; University of Guelph, 2018; University of Waterloo, 2016). More importantly, controlling for merit awards rather than the true underlying performance again risks underestimating gender gaps in compensation if gender biases influence the performance review process. By controlling for the *h*-index, we proxy for actual rather than the assessed research impact, and we are able to examine whether the return to this research impact varies by gender.[3]

Within the Canadian academy, there have been bright spots where gender gaps in pay are concerned. After previously documenting large gaps at the University of Manitoba, Brown and Troutt (2017) found that all the raw gender pay gaps could be explained by gender differences in discipline, experience, rank, and appointment type. They note, however, that this may obscure important gender differences insofar as the rate of promotion was lower among women.

Prior studies have demonstrated the lower promotion rates and longer times to promotion among female academics in Canada relative to their male peers. Using Statistics Canada data on Canadian academics, Ornstein et al. (2007) find that the median time to promotion to full professor for men was 8.83 years, compared to 9.74 years for women. In a subsequent study using all full-time faculty members at Canadian universities between 1985 and 1999, the same group of authors found that differences between fields and institutions could not explain the gender gap in time to promotion to full professor (Stewart et al., 2009). Similarly, Doucet et al. (2012) find evidence at a large, unnamed Canadian university of longer times to promotion for women between 1997 and 2006, where promotions and access to market premiums and the CRC largely explained the gender pay gap.

If gender differences in time to promotion cannot be explained by differences in fields and institutions, one possibility is that female faculty may be less productive than their male peers. In a 2015 survey of faculty from eight Canadian universities, Wijesingha and Ramos (2017) found that the lower promotion rates among female faculty in their sample can be largely explained by differences in fields and research productivity, where research productivity is measured using books, chapters, articles, edited books, and grants. Similarly, Millar and Barker (2020) found gender differences in the number of books, chapters, articles, and edited books published in an analysis of promotions from associate to full professor among faculty appearing in Ontario's public listing of salaries between 2010 and 2014, which they suggest might explain the gender difference in promotions in their data.

The studies of both Wijesingha and Ramos (2017) and Millar and Barker (2020), however, examine diverse groups of academics, and within these groups significant differences exist in how productivity would be measured as discussed in the introduction. By contrast, in our sample there is no ambiguity about the currency of success in academic medicine—refereed journal articles. Moreover, promotion decisions are not typically simply counting exercises; the committees weighing promotion decisions consider the quality and impact of research. Thus, we consider whether gender differences in research output and impact can explain the observed gender differences in promotion to full professors and whether gender differences exist in how research impact influences promotion—among the most important rewards for productivity available to any academic.

Institutional Background

The University of Alberta is a large, medical/doctoral public university located in Edmonton, Canada. The University has 40,061 students (80% undergraduate) and 14,438 employees among 18 faculties (University of Alberta, 2019b). The Faculty of Medicine & Dentistry is an elite academic health sciences centre that ranks within the world's top 100 medical schools (Quacquarelli Symonds, 2021) and consists of 21 departments and numerous research institutes and centres.

Faculty compensation is determined by a collective bargaining agreement with three scales for each of the three tenure-stream ranks (assistant, associate, and full professor). Both the assistant and associate professor pay scales have maximums that impose salary ceilings on individuals who rise to the highest step on the scale; there is no corresponding ceiling on the full professor scale. The maximum salary per the 2017 salary scale for associate professors was $137,003 (University of Alberta, 2017b). Faculty salaries are also influenced by market modifiers, retention awards, Canada Research Chairs, and endowed Chairs.

Faculty are subject to annual reviews that evaluate performance in three domains: teaching, research, and service. These reviews—performed by a Faculty Evaluation Committee (FEC) consisting of the department chairs and faculty dean—determine the number of steps on the relevant pay scale that the individual ascends in a given year. The FEC can award faculty members between zero and three increments (corresponding to movements up the pay scale) in quarter increments. Each year, the FEC merit increments are constrained by a required faculty average. In most years, the average increment for the Faculty of Medicine & Dentistry is around one. While the FEC evaluates research output for each individual in terms the number of publications and the impact factor of the journal(s) that the individual has published in, it does not consider the *h*-index of each member. The same FEC also considers promotion and tenure cases.

Data

The compensation data derive from the 2017 Compensation Disclosure List (CDL) (University of Alberta, 2017a). From 2015 onward, the Government of Alberta has required public sector employers to publicly disclose details on employee compensation above a threshold that is indexed from year to year (Government of Alberta, 2015). For the 2017 calendar year data used in this study (the most recent data available at the time the study was conducted), the disclosure threshold was $127,765. Compensation combines "salary, allowances, supplements, and other earnings" (Human Resource Services, 2022). Individuals receiving compensation above the threshold appear on the CDL unless they have requested an exception on personal safety grounds.

While the CDL discloses the names and positions of disclosed individuals, no other information is provided. Data on the professoriate are available through the annual Continuing Academic Staff List (CASL) published as part of the University's Calendar (University of Alberta, 2019a). We used the 2015 to 2019 CASLs to extract name, degrees, year of hire, rank, year current rank started, and Faculty, as the data presentation in the Calendar has changed over time. For faculty who received their degrees from the University of Alberta, the year of degree was also available on the CASL. If the degree year was not present, we used online sources to obtain year of degree. Gender (either female or male) was determined through acquaintance with the individual or searching the faculty members' webpages for photos and pronouns.[4] [5]

To determine total publications, number of citations, and the *h*-index for each professor, Harzing's Publish-or-Perish software (Harzing, 2007) was used to extract bibliometric data from the Scopus database (Elsevier, 2022). The bibliometric data are based on all publications prior to and including 2016 with citations to these publications through August 2021 when the data were collected. An *h*-index represents the largest number of a faculty member's publications that have been cited at least *h* times.[6] The *h*-index has been widely adopted as a measure of citation impact for both authors and journals in Scopus, Mendeley, ResearchGate, and Google Scholar, but we consider the robustness of our findings using alternative measures of research impact constructed from the same bibliometric data—including measures that account for co-authorship. Finally, we also use the bibliometric data to construct longitudinal records of publication output and research impact for each faculty member in every year past the receipt of their degree for use in our analysis of promotions.

Assessments of research performance by faculty in the Faculty of Medicine & Dentistry may also be influenced by the receipt of research funding and other prestigious research awards. To measure funding success, we accessed online funding databases from the Canadian Institutes of Health Research (2007–2016) (Canadian Institutes of Health Research, n.d.) and the Natural Sciences and Engineering Research Council of Canada (1991–2016) (Natural Sciences and Engineering Research Council of Canada, n.d.) to obtain the total funding received as a principal investigator for each faculty member through 2016. These funders are the primary national, publicly funded agencies that professors in the Faculty of Medicine & Dentistry would access for research funds. We excluded training programs like graduate awards and post-doctoral fellowships.[7] These funding reports also indicated which professors were CRCs in 2017.

Our target population consisted of all associate and full professors in the Faculty of Medicine & Dentistry with PhDs, PharmDs, or equivalents who do not also possess MDs, DDSs, or equivalents. We exclude faculty who are MDs, DDSs, or equivalents because these individuals receive only partial compensation from the University and have outside funding for their clinical work, and thus their compensation is not strictly comparable to other faculty. We exclude assistant professors in the Faculty of Medicine & Dentistry primarily for three reasons. First, gender differences in compensation related to performance are least likely to be observed among new faculty as their performance has been assessed the least. Second, we examine gender differences in promotion to full professor, and thus it makes sense to restrict this analysis to those who have already passed the first promotion hurdle. Finally, as a practical matter, the compensation of assistant professors cannot be observed as only two assistant professors had compensation above the 2017 public disclosure threshold and appear in the CDL.

In total, there were 763 professors (170 assistant, 298 associate, 295 full) from the Faculty of Medicine & Dentistry listed in the CASLs in 2017. Of the associate and full professors, 30.8% (183) did not have an MD, DDS, or equivalent clinical degree based on the degrees noted in the CASL or by inspection of professorial webpages. We further exclude one full professor who had taken on a major role external to the university and three full professors who were part of a group that does not follow the salary scales to yield 179 associate and full professors. When merged with the CDL, 149 of these 179 individuals matched, leaving us with a final sample of 149 faculty members who earned above the CDL threshold in 2017 and had not received an exception. Thus, 83.2% of the target population is in our compensation analysis sample.[8] For three faculty members, the 2017 compensation was not disclosed but we carried forward their 2016 compensation and added an additional 1% (based on the average increase seen year over year for disclosed individuals). The same action was taken for two faculty members who had large (>13%) decreases in 2017 compensation that were indicative of leaves. For the proportional hazard models of the probability of promotion, we are able to use the full sample of 179 faculty members regardless of whether we observe their compensation.

Table 1 reports summary statistics for our compensation analysis sample by gender (Table 2 provides summaries for the 179 faculty used in our analysis of promotion). Among the 149 associate and full professors with compensation disclosed, 43 (29.5%) were women. The average compensation for men was \$200,002 and the average compensation for women was \$170,176—a difference of 15% ($p = 0.003$). Likewise, there were disproportionately higher numbers of men (71.4%) at the full professor rank compared to women (50.0%, Table 1). Men averaged 2.8 more years at rank and had five more years since their PhD/PharmD. Men also had higher *h*-indices, total publications, and citations. The median *h*-indices for female and male faculty members in our sample are 25 and 31, respectively, which reflects the relatively high citation rates in the sciences relative to other disciplines.

Perhaps the two most important stylized facts that emerge from our study are evident in Figures 1 and 2, which display lowess curves by gender of the relationships between compensation and years since hiring and *h*-indices, respectively. The data for the 30 individuals with undisclosed compensation are also shown in at the bottom of the y-axis (denoted by NA). First, the lowess curves relating compensation to years since hiring suggest separation in compensation by gender with more years of employment.[9] Second, the lowess curve relating compensation to *h*-indices has a clear upward-slope for men but is essentially flat for women—suggesting that the return to research impact may be gendered. We take up these issues in the next section.

Findings

Compensation

Table 3 reports the coefficient estimates from linear regressions of the natural log of compensation on different sets of controls. Without other controls in Column (1), female faculty in the Faculty of Medicine & Dentistry earn an estimated 15% less than male faculty. Column (2) adds controls for rank and employment history that are likely to influence compensation given the nature of the collective bargaining agreement. For instance, we control for years since receiving a PhD and years since hired at the university because the difference between the two (i.e., the career stage at hiring) will be reflected in where a faculty member starts on the pay scales.[10] With the addition of these controls, female faculty earn

Table 1

Characteristics of 149 PhD/PharmD Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta with Compensation Disclosed, 2017

Variable	Women		Men		*p*
n (%)	44	(29.5%)	105	(70.5%)	
Compensation					
Mean (SD)	$170,176	(45179)	$200,002	(58452)	.003
Median [Min, Max]	$159,224	[128031, 354637]	$180,703	[129399, 381121]	
Years since PhD/PharmD					
Mean (SD)	21.8	(6.9)	26.8	(8.9)	.001
Median [Min, Max]	21	[7,42]	25	[10,51]	
Years since Hire					
Mean (SD)	15.6	(6.7)	18.1	(8.9)	.096
Median [Min, Max]	16	[4,34]	17	[1,43]	
Rank					
Associate	22	(50.0%)	30	(28.6%)	.021
Full	22	(50.0%)	75	(71.4%)	
Years at Rank					
Mean (SD)	7	(4.7)	9.8	(7.8)	.030
Median [Min, Max]	6	[1,22]	8	[1,32]	
Total Publications					
Mean (SD)	72.4	(55.1)	103.5	(89.3)	.033
Median [Min, Max]	56	[8,245]	74	[12,458]	
Total Citations					
Mean (SD)	4019.0	(4470.7)	5706.2	(6898.6)	.137
Median [Min, Max]	2561	[115,23356]	3545	[728,46489]	
h-index					
Mean (SD)	28.1	(15.3)	34.5	(15.7)	.024
Median [Min, Max]	25	[5,69]	31	[10,91]	
Current Canada Research Chair	1	(2.3%)	7	(6.7%)	.492
NSERC/CIHR Funding as a PI					
Mean (SD)	$838,863	(1168783)	$1,039,060	(1183121)	.346

Variable	Women		Men		*p*
Median [Min, Max]	$324,664	[0,5090261]	$723,076	[0,5535552]	

Note: SD=standard deviation, Min=minimum, Max=maximum

Table 2

Characteristics of 179 PhD/PharmD Eligible Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta with and without Compensation Disclosed, 2017

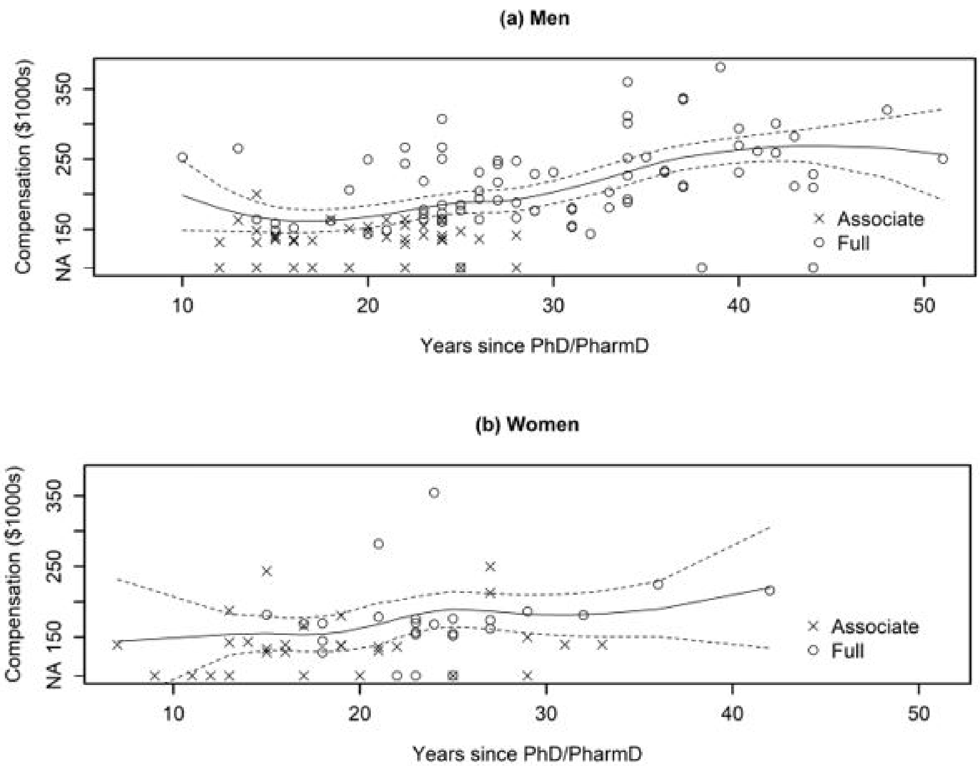
Variable	Women		Men		*p*
n (%)	58	(32.4%)	121	(67.5%)	
Years since PhD/PharmD					
Mean (SD)	20.7	(7.1)	25.9	(9.3)	<.001
Median [Min, Max]	21	[7,42]	24	[2,51]	
Years since Hire					
Mean (SD)	14.7	(6.4)	17.3	(9.1)	.056
Median [Min, Max]	14.5	[4,34]	17	[1,43]	
Rank					
Associate	33	(56.9%)	43	(35.5%)	.011
Full	24	(43.1%)	78	(64.5%)	
Years at Rank					
Mean (SD)	6.3	(4.4)	9.4	(7.5)	.004
Median [Min, Max]	5	[1,22]	8	[1,32]	
Total Publications					
Mean (SD)	65.7	(51.2)	99.4	(85.8)	.005
Median [Min, Max]	48	[8,245]	73	[12,458]	
Total Citations					
Mean (SD)	3438.1	(4067.7)	5267.7	(6567.1)	.053
Median [Min, Max]	2290.5	[115,23356]	3290	[393,46489]	
h-index					
Mean (SD)	26.1	(14.4)	33	(15.6)	.005
Median [Min, Max]	23.5	[5,69]	30	[9,91]	
Current Canada Research Chair	1	(1.7%)	7	(5.8%)	.399
NSERC/CIHR Funding as a PI					
Mean (SD)	$669,930	(1070502)	$937,421	(1144080)	.152

Variable	Women		Men		*p*
Median [Min, Max]	$46,500	[0,5090261]	$633,068	[0,5535552]	

Note: SD=standard deviation, Min=minimum, Max=maximum

Figure 1

Compensation of 179 PhD/PharmD Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta in 2017 (30 Missing Compensation denoted by NA) by Gender, Rank, and Years since PhD/PharmD, with lowess Curves and Associated 95% Confidence Intervals



an estimated 3.2% less than similar male peers—a difference which is no longer statistically significant. The R^2 in this specification (0.52) is high for a log-wage regression, reflecting the fact that the collective bargaining agreement strongly links compensation to years of employment and seniority.

Column (3) reports the coefficient estimates when we add to the controls the faculty member's *h*-index. A one-unit increase in the faculty member's *h*-index is associated with an estimated 0.4% increase in compensation. We then consider whether the return to research impact varies by gender by including in the model in Column (4) an interaction between the female indicator and the *h*-index. The coefficient estimates imply that for male faculty, a one-unit increase in the *h*-index is associated with an estimated 0.6% increase in compensation, but for female faculty members increases in the *h*-index are essentially unrelated to compensation. Taking into account the female coefficient (which is not directly interpretable as it reflects the gender gap at an *h*-index [0] not observed in our sample), our estimates imply that female faculty members earn less than otherwise identical male

Figure 2

Compensation of 179 PhD/PharmD Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta in 2017 (30 Missing Compensation denoted by NA) by Gender, Rank, and h-index, with lowess Curves and Associated 95% Confidence Intervals

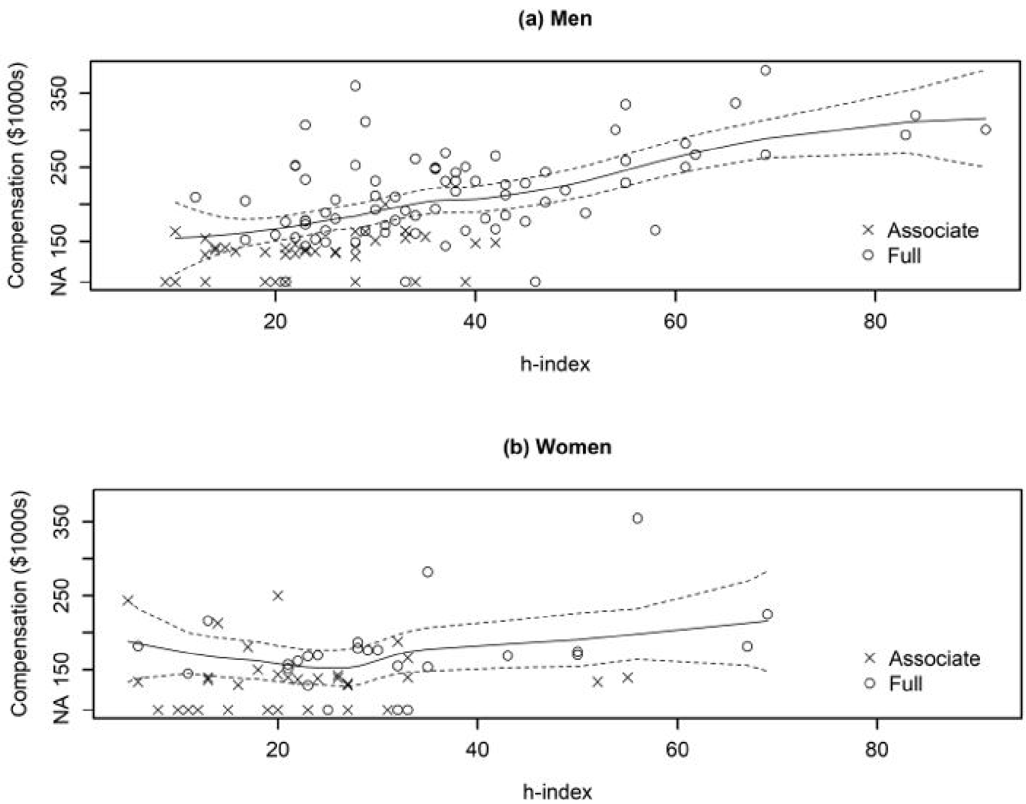


Table 3

Log-compensation Regressions of 149 PhD/PharmD Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta, 2017

Control	(1)	(2)	(3)	(4)	(5)	(6)
Female	-0.150**	-0.032	-0.026	0.129†	0.140*	0.108
	(0.047)	(0.036)	(0.034)	(0.071)	(0.068)	(0.074)
Years since degree		0.009**	0.007*	0.006*	0.009**	0.008*
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Years since hired		-0.009**	-0.008**	-0.008**	-0.009**	-0.007*

Control	(1)	(2)	(3)	(4)	(5)	(6)
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Years in rank		-0.005	-0.002	-0.002	-0.003	-0.006
		(0.008)	(0.008)	(0.008)	(0.007)	(0.008)
Full Professor		0.136*	0.124*	0.132*	0.115†	0.096
		(0.065)	(0.062)	(0.061)	(0.058)	(0.062)
Years in rank*		0.018*	0.014†	0.013†	0.013†	0.017*
Full professor		(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
h-index			0.004**	0.006**	0.004**	0.006**
			(0.001)	(0.001)	(0.001)	(0.001)
h-index*Female				-0.005*	-0.005**	-0.005*
				(0.002)	(0.002)	(0.002)
Canada Research Chair					0.157*	
					(0.066)	
Funding/$100k as PI					0.003*	
					(0.01)	
Departmental fixed effects	No	No	No	No	No	Yes
R^2	0.065	0.520	0.569	0.588	0.624	0.677

Notes: Each column in the table reports the coefficient estimates from regressions of the natural log of total compensation on different sets of controls. A negative coefficient indicates a greater disadvantage for females. The Canada Research Chair (CRC) indicator equals one if an individual held a CRC in 2017 and 0 otherwise. The "Funding/$100k as PI" variable measures the cumulative research grant dollars an individual had received as of 2017 from either NSERC or CIHR as a principal investigator. Column 6 includes indicators for the 18 departments in FoMD. Standard errors are given in parentheses. Significance levels: ** 1%, * 5%, † 10%.

peers for all *h*-indices greater than 24 (women had a median of 25; Table 1). At an *h*-index of 35, the mean value for men in our sample (Table 1), a female faculty member would earn an estimated 6.0% less than an otherwise similar male faculty member with the same *h*-index.

In the remainder of Table 3, we assess the robustness of the specification in Column (4) to potential omitted variables biases. First, we consider whether the gender gap in the returns to research impact stems from the omission of measures of research success that the FEC may reward in annual reviews. Specifically, Column (5) includes among the controls total funding received from the Canadian Institutes of Health Research (CIHR) and Natural Sciences and Engineering Research Council of Canada (NSERC) as a principal investigator and an indicator for holding a CRC chair. While the coefficient of the *h*-index falls reflecting its correlation with research funding success and holding a CRC, the estimated coefficient of the interaction between the *h*-index and the female indicator is effectively unchanged.[11]

Second, if departments differ in the market modifiers their members receive (i.e., supplements to the basic salary scales reflecting market demand), their average research impact as proxied by the *h*-index, and their gender composition, then the omission of departmental controls in Column (4) could influence the coefficient of the *h*-index-female interaction term. Including fixed effects for the 18 departments in Faculty of Medicine & Dentistry in Column (6), however, suggests that this is unlikely to be the case as the coefficients of the female indicator, the *h*-index, and their interaction are all very similar to those in Column (4).[12]

We proxy for research impact in Table 3 using the *h*-index given its widespread adoption as a research impact metric in academia, but in Table 4 we assess the robustness of the gender difference in the return to research impact using alternative proxies. A potential criticism of the *h*-index is that it fails to reflect the potentially outsized importance of very highly cited articles. The *g*-index (Egghe, 2006) attempts to address this issue by placing more weight on highly cited articles. Specifically, the *g*-index is the (unique) largest number such that the top *g* articles (when ranked in descending order by number of citations) received (together) at least g^2 citations. Column (1) reports estimates replacing the *h*-index with the *g*-index in Table 4. Similar to the estimates in Column (4) of Table 3, the compensation of female faculty members is essentially uncorrelated with the *g*-index while the compensation of male faculty members is strongly increasing in the *g*-index.

Both the *h*-index and *g*-index are ultimately functions of citations, and thus in Column (2) we instead directly control for the natural logarithm of citations and its interaction with the female indicator. Among male faculty, the estimates suggest that a 10% increase in citations is associated with a 1.1% increase in compensation, but no increase in compensation among female faculty.

If true research impact is non-linear in citations, then the number of highly cited publications might better proxy for research impact than either the *h*-index or total citations. Alternatively, individuals with highly cited publications might be academic superstars who have been recruited with larger market differentials or who have received outside offers that result in higher compensation independent of the FEC process.[13] In Column (3), we control for the number of publications with more than 100 citations and its interaction with the female indicator. Each publication with more than 100 citations is associated with an estimated 0.6% increase in compensation among male faculty, but compensation among

Table 4

Log-compensation Regressions Employing Alternative Measures of Research Impact of 149 PhD/PharmD Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta, 2017

Control	(1)	(2)	(3)	(4)	(5)	(6)
Female	0.093	0.818**	0.027	-0.006	0.099	0.558*
	(0.065)	(0.263)	(0.043)	(0.051)	(0.069)	(0.265)
Years since degree	0.006†	0.006*	0.007*	0.005†	0.005†	0.005†
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Years since hired	-0.008**	-0.008**	-0.008**	-0.010**	-0.010**	-0.010**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Years in rank	-0.002	-0.001	-0.004	0.001	0.0004	0.001
	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)
Full Professor	0.124*	0.132*	0.138*	0.149*	0.151*	0.146*
	(0.061)	(0.060)	(0.061)	(0.059)	(0.059)	(0.058)
Years in rank*	0.015*	0.013†	0.015*	0.012	0.011	0.011
Full professor	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
g-index	0.003**					
	(0.001)					

Control	(1)	(2)	(3)	(4)	(5)	(6)
g-index*Female	-0.002*					
	(0.001)					
Ln(Citations)		0.114**				0.048
		(0.023)				(0.030)
Ln(Citations)*		-0.106**				-0.074*
Female		(0.033)				(0.033)
Pubs > 100 cites			0.006**			
			(0.001)			
Pubs > 100 cites*			-0.006*			
Female			(0.003)			
# Publications/10				0.012**	0.010**	0.009**
				(0.002)	(0.003)	(0.003)
# Publications/10*				-0.003		
Female				(0.005)		
h-index					0.002	
					(0.002)	
h-index*Female					-0.004*	
					(0.002)	
R^2	0.584	0.589	0.578	0.608	0.619	0.620

Notes: Each column reports coefficient estimates from regressions of log-compensation on different sets of controls using alternative measures of research impact. A negative coefficient indicates a greater disadvantage for females. Column 1 uses the g-index. Column 2 uses the natural logarithm of total citations as of August 2021. Column 3 uses the number of publications with 100 or more citations. Column 4 uses the total number of publications (divided by 10). Standard errors are given in parentheses. Significance levels: ** 1%, * 5%, † 10%.

female faculty is not increasing in the number of highly cited articles.[14]

Faculty are required to provide impact factors of publication outlets in their annual reports in the Faculty of Medicine & Dentistry, suggesting that the FEC is considering both the quantity and the quality of research. Nevertheless, difficulties in comparing journal outlets across disciplines may result in the FEC placing an undue weight on publication quantity. In Column (4), we replace the *h*-index with the number of publications. Compensation is strongly increasing in the number of publications. For every 10 publications, compensation increases by an estimated 1.2% for male faculty. In contrast to the other specifications with alternative proxies for research impact, the interaction between the number of publications and the female indicator is statistically insignificant. Much like with research funding, counting publications involves little subjective evaluation and may thus present less scope for gender bias. The fact that the R^2 is higher in this regression than in all other specifications with alternative measures of research impact strongly suggests that the FEC rewards output as measured by publication counts.

To examine whether the FEC rewards both publication counts and research impact, Column (5) reports estimates controlling for the total number of publications, the *h*-index, and its interaction with the female indicator. The difficulty with this specification is the high degree of collinearity between the publication count and the *h*-index—as evidenced here by the increase in the standard errors for both controls. In this specification, the estimated coefficient of the number of publications falls relative to Column (5) as one would expect when the female interaction is omitted and the positively correlated *h*-index is included, but it remains positive and statistically significant. Likewise, the estimated coefficient of the *h*-index falls with the inclusion of the publication count, but the estimate is statistically insignificant. By contrast, the estimated coefficient of the *h*-index-female interaction term remains negative and statistically significant. Even after controlling for the number of publications, it remains the case that the predicted compensation for female faculty is lower than for observationally equivalent men at *h*-indices above the female median. Likewise, Column (6) reports estimates using log-citations instead of the *h*-index given that log-citations are less collinear with the publication count. The coefficient estimate for log-citations controlling for the publication count is nearly statistically significant ($p = 0.108$), while the coefficient estimate for the interaction between log-citations and the female indicator is again statistically significant and implies that female faculty experience no benefit in terms of compensation from higher citations.

When assessing a faculty member's research contributions, the FEC may also take into account article authorship, which may influence assessments of research impact in at least two ways. First, within academic medicine the order of authors is usually informative, with the first and last authors being individuals who contributed the most to the publication. As a consequence, the FEC may discount the contributions of faculty members to publications for which they are not the first or last author. Second, coauthoring is common in academic medicine, and the number of authors is potentially very large. Given that the expected contribution of any one author is decreasing in the total number of authors, the FEC may discount contributions to publications with large numbers of authors.

In Table 5, we consider the influence of authorship on our estimates by replacing the *h*-index with measures of research impact that account for author ordering and the number of co-authors in specifications that also control for the total number of publications.[15] In Column (1), we use the faculty member's *h*-index from among only those publications on which the faculty member was the first or last author as the measure of research impact, while in Column (2) we use the natural logarithm of citations to publications on which the faculty member was a first or last author. While the estimated compensation of male faculty is essentially uncorrelated with either measure, the coefficient estimates of the interactions between the primary author *h*-index or the log of citations to primary publications and the female indicator are negative and statistically significant. Using only publications for which faculty members are primary authors may discount faculty members' contributions to other articles too steeply. For this reason, we construct an authorship index between zero and one which divides the author's order (where last authors are assigned a position of zero) by the number of authors. We then multiply the number of citations to a publication by one minus this index and use the logarithm of the total number of indexed citations as the research impact measure in Column (3). Again, however, the coefficient estimate of the interaction between the impact measure and the female indicator remains negative and statistically significant. If anything, these specifications seem to indicate that the compensation of male faculty must increase with citations to articles for which they are not a primary author.

The last two columns of Table 5 consider the influence of the number of authors per publication on our estimates. Specifically, we replace the *h*-index in Column (4) by Harzing's (2007) suggested *h*-index, constructed in the same way as the usual *h*-index but using the citations-per-author for each publication. In contrast to all our other specifications, the estimated coefficient of the *h*-index-female interaction in this specification—while negative—is imprecisely estimated. Using the logarithm of the sum of the citations-per-author in Column (5), however, we again find a negative correlation between the compensation of female faculty and these author-weighted citations. Neither gender differences in author order nor the number of co-authors would appear to explain the gendered relationship between research impact and compensation in our sample.

Finally, the size of our sample ($n = 149$) implies both that our estimates may be sensitive to outliers and that our sample may not have sufficient common support to estimate the compensation models over certain regions of the controls. To address the first issue, we replicate the estimates in Column (4) of Table 3 excluding the top

Table 5

Log-compensation Regressions Assessing the Relevance of Author Ordering and Co-Authorship of 149 PhD/PharmD Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta, 2017

Control	(1)	(2)	(3)	(4)	(5)
Female	0.077	0.418†	0.444*	0.032	0.467*
	(0.060)	(0.220)	(0.216)	(0.064)	(0.214)
Years since degree	0.006†	0.005†	0.005†	0.005†	0.005†
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Years since hired	-0.010**	-0.010**	-0.009**	-0.010**	-0.010**
	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)
Years in rank	0.001	0.0003	0.001	0.001	0.002
	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)
Full Professor	0.165**	0.146*	0.145*	0.150*	0.167**
	(0.059)	(0.060)	(0.059)	(0.059)	(0.059)
Years in rank*	0.010	0.011	0.011	0.012†	0.010
Full professor	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
# Publications/10	0.011**	0.010**	0.010**	0.014**	0.012**
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
h-index (Primary author)	-0.0001				
	(0.001)				
h-index (Primary author)*	-0.006*				
Female	(0.003)				
Ln(Primary citations)		0.032			
		(0.028)			
Ln(Primary citations)*		-0.062*			
Female		(0.030)			
Ln(Index Citations)			0.040		
			(0.027)		
Ln(Index Citations)*			-0.066*		
Female			(0.030)		
Harzing *h*-index				-0.001	
				(0.001)	
Harzing *h*-index*Female				-0.003	

Control	(1)	(2)	(3)	(4)	(5)
				(0.003)	
Ln(Weighted Citations)					0.017
					(0.031)
Ln(Weighted Citations)* Female					-0.080*
					(0.033)
R^2	0.623	0.619	0.620	0.613	0.629

Notes: Each column reports coefficient estimates from regressions of log-compensation on different sets of controls. A negative coefficient indicates a greater disadvantage for females. Standard errors are given in parentheses. Significance levels: ** 1%, * 5%, † 10%.

5% of observations by total compensation in Column (1) of Table 6. The estimates using this restricted sample are similar to those in Table 3. Gender differences among very high-compensation individuals in our sample do not appear to drive the gender differences in the return to research impact that we observe.

To address the common support issues, in Column (2) we report estimates dropping individuals with *h*-indices greater than 40, while in Column (3) we report estimates dropping individuals who received their terminal degree more than 35 years prior to 2017. Figures 1 and 2 make it clear that relatively few female faculty fall in these regions. The estimates in Column (2) indicate that the difference in the return to research impact between male and female faculty is observed even among faculty with *h*-indices below 40, while the estimates in Column (3) imply that our findings are not a byproduct of gender differences among the small number of faculty who received their degrees prior to 1982.

Our estimates may also be influenced by sample selection and data quality concerns given that we rely on public compensation data. Individuals are only observed if they did not receive a compensation disclosure exemption and their compensation exceeds a threshold, and leaves (i.e., medical, parental, sabbatical) and other idiosyncratic factors influencing compensation are not observed. While a few of the 30 individuals without observed compensation meeting our sample selection criteria may have received a disclosure exemption on personal safety grounds, most (given that they are largely associate professors) likely have compensation below the disclosure threshold. To examine the influence of this left-censoring of compensation on our estimates, Column (4) reports estimates using a Tobit estimator. The estimates are essentially identical to those in Column (4) of Table 3. To address concerns about the measurement of compensation and data quality, in Column (5) we exclude 14 individuals who experienced either large jumps in compensation or large reductions in compensation relative to 2015 or 2016. The exclusion of these individuals, however, has no appreciable influence on our estimates. Alternatively, in Column (6) we use the natural logarithm of the average of disclosed compensation (when available) in 2015, 2016, and 2017 as the dependent variable in order to smooth out idiosyncratic variation. These estimates too are similar to those in Table 3. The gendered returns to research impact evident in our data do not appear to be a byproduct of measurement error resulting from our use of public compensation data.

Promotion

As the estimates in the previous section make clear, promotion to full professor is a key factor in compensation. Gender gaps in compensation will be underestimated if women are disadvantaged in the promotion process. In this section, we examine both whether female faculty are promoted to full professor at a rate similar to that of their male peers and whether the effect of research impact on the probability of promotion differs by gender.

To begin, we calculate the 13+ Club Index (Geisler et al., 2007). A measure of non-promotion of faculty members, the 13+ Club Index is defined as the ratio of the proportion of female faculty members who are 13 years or more past their highest degree who have not been promoted to full professor to the corresponding propor-

Table 6

Log-compensation Regressions Assessing the Influence of Outliers, Sample Selection Concerns, and Data Quality Issues of 149 PhD/PharmD Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta, 2017

Control	(1)	(2)	(3)	(4)	(5)	(6)
Female	0.163*	0.211†	0.109	0.129†	0.120†	0.143*
	(0.063)	(0.109)	(0.081)	(0.070)	(0.071)	(0.071)
Years since degree	0.006*	0.008*	0.003	0.006*	0.004	0.007*
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)
Years since hired	-0.008**	-0.012**	-0.012**	-0.008**	-0.007**	-0.008**
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Years in rank	-0.002	-0.0004	0.003	-0.002	-0.001	-0.003
	(0.007)	(0.007)	(0.008)	(0.008)	(0.007)	(0.008)
Full Professor	0.123*	0.130*	0.148*	0.132*	0.155*	0.126*
	(0.053)	(0.062)	(0.066)	(0.060)	(0.061)	(0.060)
Years in rank*	0.012†	0.015*	0.015†	0.013†	0.012†	0.013†
Full professor	(0.006)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)
h-index	0.006**	0.006*	0.005**	0.006**	0.006**	0.006**
	(0.001)	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)
h-index*Female	-0.007**	-0.009*	-0.005†	-0.005*	-0.006*	-0.006**
	(0.002)	(0.004)	(0.003)	(0.002)	(0.002)	(0.002)
# of observations	141	114	128	179	135	179
R^2	0.596	0.524	0.476		0.620	0.583

Notes: Each column reports the coefficient estimates from log-compensation regressions with the same controls as in Column 4 of Table 2. A negative coefficient indicates a greater disadvantage for females. Column 1 excludes the top 5% of observations by compensation. Column 2 reports OLS estimates excluding individuals with h-indices greater than 40. Column 3 reports OLS estimates excluding individuals who received their PhD or PharmD more than 35 years earlier. Column 4 reports estimates using a Tobit estimator using the estimation sample plus 30 observations with missing compensation data. Column 5 reports OLS estimates excluding individuals with dips or spikes in their publicly disclosed 2017 compensation relative to the compensation reported in 2015 or 2016. Column 6 uses the natural logarithm of the average of reported compensation in 2015, 2016, and 2017 (when available) as the dependent variable. Standard errors are given in parentheses. Significance levels: ** 1%, * 5%, † 10%.

tion of male faculty members. A value of 1 suggests both genders are being promoted at the same rate, while a value greater than 1 suggests that women are being promoted more slowly. Table 7 shows the 13+ Club Index as well as analogous indices based on other years-past-degree thresholds for all 179 faculty members. For 13+ years, 28/53 (52.8%) women had not yet been promoted to full professor, whereas 39/116 (33.6%) of men had not yet been promoted to full professor. The ratio of 1.57 suggests that women have been promoted more slowly. When other thresholds were used (i.e., 13 to 25), the ratio does not fall below 1.53. For all of the years-past-

Table 7

Non-promotion by Gender at Different Career Stages for 179 PhD/PharmD Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta, 2017

	Proportion not promoted to full professor as of years-past-degree threshold				
Years past degree:	Women		Men		Index
13+	28/53	(52.8%)	39/116	(33.6%)	1.57*
15+	22/47	(46.8%)	33/108	(30.5%)	1.53†
20+	11/31	(35.5%)	20/90	(22.2%)	1.59
25+	7/17	(41.2%)	5/59	(8.5%)	4.86*

Notes: The table reports the number of faculty not yet promoted to full professor by gender at different year after the terminal degree as well as the number of faculty observed at that career stage. The proportions by gender of faculty observed at a given career stage not yet promoted are given in parentheses. The last column reports the ratio of the proportion of female faculty not yet promoted to the proportion of male faculty not yet promoted at a given career stage as well as the significance levels for tests of the equality of the male and female proportions not-yet-promoted. Significance levels: ** 1%, * 5%, † 10%.

degree thresholds in Table 7 other than 20+ years, we reject the null of common proportions of men and women not yet promoted at least at the 10% significance level. Men appear to be more rapidly promoted than women.

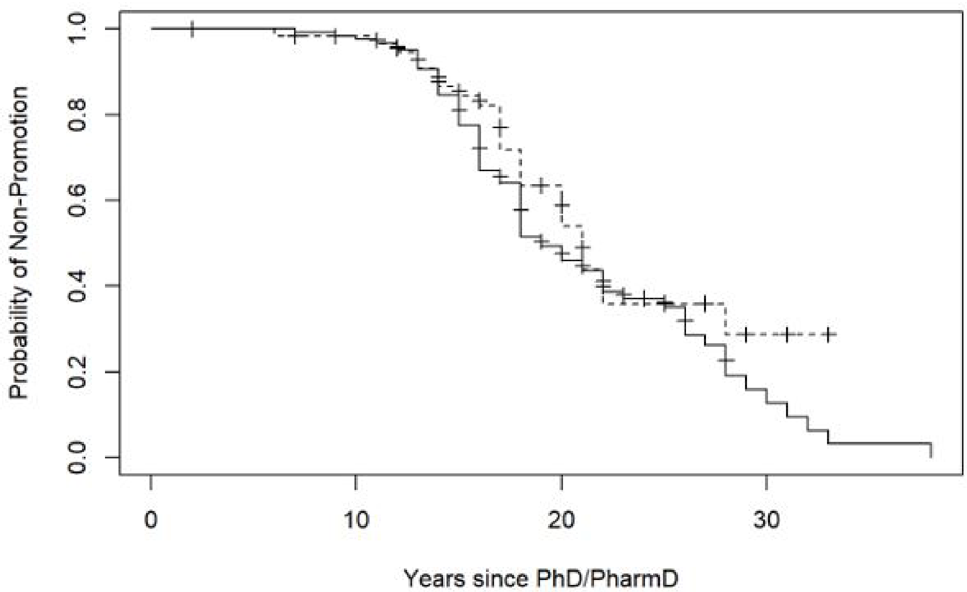
As an alternative to the 13+ indices in Table 7, Figure 3 displays the fraction of male and female faculty members in our sample who remain associate professors at different years-past-degree conditional on being observed at that point in the career in 2017. The survival probabilities are similar for men and women up until around 14 years past the receipt of their terminal degree. At that point, a clear separation between the curves emerges indicating that between roughly 15 and 23 years past the receipt of the degree—years in which many faculty members go up for full professor—female faculty are much less likely than male faculty to be promoted to full professor.

To examine whether the probability of promotion is influenced by research impact and whether the effect of research impact depends on gender, we estimate discrete time, proportional hazard models of the probability of promotion implemented using the complementary log-log maximum likelihood estimator. At-risk spells for each faculty member last from the year of their degree receipt to the year in which they are promoted inferred from the CASL in 2016 for associate professors. The bibliometric databases permit the reconstruction of the research record in each year after the degree. This allows us to control for the number of publications that FEC would have observed in any given year, the number of citations (as of 2021) to the articles published prior to that year, and the *h*-index (using 2021 citations) based on these articles.[16] [17] Thus we can exploit both information about the timing of promotions as well as temporal variation in the research record. Our estimation sample includes 179 individuals and 3,096 at-risk individual-year observations. In our models, we include a flexible, piecewise baseline hazard function consisting of indicators for one to five years after the receipt of the degree and then every two years thereafter up to 31 years after the degree, the last year in which we observe a promotion event.

Table 8 reports our estimates from these models with alternative sets of controls. In Column (1), we include only the female indicator along with the piecewise hazard function. The coefficient implies that women are less likely to be promoted in any at-risk period, but the estimate is statistically insignificant ($p = 0.162$). In Columns (2), (4), and (6), we include the number of publications observed as of the at-risk year, the *h*-index based on these publications, and the total citations (as of 2021) to these articles, respectively. In each of these models, however, the coefficient estimate of the proxy for re-

Figure 3

Estimated Proportion of 179 PhD/PharmD Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta in 2017 Not Yet Promoted by Years since PhD/PharmD and by Gender (solid=male, dashed=female)



search productivity is statistically insignificant, suggesting that the hazard rate of promotion is insensitive to the publication record—a surprising result in itself.

In Columns (3), (5), and (7), we add the interaction between the research output proxy and the female indicator. In each specification, the coefficient estimate of this interaction term is positive and—in the case of the publication counts and *h*-indices—precisely estimated. While the estimates indicate that the probability of promotion in any year is strongly increasing in measures of research output or impact for female faculty but not male faculty, this comes with a significant caveat. In each specification interacting the female indicator with measures of research impact, the coefficient of the female indicator itself is large in magnitude, negative, and precisely estimated, which suggests that female faculty must achieve thresholds for research output below which they have a lower hazard rate of promotion than observationally equivalent male faculty members. The estimates in Columns (3), (5), and (7) imply that these thresholds are 58 total publications, an *h*-index of 28, and 5,464 citations, respectively. As noted in the Introduction, all these thresholds are significantly higher than the median values for associate professors.

Perhaps more to the point, in the year in which we observe full professors having been promoted, these individuals had a median publication count of 50, a median *h*-index of 25, and a median citation total of 2,580. That is, female faculty only achieve parity with observationally equivalent male faculty in predicted promotion probabilities at values of the measures of research impact that in some cases significantly exceed what might be considered benchmark values for these measures at the time of promotion. One plausible interpretation of these estimates is that the bar for promotion is set higher for female faculty. Alternatively, female faculty may delay applying for promotions until their research records surpass those of male faculty applying for promotion. Unfortunately, we do not observe applications for promotion and cannot distinguish between these possibilities. We note, however, that with only 58 women in our sample, there are relatively few female promotion events. As such, the estimated effects of gender in Table 8 should be viewed with some skepticism. We report them mainly

Table 8

Discrete Time Proportional Hazard Models of Promotion of 179 PhD/PharmD Faculty Members at the Faculty of Medicine & Dentistry, University of Alberta, 2017

Control	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Female $(\widehat{\beta_1})$	-0.336	-0.350	-1.005**	-0.310	-1.419**	-0.331	-0.610*
	(0.229)	(0.230)	(0.361)	(0.229)	(0.475)	(0.230	(0.303)
# Publications/10		-0.009	-0.016				
$(\widehat{\beta_2})$		(0.014)	(0.016)				
# Publications/10			0.169**				
*Female $(\widehat{\beta_3})$			(0.061)				
h-index $(\widehat{\beta_2})$				0.009	0.004		
				(0.006)	(0.007)		
h-index*Female					0.050**		
$(\widehat{\beta_3})$					(0.017)		
Citations/100						0.001	-0.0001
$(\widehat{\beta_2})$						(0.002)	(0.002)
Citations/100							0.011
*Female $(\widehat{\beta_3})$							(0.007)
$(\widehat{\beta_1})$ / $(\widehat{\beta_3})$			5.95		28.47		54.98
Log-likelihood	-371.2	-371.1	-368.0	-370.2	-366.6	-371.2	-370.2

Notes: The table reports coefficient estimates for discrete complementary log-log (proportional hazard) models estimated via maximum likelihood. For each individual in our sample, the at-risk spell runs from the year of degree receipt to the year of promotion or 2016 in the case of associate professors; the period of analysis is a calendar year. The estimation sample includes 179 individuals and 3,096 at-risk years. The dependent variable equals one if the individual is promoted in a given year and zero otherwise. The baseline hazard includes 16 indicators for observations between 1 and 5 years after the terminal degree and then for every two years thereafter (e.g., an indicator for whether the observation falls in the 8th or 9th year after receipt of the terminal degree) through the 31st year, the last year in which we observe individuals in our sample at-risk. Every such interval includes at least one promotion event. A negative coefficient indicates a greater disadvantage for females. Standard errors are given in parentheses. Significance levels: ** 1%, * 5%, † 10%.

to offer preliminary evidence on the relationship among gender, research impact, and promotion in the hopes that other researchers will investigate the relationship with better data.

Discussion

In this section, we discuss potential explanations for the gender differences in the returns to academic productivity where compensation and promotion are concerned.

Gender Biases in Forecasting Publication Impact and/or Assigning Credit for Publications

Among academic economists, evidence suggests that female faculty members are penalized for co-authoring during tenure reviews, while their male peers are not. Further evidence from laboratory experiments in the same study finds that women receive less credit for output in team work settings (Sarsons et al., 2021). In the annual review process, departmental chairs may either undervalue the potential research impact of publications by female faculty, or they may undervalue the contributions of female faculty members to these coauthored publications.[18]

Gender Differences in Leadership Positions and Gender-Biased "Horse-Trading"

Faculty performance is reviewed by a committee of departmental chairs. With fewer senior female faculty, there have naturally been fewer female departmental chairs over the years sitting on these evaluation committees. Given evidence in the human resources literature that leaders and managers exhibit positive same-gender biases in evaluations (Furnham & Stringfield, 2001; Varma & Stroh, 2001), this dynamic could have negatively affected the performance reviews of female faculty members. Moreover, the zero-sum nature of the annual review process may well exacerbate any gender biases. The FEC is constrained in the average merit increment that it can award (equivalently the total step increases across faculty being reviewed). A higher increment for one faculty member necessarily requires a lower increment for another. To the extent that departmental chairs must engage in inter-departmental *horse-trading* (i.e., bargaining) to meet the faculty-level constraint, diminished advocacy on behalf of female faculty member may result in lower increments for female faculty.

Gender Differences in Mentoring

Mentors can help young faculty members navigate the publication process (e.g., selecting journals valued by the FEC, feedback on projects and drafts), the grant application process, and in some instances they may even involve junior faculty in ongoing research. At the Faculty of Medicine & Dentistry, mentors can help faculty understand what the FEC "wants to see" in the annual reviews. The lack of mentoring for female faculty members in medical schools has been widely discussed (e.g., Levine et al., 2011; Lowenstein et al., 2007). Female faculty members at the Faculty of Medicine & Dentistry have fewer opportunities for mentoring relationships with same-gender colleagues given the relatively smaller share of female faculty—especially among senior faculty—and may be adversely affected in the annual review process as a consequence.

Gender Differences in Applications for Promotion and the Pursuit of Outside Offers

Evidence from France suggests that female professors are less likely to apply for promotion than their male peers—a difference that accounts for 76% percent of the gender difference in promotion rates (Bosquet et al., 2019). Even if the bar for promotion to full professor is the same for all faculty, a perception among female faculty in the Faculty of Medicine & Dentistry that they face a higher bar would be sufficient to induce delays in applications for promotion that would produce the promotion patterns observed in our data. Here again, mentorship in academic medicine could potentially play an important role in ameliorating gender differences in promotion outcomes.

Female faculty may be similarly reticent to pursue outside job offers that would necessitate competing offers from the university. Among academics in the United Kingdom, Blackaby et al. (2005) show that male faculty receive more outside offers than similar female faculty and receive larger pay increases in response. Thus, the gender difference in the relationship between research impact and compensation that we observe may not stem from decisions made in the FEC. We note, however, that this explanation would not imply that gender biases do not exist in academic medicine, as it would suggest that university hiring committees overlook high-performing, lower-compensated female faculty when making external offers.

There is likely no single solution to any of the above sources of potential bias, but we offer one broad suggestion: radical transparency in the way committees reviewing the performance of their peers operate. These committees—which exist in one form or another in many Canadian universities—make several judgements that contribute to faculty evaluations: determining journal quality, assessing contributions in co-authored studies, discounting research based on the number of co-authors, providing subjective assessments of the intellectual contribution of research, etc. These judgements are seldom subject to scrutiny, and the committees themselves are reluctant to commit to objective standards given the horse-trading that must take place and differences across disciplines assessed by the FEC. Nevertheless, increasing the transparency would reduce the potential for informational asymmetries that result in some faculty pursuing suboptimal publication strategies while also introducing a measure of accountability for the potential gender biases discussed above.

Conclusion

We examine whether the return to research impact varies by gender in terms of compensation and promotion among faculty members at the University of Alberta's Faculty of Medicine & Dentistry. Measuring research impact using *h*-indices, we find that female faculty have lower predicted compensation than male faculty with similar *h*-indices even after controlling for the number of publications, rank, and other aspects of the individual's employment history. Female faculty also achieve parity in predicted hazard rates of promotion to full professor at *h*-indices higher than the median value of *h*-indices for full professors in our sample in the year they were promoted. Taken together, these findings suggest that female academics are not rewarded for their scholarly output in the same ways as their male peers in terms of their research impact and citations.

While the implications of these findings are enormously important, additional research on the relationships among gender, research impact, and rewards in the university environment is essential. By necessity, we focus on relatively senior academics in a medical/dental school setting. We urge that similar analyses be conducted within other medical schools and other faculties where the metrics of research success are well-defined in order to determine to what extent our findings generalize to other disciplines and universities. We also acknowledge that there may be intersectional effects of race and gender influencing our results that we cannot examine due to data limitations. Investigating these intersectional effects represents an important area for future research.

Likewise, future research should endeavour to examine how changes in compensation over time are related to gender and research performance. Our findings suggest that compensation in 2017 exhibited different relationships to research impact over the career for men and women, but the merit pay systems at many Canadian universities reward academics for output over a fixed period of time. A direct test for inequities in merit pay would examine the gendered relationships between compensation growth and changes in publication records and citations.

Following through on this research agenda, however, will require better data—data which at present are difficult to obtain. Many studies on academic compensation and other career outcomes rely on discontinued Statistics Canada data (e.g., Warman et al., 2010), publicly available compensation data from "sunshine lists" (e.g., Momani et al., 2019) or surveys (e.g., Wijesingha & Ramos, 2017). The reliance on data from sunshine lists necessarily limits our ability to examine gender disparities among junior faculty and faculty with lower compensation while simultaneously introducing significant measurement error. Likewise the reliance on survey data may limit the generalizability of the findings to the extent that respondents are not representative.

A comprehensive examination of non-public compensation data for professors across ranks and in different disciplines is required to better understand the sources of gender gaps in promotion and compensation. That we and others continue to find clear evidence of gender pay inequity despite controlling for objective measures of productivity highlights the imperative in academia to continue to bring light to this complex issue and to focus efforts and resources aimed at correcting systemic biases. We strongly recommend that faculty associations and universities consider *h*-indices when reviewing individual cases of salary disparities as the current system focusing on publications counts and impact factors may result in systemic biases that under-reward some faculty groups for their research impact.

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Notes

1 The Canadian Institutes of Health Research defines biological sex as male and female, while gender is defined by social constructs leading to men and women (or other) identities. We use the terms male and men interchangeably as well as female and women interchangeably in this work.

2 Ginther and Hayes (1999) (in the humanities), Weisshaar (2017) (in sociology, computer science and English), Bosquet et al. (2019), Antecol et al.(2018), and Sarsons (2017) (all in economics) similarly examine gender differences in compensation and promotion in narrowly defined academic disciplines controlling for refereed journal publications. Among these, only Weisshaar and Bosquet et al. examine whether research impact influences gender differences in academic career outcomes. Weisshaar proxies for research impact using citations and publications in top journals, while Bosquet et al. proxy for research impact using publication length and journal quality, but neither report whether the returns to research impact vary by gender.

3 Research impact may itself be a biased measure of research quality—what universities presumably wish to incentivize with merit increments. For instance, men have been shown to co-author more frequently with other males (e.g., Holman and Morandin [2018] in the life sciences) and to disproportionately cite the work of male authors (e.g., Beaudry & Larivière [2016] in the sciences and medicine; Dworkin et al. [2020] in neuroscience) and themselves (Ghiasi et al., 2016)—tendencies that together work to inflate men's citation counts relative to women's citation counts. See Hamermesh (2018) for an excellent discussion of the issues surrounding the use of citations as proxies for academic productivity.

4 While gender is not necessarily a binary construct, inspection of faculty webpages did not suggest the need for additional categories beyond male and female.

5 All data used in this study are publicly available online, and thus Research Ethics Board approval was not required.

6 The *h*-index of research published prior to 2016 constructed using citations through 2021 is undoubtedly a better proxy for the research impact of these publications than an *h*-index based on the same publications using citations through 2016 given the lag between publication and citations.

7 Our research funding measure has noteworthy shortcomings. Specifically, funding was matched to unique principal investigators by name. Funding received as a co-principal investigator cannot be observed in the funding databases. In addition, the NSERC and CIHR funding databases extend back only to 1991 and 2007, respectively, meaning that funding receipt will be understated for older faculty members. Finally, funding from sources other than NSERC and CIHR is not included in our measure.

8 Twenty-four associate professors (11 female) and six full professors (three female) met our selection criteria but do not appear on the Compensation Disclosure List because they either received compensation below the threshold or had requested an exception on personal safety grounds.

9 Lowess curves plotting the relationship between compensation and years since PhD or years in rank show similar divergence between genders.

10 We allow the return to years in rank to vary by rank because the first four steps on the full professor scale lead to larger increases in salary than do the steps on the associate level. Specifically, the first four steps on the full professor scale are associated with salary increases of $3,847, the next four steps at $3,271, and unlimited steps at $2,552. Steps on the associate professor scale correspond to salary increases of $3,271, and the associate scale has a maximum step beyond which further increases in salary as associate professors are not possible. As a consequence, compensation is likely to increase more slowly with years in rank for associate professors, which is borne out in the estimates in Table 3.

11 In estimates available from the authors, we also rejected the hypothesis that the return to research funding varies by gender. There were not sufficiently many CRC holders in the sample to examine whether the return to being a CRC varied by gender. As discussed earlier, the grant receipt data go back only as far as 1991 and 2007 for NSERC and CIHR, respectively. Given the correlation between career start dates and gender in our data, this implies that this measurement error is likely correlated with gender. In addition, the CRC program has been shown to suffer from equity issues (Halliday, 2019; Side & Robbins, 2007). Together these issues suggest that the grant and CRC receipt variables are likely endogenous. Given that the inclusion of these variables has little effect on the coefficients of interest here and in other specifications, we opt not to include them in subsequent specifications.

12 Faculty are roughly evenly distributed across departments by gender, and as such we do not include the departmental fixed effects—which add 17 parameters to each model—in subsequent specifications and the promotion models.

13 We do not observe whether individuals in our sample have received outside offers, but four individuals in our sample experience compensation increases of more than 13.5% relative to compensation in 2015. This

threshold is based on the increase we would expect to see for individuals returning from sabbatical leaves, but these individuals may also be returning from medical or parental leave. Related to outside offers, mobility in our sample does not appear to be particularly substantial as only one individual out of 179 had left the university in the four years following 2017 for reasons other than death or retirement.

14 We obtain qualitatively similar but less precise estimates using the number of publications with more than 500 or 1,000 citations as our measure of impact given the relatively small number of such publications observed.

15 Authorship information could be obtained for only 89% of the 16,125 publications by faculty in our sample. Most of the missing observations are due to missing digital object identifiers (DOIs) which were introduced in the late 1990s. Some journals were slow to adopt DOIs, and many have not retroactively acquired DOIs for past publications given that doing so is not costless. As a consequence, our measures in Table 5 accounting for authorship are constructed using only publications with non-missing authorship data.

16 The FEC would observe the faculty member's research record in each year as part of the annual review process, but faculty members must apply for promotion in order for the FEC to consider a promotion case.

17 Using the citations as of August 2021 for articles published prior to a given year might appear odd, but again we use them as proxies for research quality or impact. In this case, using citations observed at a later date likely reduces the measurement error in our attempt to proxy for quality.

18 Uhlmann and Cohen (2005) and Correll et al. (2007) document biases against females in evaluation processes in experimental settings and audit studies.