Justice and Fairness in Academia: Are Women Underrepresented/ Underpaid in Engineering and Science Fields? Comparing 2018 and 2021 Data

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Although the U.S. government has made significant efforts to achieve gender equality, there still are some gender-based differences in worker compensation. This study investigates the existence of salary disparity by sex, academic rank, pre/during-COVID pandemic, and size of universities within Science, Technology, Engineering, and Mathematics (STEM) programs. We base our empirical analysis on data gathered from the faculty of 4-year public universities in one state in the south-central U.S. in 2018 and 2021. We use factorial N-way ANOVA to control for faculty heterogeneity. Our analysis showed size, rank, year, and sex are all significant factors. Smaller universities pay less than larger public universities, the more senior tenured ranks make more, and pay did increase from 2018 to 2021. There are interesting findings when considering sex, as men earned more than women in STEM in both 2018 and 2021 as well as at all three school sizes. The exception was for full professors. Our study provides fresh insights into the gender pay gap, especially in male-dominated academic disciplines.

Keywords: pay gap, STEM faculty, sex, COVID-19

INTRODUCTION

Despite significant efforts by the U.S. government to achieve gender equality, sex-based differences in worker compensation persist (Barroso & Brown, 2021). Women tend to make less money than their male colleagues in their corporate jobs and as faculty members (Strittmatter & Wunsch, 2021). The unexplained wage inequalities between women and men have been widely studied for over 50 years (Blau & Kahn, 2000; Blau & Kahn, 2017; Goldin & Mitchell, 2017; Olivetti & Petrongolo, 2016; Olivetti & Petrongolo, 2008). Studies show that work establishments are important for creating and maintaining gender equality (Huffman et al., 2017). Even with the increases in the number of female faculty in the workforce, male faculty still earn higher salaries than women (Ordway, 2017). This study investigates the existence of salary disparity by the size of universities, academic rank, year: pre/during-Covid-19, and sex. We base our empirical analysis on data gathered from the faculty of 4-year public universities in the Science, Technology, Engineering, and Mathematics (STEM) fields in one state in the south-central U.S. in 2018 and 2021.

The existing literature on the gender pay gap in the U.S. falls under two themes. The first focuses on increasing the understanding of existing gender pay gaps while the second focuses on the impact of research methodological choices. We contribute to the first theme by focusing on faculty remuneration. We use factorial N-way ANOVA for our analysis to control for faculty heterogeneity. In this paper, first, we present existing related works which drove our research questions in the literature review section. Then we discuss the methodology for our analysis. We show our findings in the results section. Finally, in the conclusion section, we summarize our work and possible future research.

LITERATURE REVIEW

The existence, impact, and measurement of gender pay disparities have been the topic of extensive research for decades (Olivetti & Petrongolo, 2016; Olivetti & Petrongolo, 2008; Strittmatter & Wunsch, 2021). Despite some improvement over the years, studies show that there remains a substantial gap even if a large set of observable characteristics are adjusted for (Blau & Kahn, 2017; Ding et al., 2021). Several factors have been found to impact gender pay disparity in work establishments. These policies reduce gender inequality in general, especially among lower-wage earners.

Science, Technology, Engineering, and Mathematics (STEM)

In the US, women are significantly underrepresented in the Science and Engineering (S&E) fields (Guy, 2022; Varma, 2018). This trend is observed in both S&E degrees earned and subsequent careers held (Iwasaki, 2015; Ong et al., 2011). In the past two decades, the drivers of women and minority (non-white) underrepresentation in the S&E fields has been extensively studied, however, the findings of such studies have not been successfully applied in outreach efforts (Aspray, 2016; Varma 2018). Underrepresentation of women in S&E fields affects high technology firms that will be unable to benefit from women's much-needed talent.

Research suggests that this could be a direct result of fewer women enrolling in STEM educational programs and thus not being available to enter S&E fields (Moso-Diez et al., 2021; Diekman et al., 2015). Other studies suggest that this underrepresentation is attributable to the poor experiences women tend to have in the male-dominated science and engineering fields (Guy, 2022). Such treatment might motivate them to seek work in other fields or withdraw from the work field completely to focus on family life (Iwasaki, 2015).

Size

Both the size of the university (McCarron, 2021) and the size of the company (Keenan, 2017) one works for can impact pay with smaller ones paying less. Smaller universities tend to be more Liberal Arts and teaching-focused and not Engineering or research focused. Johnson and Taylor (2019) showed that when a college is not Engineering or research focused, they paid less. In addition to the overall lower pay at teaching schools, women are paid less than men at research universities. (Flannery, 2022)

Rank

Faculty salaries are generally increasing from the lowest paid being the non-tenure-track Lecturer and Instructors followed by the tenure-track ranks from lowest to highest (Assistant, Associate, and Professor). (Full, 2022) The caveat to this is the assertion that faculty salaries suffer from inversion and compression (Homer et al., 2020) with newer hires earning close to or more than senior faculty who hold a higher rank. Although many studies have presented compression concerns, they only found those valid in Colleges of Business. (Homer et al., 2020; McDonald & Sorensen, 2017) So, to earn higher pay, one needs to hold a tenured higher rank. However, women still tend to achieve the higest ranks less often than men. (Society, 2021) As eligibility to apply for tenured promotions are time-driven (normally in 6-year increments), then for one to hold one of these higher-paying positions, they would have had to receive their terminal degree more than a decade ago. Since women have earned more than 50% of all doctoral degrees in the US since 2006 (Johnson, 2017) and among these women, only a quarter chose to work in the industry rather than academia (NSF, 2019), this influx of women in academia for well over a decade should be showing itself in these higher paying jobs. However, research suggests that academia has a wider gender pay gap relative to industry (Ding et al., 2021) and other research has shown that women who are full professors earn more than their male counterparts (Chettri, 2021) – however, the existence of controlling for other variables was not evident in that research.

Year

If salaries matched inflation, then for every dollar earned in 2018, faculty would need to earn 1.08 in 2021 (CPI, 2022). However, the average salary increase in the US was 1.16 during the same period (Social, 2022). AAUP reports increases in salaries during these three years of 2, 2.8, and 1 percent year to year. (Faculty, 2018, 2019, 2020) For all the references to salary, there should be salary increases (however slight) and not decreases.

However, 2021 was a hard year for workers with almost 2 million women losing their jobs and not regaining them by January 2022 whereas male workers did regain their jobs. (Fry 2022; Gonzales, 2022) If the faculty who lost their jobs were tenured and of higher rank, then we might see a reduction in salary due to higher-paying jobs being lost and/or lower-paying jobs being filled.

Sex

While the existence of gender wage disparity has been well-researched for prestigious occupations, there is a need for more granular studies which focus on specific fields. For example, academia, though prestigious, is also notable for its flexible work schedule with a relatively balanced family and personal life (Crowder & Mouratidou, 2020) as well as having significant control over work travel. Studies, however, show that even in academia, gender pay disparities persist (AAUW, 2014). A study by Renzulli, Reynolds, Kelly, and Grant (2012) showed institution type and academic rank affect salary interdependently. Further, they found that the locations men and women occupy mediate the effect of gender on pay.

In addition to the inherent bias towards paying women less, even in academia, this particular period was harder on women than it was on men. Research by Mckinsey & Company showed that women had never opted out of the workforce at higher rates than men until the pandemic hit. This was particularly hard felt by those with children and more senior women. (Bateman & Ross, 2020; Seven, 2021) Other research shows that many of the more senior women are being asked to care for their older ill family members – which increased during this pandemic. (Boelkes, 2021) This hits women in both the younger and older age demographics.

Public vs Private Universities

Lastly, the topic of public vs private universities comes up. Many research projects have shown that private institutions earn more than public institutions. Bryant (2021), Characteristics (2020), Gulik (2022), and Kingkade (2013) state that within universities, pay also is different based on the type of university: public, private, independent, or religious.

METHODOLOGY

This research is part of a much more in-depth project looking at pay gaps at different times (Nichols et al., 2022) and within the business discipline (McKinzie et al., 2022). One disparity in pay is the discipline of employment including the different university disciplines. (McCarron, 2021) This drove our research to expand not only our time horizon in this study to address both pre-pandemic (2018) and mid-pandemic (2021), but to focus on the STEM fields as a specific discipline. To begin our research, we first had to determine and collect the variables. Then we conducted exploratory data analysis (EDA), and lastly our statistical tests using the Sum of Squares.

The Data

Before collecting our data, we had to determine the variables of most interest. As we wanted to know the impact on salary, we knew our dependent variable was annual income. We restricted this to only nine-month faculty by eliminating those in leadership positions. The mixing of nine vs 12-month faculty salaries might have skewed the data by mixing in administrative faculty.

The next variable we chose was the size of the university. Larger universities tend to be more research focused and smaller universities are more teaching-focused. In as much, the latter has a heavier teaching load and less research load, and they pay less than research-oriented schools. (Non-Tenure, 2020; Salary, 2014)

Our next variable (rank) was chosen because we knew that faculty are given pay raises when they get promoted, but we also have read about salary compression. We were not sure which of these concepts were the primary drivers of income. However, since we were studying STEM faculty and most studies show that salary compression is only evident in Colleges of Business (Homer et al., 2020; McDonald & Sorensen, 2017) we decided to include rank believing the tenured and higher ranks should pay more.

Faculty are seeing pay increases year to year (Flaherty, 2018) but those are less than the inflation rate (Flaherty, 2022) which results in a relatively smaller salary over time. If it weren't for the disparity of more women leaving the workforce (both younger and older women) in larger numbers than men, then it would be easy to conclude that salaries should increase from 2018 to 2021. Although the confounding events make this hard to predict, we stipulate that salaries should still increase, but the salary of women might not increase at the same rate as men.

Since this study was focused on understanding if sex was a primary determinant, we knew that was an important variable. We considered using gender with its more robust categories, but that information was not publicly available.

Lastly, we knew we had to either account for public vs private universities or collect data from only one as faculty at private institutions earn more than public institutions. (Gulik, 2022; Kingkade, 2013) Since public data was open-source, we restricted our data to public universities.

Exploratory Data Analysis (EDA)

We used measures of central tendency to compare our data by breaking out the income with our factors (size, rank, year: pre/during- Covid-19, sex). This initial exploratory analysis allowed us to understand the relationships and representativeness of the data. Before continuing our analysis, we wanted to ensure our data was representative of our expected population and to understand if there were any gaps or under-represented categories.

Statistical Analysis

We then used an N-way analysis of variance (ANOVA) to test for differences as this allows us to study the influence of multiple independent variables on a single dependent variable. We had a numerical (interval) dependent variable and four categorical (ordinal and nominal) independent variables. Since we were studying salary (dependent variable) and wanted to control for sex, rank, university size, and year (pre/during-Covid -19) this was the most appropriate statistical method as factorial ANOVA (UCLA, n.d.) specifically allows us to test and partition this data using the Type I, II, and III sum of squares (SS) (Gottingen, n.d.). We had no missing data (empty cells) so Type IV SS was not necessary as this is the same as Type II when there are no empty cells.

RESULTS

We begin with a descriptive analysis of the data and then provide the statistical results controlling for size, rank, year, and sex.

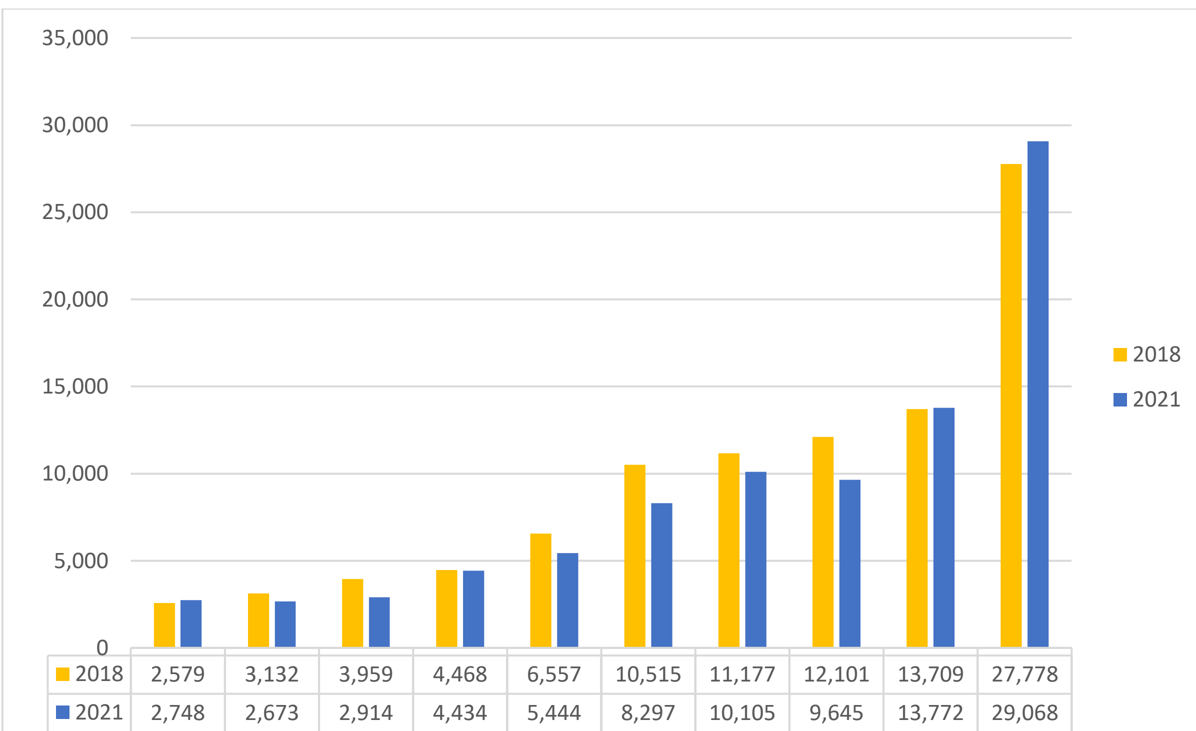
The Data

This data was collected from publicly available data from all four-year public universities in one state in the south-central United States (Arkansas, 2018; ADHE, 2022). This state requires all public schools to submit data on an annual basis and includes the university, faculty by name, department, and college, and often their rank. When the rank was not clear, we used other open-source websites such as the university pages or the faculty member's LinkedIn page to verify this data. The one piece of information we had to interpret was the faculty member's sex. We used their photo image and references to them by pronoun on university pages, LinkedIn, and other social media to confirm. There were no questionable classifications.

Size

There were ten four-year public universities in this state. We used the student body size to help group universities by their size. (CollegeSimply, n.d.; ADHE, 2022) As noted in Figure 1, there was just one large university and it is viewed as a research university where many faculty have a 2/2 or smaller teaching load. There were four universities where teaching loads are generally 4/4 or 3/3 and are viewed as teaching/research schools. Their student body size was 8-14 thousand students and was classified as medium-sized schools. The remaining five universities are teaching schools where faculty teach a load of about 5/5 and are grouped into smaller schools. Of note from this image is that most of these schools lost students from 2018 to 2021 as is the nationwide trend. (Nadworny, 2022)

FIGURE 1
STUDENT POPULATION BY UNIVERSITY



When we dig deeper into the salary of faculty by the school size and break this out by year and sex, we can see that on average men earn more than women at each sized school and in both years with a pay increase for all school sizes and both sexes as noted in Table 1. The larger the school, the more the pay (statistical verification later).

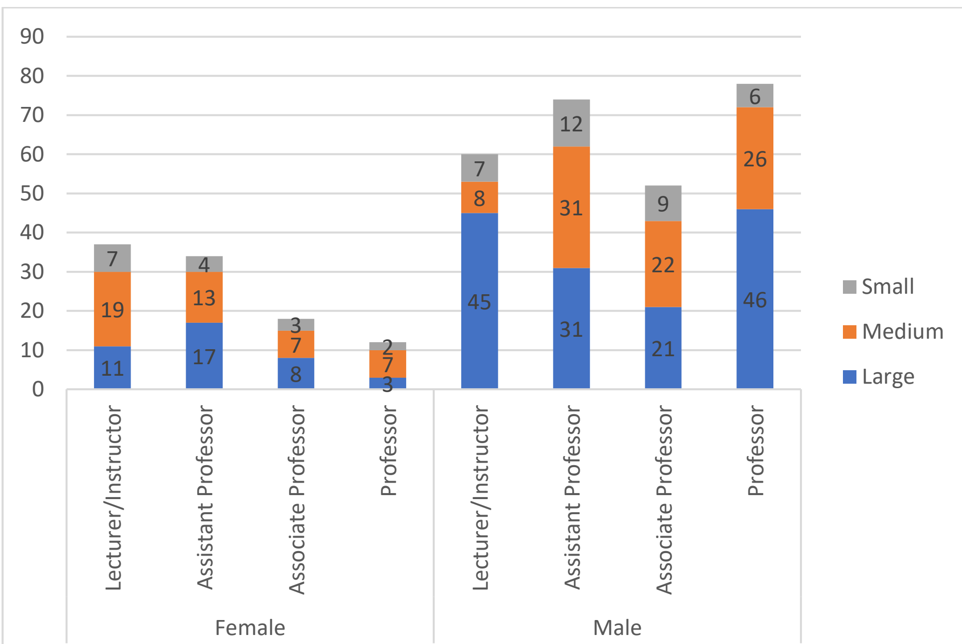
TABLE 1
THE AVERAGE INCOME BY SIZE OF THE UNIVERSITY, SEX, AND YEAR

	2018		2021	
	Female	Male	Female	Male
Small	56,033	60,511	60,356	80,790
Medium	61,983	79,533	62,437	87,512
Large	83,043	99,513	115,375	135,913

Rank

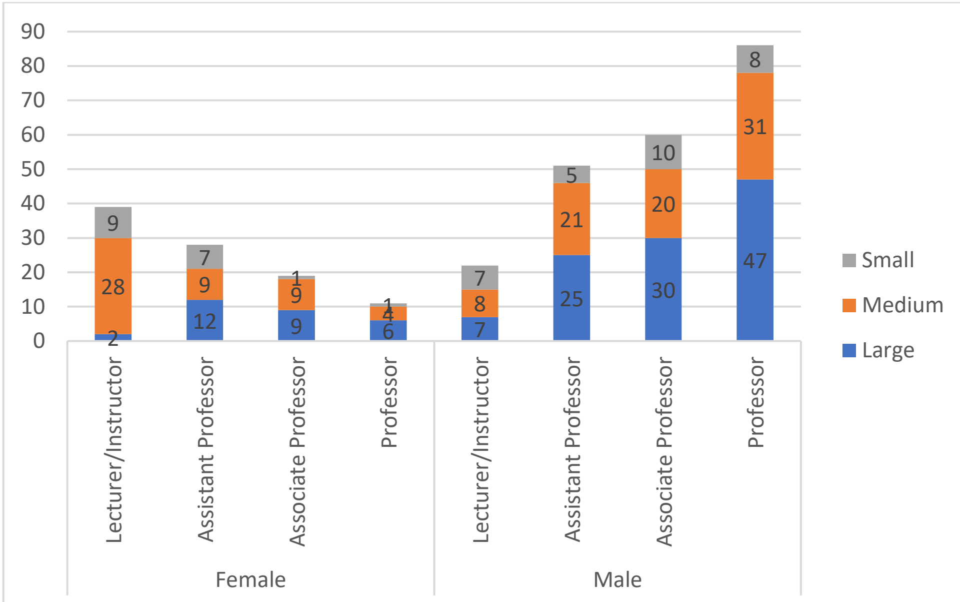
University pay is tied to rank. If men and women are to have equal pay, they should have similar ranks at their universities. As shown in Figure 2 which depicts the demographics in 2018, there are far fewer women than men teaching in the STEM field at every rank and almost all school sizes. Whereas the number of women faculty decreases as the rank increases, that is not true for men. Except for Associate Professor, the number of men increases as rank increases.

FIGURE 2
DEMOGRAPHICS OF THE STEM FACULTY IN THREE UNIVERSITY SIZES IN 2018



Where Figure 2 shows the pre-COVID numbers, Figure 3 reflects the numbers in 2021 (during COVID). We can see significant shifts in the faculty both by rank and by school size. The most notable is the loss of male faculty in the Lecturer/Instructor and Assistant Professor ranks. These are the non-tenured ranks that are not protected in times of economic downturn.

FIGURE 3
DEMOGRAPHICS OF THE STEM FACULTY IN THREE UNIVERSITY SIZES IN 2021



Taking a look at average salaries, Table 2 shows faculty pay by rank, year, and sex. On average, men earn more money than women at all ranks and in both years except for the full Professor ranks. For all but male Associate Professors in 2018, the average pay increases as the rank changes to tenure-track and as rank increases. The loss of so many male Associate Professors from 2018 to 2021 corrected this anomaly. And even though Table 1 showed average salaries increasing from 2018 to 2021 by school size, Table 2 shows us that when looking at rank, the average salary drops for the lowest rank faculty of Lecturer/Instructor and women Assistant Professors.

TABLE 2
THE AVERAGE INCOME BY FACULTY RANK, SEX, AND YEAR

	2018		2021	
	Female	Male	Female	Male
Lecturer/Instructor	63,507	85,523	42,975	53,256
Assistant Professor	84,216	100,914	81,727	101,068
Associate Professor	91,172	92,384	111,185	119,091
Professor	126,348	115,509	213,089	177,497

The lowest-paid faculty are the non-tenure-track rank of lecturer/instructor where women comprise 37% of the women faculty. As we consider the tenure-track and tenured ranks, women comprise less and less of the faculty: 33% of Assistants, 25% of Associates, and only 12% of Professors. Because there are fewer and fewer women as the ranks (pay) progress, we would expect to see women making less money than men. If we had only considered this construct, we might contribute the pay differences to rank.

Sex

In 2018, there were 365 faculty in STEM colleges in this study. Of that 101 were women and 264 were men. On the other hand, in 2021, there were 316 faculty in STEM disciplines. This shows a decrease in the number of faculty in these colleges during the Covid-19 pandemic. There was a ten-fold larger loss of jobs by men (45) than by women (4) in STEM areas. The number of faculty decreased in all ranks but mostly in assistant professor and lecturer/instructor ranks. Among the three university sizes, the largest university experienced the most faculty decrease, 182 to 138, from 2018 to 2021.

As women make up approximately 28% of the STEM disciplines (AAUW, 2020) and this data showed women being 29% of the data set, we felt that the representation was approximate enough especially when we explored the proportion of sex by the different colleges. We found that women were represented at 35% in both the level 2 and level 3 colleges. In the largest colleges (level 1) women were represented in even smaller quantities (21%). This is only one of the imbalance cases that led us away from using Type I SS.

When we consider all three factors (sex, university size, and rank), we begin to see a slightly different pattern from more men at larger universities and more men at higher pay scales. We can also see that new tenure-track (Assistant) and non-tenure-track faculty at the smaller schools are mostly women. The more senior women (Associate and Professor) comprise less than half of those categories as their male counterparts (for all but one category).

On average, women made $69,172 and men made $87,906 in 2018. In 2021, women on average made $77,878 and men made $110,681. So, where women in the study made on average 78.7% of what men earned, in 2021, they were earning 70.4% of what men earned. This income disparity has sometimes been attributed to other factors which is why we are controlling for both the faculty member's rank and university size to see if one's sex impacts one's income. As seen in Tables 1 and 2, there are differences in income at the different ranks and university sizes. The question was, are they significant, and are those categories significant contributors to the income disparities?

Sum of Squares (SS)

Reviewing the demographics in Figures 1 and 2, we do not have balanced data in every category. This imbalance informs us that we should not use SS Type I as it might give us erroneous results. We display it here in Table 3 to show that if one only tested for sex, size, and rank using SS Type I, they would conclude that one's sex does impact one's salary (if alpha = 0.01). This is shown in the top row (Sex) of the table where the Pr>F values are all larger than 0.01.

TABLE 3
SUM OF SQUARES TYPE I

	Pr > F			
	1-way	2-way	3-way	Full
Sex	0.0280	0.0212	0.0196	0.0201
Size	<0.0001	<0.0001	<0.0001	<0.0001
Rank	<0.0001	<0.0001	<0.0001	<0.0001
Year	<0.0001	<0.0001	<0.0001	<0.0001
Sex*Size		0.6005	0.5925	0.5951
Sex*Rank		0.0804	0.0744	0.0763
Size*Rank		<0.0001	0.0003	0.0003
Sex*Year		0.2867	0.2805	0.2825
Size*Year		0.0290	0.0264	0.0273
Rank*Year		<0.0001	<0.0001	<0.0001
Sex*Rank*Year			0.8306	0.8323
Sex*Size*Year			0.4340	0.4370
Size*Rank*Year			0.0002	0.0001
Sex*Size*Rank			0.5896	0.5947
Sex*Size*Rank*Year				0.9143

The initial analysis using the measures of central tendency confirmed we had unbalanced data as we expected. This led us to consider the interaction effects and if there were impacts from these. Type I SS lets us know if men or women get paid more. We already know that different studies have concluded both. But, knowing that the different ranks get paid differently and our data was unbalanced at these ranks, we knew we needed to control for that imbalance (Cooper, 2011). We also hypothesized that people at larger universities get paid more and that was also unbalanced and needed to be controlled. Thus, although we conducted Type I SS, we were not as concerned with that result. We do note that if there are no interaction effects, then we should rely on Type II over Type III as it will be more powerful. On the other hand, if there are significant interactions, then the main interactions should not be further analyzed.

Our Type I SS indicated we had interaction effects. Since we also recognized that our data was imbalanced, we used SS Type III for our analysis. As seen in Table 4, sex was not statistically significant at 0.01, but it was if we were willing to accept a p-value of 0.05. This shows that the other three of our factors (by themselves) help to determine one's salary. But more importantly that the interaction of these variables is determining salary and not one's sex. As noted earlier pay increases with the size of the university, faculty rank, and from 2018 to 2021. Every combination of variable interactions that included sex was not significant. All other variables and interactions were significant (except size-year).

TABLE 4
SUM OF SQUARES TYPE III

	Pr > F			
	1-way	2-way	3-way	Full
Sex	0.0280	0.0391	0.0197	0.0202
Size	<0.0001	<0.0001	<0.0001	<0.0001
Rank	<0.0001	<0.0001	<0.0001	<0.0001
Year	<0.0001	<0.0001	<0.0001	<0.0001
Sex*Size		0.9557	0.9824	0.5951
Sex*Rank		0.0316	0.0926	0.0948
Size*Rank		0.0005	0.0003	0.0003
Sex*Year		0.3753	0.8960	0.8965
Size*Year		0.0290	0.0202	0.0209
Rank*Year		<0.0001	<0.0001	<0.0001
Sex*Rank*Year			0.8306	0.8323
Sex*Size*Year			0.5345	0.5373
Size*Rank*Year			0.0002	0.0002
Sex*Size*Rank			0.6588	0.6634
Sex*Size*Rank*Year				0.9951

CONCLUSIONS

This Research

Size matters. Smaller universities pay less than larger public universities. At these smaller universities, there are 35% women, but at the larger universities, there are only 21% women in STEM. This research concluded that the university size (0.0001) does contribute to one's salary with universities with under 8,000 students paying less and universities with over 15,000 students paying more. But that was not the whole story. It is not just the size, but with an imbalanced faculty at different ranks, this played into the salary differences as did the different time points in the study.

Rank matters. Pay raises are tied to promotions and tenure-track professors earn more than non-tenure-track professors. But there has been an argument that recent hires make more than those with long-standing at the university. As recent hires are more likely to be either lecturers or lower rank tenure-track professors, if inversion/compression were in existence, we would not see the results in this study. We conclude that (0.0001) there is no inversion or compression and that salary is directly tied to one's rank in STEM at public universities. As we saw with the size of the universities, one's pay was not directly tied to faculty rank, but influenced by the size of the university and the year.

Year matters. Faculty are seeing on average increases in pay from 2018 to 2021. We also saw the impacts of the interaction variables of faculty rank and the size of the university.

Sex does not play a statistical role in determining income in STEM. Some research has shown that men earn more and our study shows men earn more on average. When we considered other influencers of faculty income such as university size, rank, and year, this research showed that one's sex was not a contributor to one's income (alpha = 0.01). Nor was it a significant contributor when considering any combination of interaction effects.

Future Research

Prior research showed that when controlling for the size of the university and rank in a college with a relatively equal proportion of men and women, sex was not a significant contributor to rank disparities. (McKinzie et al., 2022; Nichols et al., 2022) In STEM programs where women are a significant minority, sex is still not a statistically significant determinant of salary. This is in contrast to research where minorities earn less pay than the majority demographic (notably race and ethnicity). Future research should examine if this holds when women are the majority sex in a program such as nursing or social programs.

Women make up a significantly smaller proportion of faculty in larger universities. These universities also pay more. Research needs to be conducted to see if there is retention, hiring, or self-selection bias contributing to fewer women at larger universities. Since these universities pay more, by having a smaller proportion of women at these universities, women are inherently earning less as they work at universities that pay less.

Lecturers make less than any of the tenure-track positions. Assistants make less than Associates that make less than Professors, which contradicts the notion of inversion and compression of faculty salaries. However, since there are fewer and fewer women as the ranks increase, women are making less money than men. Research should consider why there are fewer women at the higher tenure-track ranks as well as why there are more women at the ranks that do not (necessarily) require a terminal degree. Women are entering the workforce in larger numbers, have they not yet matriculated to the higher ranks (it takes at least 12 years to reach Professor)? Are they choosing not to apply for promotion? Are they being denied promotion?

While it is noted that lecturers make less than any of the tenure-track positions, there was an unexplained drop in pay for both men & women from 2018 to 2021. Additional research is warranted to determine the cause of this pay decline. This faculty rank is the most vulnerable as they are not protected by tenure and are often on a year-to-year contract. They are the rank first eliminated during economically challenging periods. Were these positions eliminated during COVID to be able to retain faculty in tenure-track positions? Will these positions return in a few years?

There was a large reduction in male faculty from 2018 to 2021. Some research shows that men have regained those positions by 2022 whereas women have not. (Fry 2022; Gonzales, 2022) A future update to this study is warranted to see if men regained these positions in academic STEM fields and if women regain them or not.

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