

Investigation of Gender Equity for Faculty Salaries at Colorado State University

The Truth, the Whole Truth.... and some Opinions

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1. Overview

In May 2014, CSU Provost Rick Miranda asked me to be on a task force, together with Professor Susan James (Mechanical Engineering) and Professor Sue Doe (English), to work with Laura Jensen (Director of Institutional Research) and some IR staff. The goal was a gender equity analysis of the salaries of regular faculty. My main role involved the statistical analysis of the FY2014 salary data, to determine if there is gender equity, and if not, to quantify the gender effect on salaries.

In Section 2 of this document, a description of the gender equity data analysis for the FY2014 faculty salaries is given. I have tried to make this accessible to everyone, even folks who say “I’m not a math person.” So, give it a try. You will find that you can follow the logic of the statistical analyses, even if you do not understand the mechanics.

In Section 3, the annual exercise called the Individual Salary Equity Study (hereafter called the Study) is discussed. This is meant to provide information for chairs and deans, to use in setting the annual raises. The methodology for the Study should be different from that of the gender equity analysis, because the purpose is different. I will argue that the Study can and should reflect CSU policy for setting salaries. The methodology for the 2014-2015 Study might have had the unfortunate effect of perpetuating gender inequity, and the resulting uproar was unpleasant for everyone.

The purpose of this document is to help people understand both the gender equity analysis and the annual Study, to clear up confusion and to help us move forward.

2. Gender Equity Analysis for 2013-2014 Salaries

Data for 1045 tenured and tenure-track faculty at CSU in FY2014 were given to the committee in an Excel file, from IR. For each faculty member, we had the following information (items in this list are called “variables”).

- Nine-month salary. For faculty with a twelve-month contract (called “basis of service” in the data base), we multiplied their listed salary by .75.
- Gender: female or male.
- Rank: The three ranks are assistant, associate, full.
- The department where the faculty member works. There were 54 departments, with 8 faculty members in the smallest (Ethnic Studies) and 64 in the largest (Clinical Sciences).
- The college where the faculty member works. There are nine colleges at CSU.
- The year the faculty member received the PhD or terminal degree.
- The number of years as faculty at CSU.

The “years in rank” variable was not available in this data set, but my understanding is that it will be available for future analyses.

Let’s start with a simple analysis of salaries by rank and sex. The average nine-month salaries by gender and rank were:

- Female Assistant: \$73,041.56
- Male Assistant: \$78,123.09
- Female Associate: \$79,320.14
- Male Associate: \$86,406.27
- Female Full: \$100,874.65
- Male Full: \$117,569.93

You can see that the salaries for male faculty were, on average, higher than for female faculty, at each rank. As we will see, some of these differences were “explained by” the fact that there were proportionally more women in departments that have, on average, lower salaries. However, we will start with a simple model to determine the statistical significance of these pay gaps, in part because it’s important to quantify these “comparable worth” issues, and in part for exposition – to start with a simple model and build on it.

We converted salaries to the logarithm scale for the statistical analysis. There are two reasons for this. First, standard statistical methods require symmetry of the “error distribution” which would be violated if the untransformed salary were used. The salary distribution tends to be skewed upward, and taking the logarithm corrects or greatly reduces this skew. Secondly, it is more natural to compare salaries as percentages. We can say, “department A salaries are about 10% higher than department B salaries,” and be roughly correct for all three ranks, while if we try to use dollar amounts to compare departments, we need three numbers. Also, salary raises are typically given in percentages, which causes the salary to increase exponentially, and the $\log(\text{salary})$ to increase linearly. All this simply means that we used $\log(\text{salary})$ instead of salary in our statistical models.

Let y_i be the $\log(9\text{-month-salary})$ for the i th faculty member, $i = 1, \dots, 1045$. Define the following “indicator variables” for the six rank/gender groups:

- $r_{1,i} = 1$ if the i th faculty member was a female assistant professor, and $r_{1,i} = 0$ otherwise
- $r_{2,i} = 1$ if the i th faculty member was a male assistant professor, and $r_{2,i} = 0$ otherwise
- $r_{3,i} = 1$ if the i th faculty member was a female associate professor, and $r_{3,i} = 0$ otherwise
- $r_{4,i} = 1$ if the i th faculty member was a male associate professor, and $r_{4,i} = 0$ otherwise
- $r_{5,i} = 1$ if the i th faculty member was a female full professor, and $r_{5,i} = 0$ otherwise
- $r_{6,i} = 1$ if the i th faculty member was a male full professor, and $r_{6,i} = 0$ otherwise

We used the model:

$$y_i = \beta_1 r_{1,i} + \beta_2 r_{2,i} + \beta_3 r_{3,i} + \beta_4 r_{4,i} + \beta_5 r_{5,i} + \beta_6 r_{6,i} + \varepsilon_i, \quad i = 1, \dots, 1045,$$

where the term ε_i is a “random error” or more accurately “variation that is not explained by gender and rank.” It was assumed that the distribution of these errors is centered at zero. For example, if the 34th

faculty member in the list is a male associate professor, then $r_{1,34} = r_{2,34} = r_{3,34} = r_{5,34} = r_{6,34} = 0$ but $r_{4,34} = 1$, so the log(salary) y_{34} is assumed to be β_4 plus some positive or negative “random error.” This means that β_4 can be interpreted as the “true average” FY2014 log-salary for male associate professors at CSU, and the other five coefficients are interpreted similarly. The quantity $\exp(\beta_4)$ is a measure of center of the salaries for this group, but not quite an average salary (nor is it a median salary).

Then $\exp(\beta_2 - \beta_1)$ can be interpreted as the ratio of centers of male assistant professor salaries to female assistant professor salaries. The estimate of β_1 , written $\hat{\beta}_1$, is simply the average of all the log(salaries) for female assistant professors, and the same holds for the other groups. The estimates of the ratios of central male to female salaries are:

- $\exp(\hat{\beta}_2 - \hat{\beta}_1) = 1.059$, meaning that male assistant professors made, on average, 5.9% more than female assistant professors.
- $\exp(\hat{\beta}_4 - \hat{\beta}_3) = 1.096$, meaning that male associate professors made, on average, 9.6% more than female associate professors.
- $\exp(\hat{\beta}_6 - \hat{\beta}_5) = 1.162$, meaning that male full professors made, on average, 16.2% more than female full professors.

If $\hat{\beta}_1 = \hat{\beta}_2$, then the ratio is one, and this reflects equal salary centers for male and female assistant professors. Of course, even if $\beta_1 = \beta_2$, the “randomness” in the actual salaries would cause $\hat{\beta}_1 \neq \hat{\beta}_2$. The question is, are these differences big enough to conclude that the gap was systematic rather than due to random variation?

If the errors ε_i can be assumed to be independent and with an approximately Gaussian (bell-shaped) distribution, with mean zero and common variance, then we can do standard t -tests to compare male and female salaries. The results for three (separate) two-sided t -tests are:

- $H_0 : \beta_1 = \beta_2$ versus $H_a : \beta_1 \neq \beta_2$: $p = .045$
- $H_0 : \beta_3 = \beta_4$ versus $H_a : \beta_3 \neq \beta_4$: $p < .0001$
- $H_0 : \beta_5 = \beta_6$ versus $H_a : \beta_5 \neq \beta_6$: $p < .0001$

The smaller the p -value, the more evidence for a systematic difference. The “cut-off” p -value is often taken to be .05; using this, the salary gaps were significant at all three levels, although the assistant professor gap might be said to be “borderline significant.” However, the gaps at the two higher ranks were too large to be explained by random variation. The multiple R^2 is .378, indicating that 37.8% of the variation in log(salary) at CSU, in FY2014, was due to rank and gender.

As mentioned earlier, there is a lot of variation in salary among the 54 departments: the highest average 9-month salary in FY2014 was \$143,461 (Marketing) while the lowest was \$48,248 (Library Sciences). If there were a high proportion of women in the lower-paying departments, compared to in higher-paying departments, then we would see significant differences in salaries by gender, even if within departments women were paid, on average, the same as men. So, it is important to “control for” the effect of department, by adding the department variable to the model.

We modeled the department effect by creating 54 indicator variables for departments, and adding 53 of these to the above model. Suppose $d_{j,i} = 1$ if the i th faculty member is in department j , and $d_{j,i} = 0$ otherwise, for $j = 1, \dots, 54$. Then our model is

$$y_i = \beta_1 r_{1,i} + \dots + \beta_6 r_{6,i} + \alpha_1 d_{1,i} + \dots + \alpha_{53} d_{53,i} + \varepsilon_i, \quad i = 1, \dots, 1045,$$

where now β_1 is “true average” log-salary for women assistant professors in department #54, and $\beta_1 + \alpha_j$ is the true average log-salary for women assistant professors in the j th department, and ditto for other rank/gender combinations. (Technical point: I checked for interaction between the department and rank/gender, and it was insignificant. This means that the salary ratios for the gender/rank combinations are approximately the same across departments.)

The department effect is highly significant, with 80.5% of the variation in log-salary explained by rank, gender, and department. This reflects large differences in average pay, across the different departments at CSU.

If we want to compare salaries of female and male full professors *in the same department*, the difference in average log salaries is still $\beta_6 - \beta_5$, because the department coefficients will cancel. That is, the ratio of male to female full professor salary centers, $\exp(\beta_6 - \beta_5)$, applies to all departments. We can perform the same hypothesis tests to get p -values for the differences in salary by gender, for each rank, after the department effect is controlled for. For the FY2014, we found:

- $H_0 : \beta_1 = \beta_2$ versus $H_a : \beta_1 \neq \beta_2$: $p = .91$
- $H_0 : \beta_3 = \beta_4$ versus $H_a : \beta_3 \neq \beta_4$: $p = .81$
- $H_0 : \beta_5 = \beta_6$ versus $H_a : \beta_5 \neq \beta_6$: $p = .0002$

After controlling for department, we find that there was no significant difference between male and female assistant professor salaries at CSU, and also no significant difference between male and female associate professor salaries. However, $\exp(\hat{\beta}_6 - \hat{\beta}_5) = 1.068$, meaning that male full professors made 6.8% more than female full professors, and this is quite significant as well as substantial. Although the department effect “explained” much of the discrepancy in full professor pay, there was still an overall gap.

Next, we should control for the effect of seniority. If male full professors had, on average, more seniority, then we would expect their salaries to be somewhat higher. The average years since degree for female full professors was 25 years, compared to 28 years for male full professors. Suppose x_i is the number of years since terminal degree, for the i th faculty member. We can add a term to the model that accounts for the effect of this variable, by letting $f(x)$ be an increasing function, and

$$y_i = \beta_1 r_{1i} + \cdots + \beta_6 r_{6i} + \alpha_1 d_{1i} + \cdots + \alpha_{53} d_{53i} + f(x_i) + \varepsilon_i, \quad i = 1, \dots, n.$$

With modern nonparametric function estimation methods, we don’t have to specify a functional form for f (such as linear or quadratic); we can simply assume that f is “smooth and increasing.” (Technical note: the R function `cgam` will perform this nonparametric regression analysis.) After controlling for the effect of years since degree, we find $\exp(\hat{\beta}_6 - \hat{\beta}_5) = 1.053$, with $p = .0006$. Seniority has explained a bit more of the gap between male and female full professor salaries, but there is still a 5.3% gap, and this is statistically significant.

Finally, let’s look at the effect of years at CSU. For a given number of years since degree, we expect faculty salaries, on average, to *decrease* as years at CSU increases. This is because one typically gets a big salary bump when moving from one university to another, and this phenomenon is not unique to CSU. If z_i is the number of years at CSU for faculty member i , and $g(z)$ is a smooth and decreasing function representing the effect of years at CSU, the (final) model is:

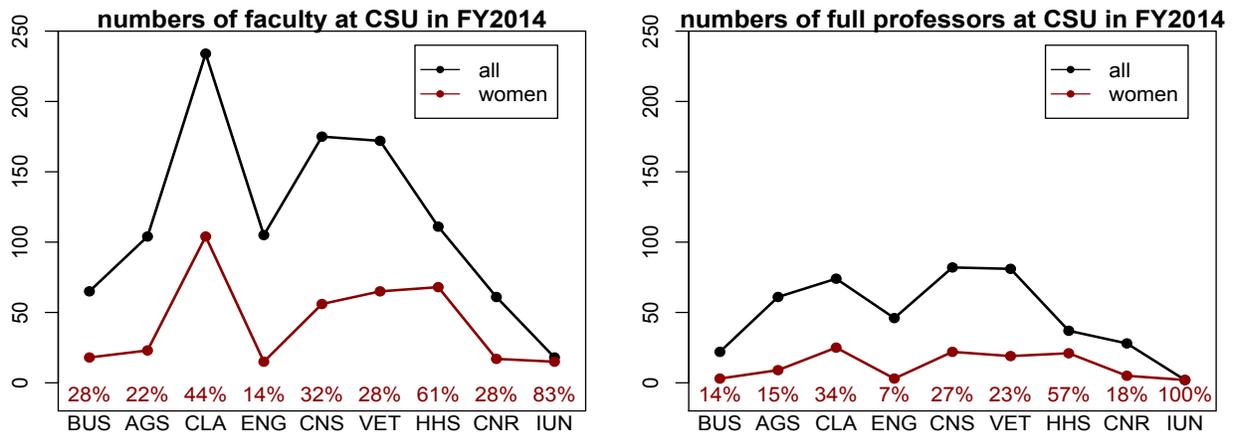
$$y_i = \beta_1 r_{1i} + \cdots + \beta_6 r_{6i} + \alpha_1 d_{1i} + \cdots + \alpha_{53} d_{53i} + f(x_i) + g(z_i) + \varepsilon_i, \quad i = 1, \dots, n.$$

Now, $\exp(\hat{\beta}_6 - \hat{\beta}_5) = 1.046$, meaning that male full professors at CSU made, in FY2014, 4.6% more than female full professors at CSU, after effects of department and both kinds of seniority are accounted for.

The p -value for $H_0 : \beta_5 = \beta_6$ versus $H_a : \beta_5 \neq \beta_6$ is $p = .0017$, indicating rather strong significance. The multiple R^2 tells us that 83.5% of the variation in $\log(\text{salary})$ is explained by the predictors: rank, gender, department, and the two kinds of seniority. Finally the fact that the gap between male and female full professors decreased when years at CSU is added to the model implies that women have, on average, more years at CSU for a given years since degree. In other words, women are less likely to arrive at CSU from another university, and/or they are more likely to stay at CSU, compared to men.

In summary, we found that for FY2014 salaries, the gender gaps in salary for assistant and associate professors were explained by the department effect. Within departments, there were no systematic gender differences in salaries for these two ranks. However, for full professors there was a substantial and significant gap in average salaries. Some of this gap is explained by the two seniority variables, but even after seniority is accounted for, there remains a substantial and significant gap.

We can repeat this same analysis individually by college. However, because there were only 109 female full professors at CSU in FY2014, the power for the tests is rather small, when the sample size is reduced. Below is a plot of the numbers and percentages of women faculty in FY2014, showing that with the exception of the Libraries department (IUN) and Health and Human Sciences (HHS), women are under-represented as faculty and especially as full professors. The FY2014 percentages of women faculty (all ranks and full) are shown for each college.



The data analysis produces, for each faculty member, a “predicted” $\log(\text{salary})$. This is obtained simply by plugging the faculty member’s information into the fitted model, and the predicted salary is interpreted as the average of $\log(\text{salaries})$ at CSU for faculty with these characteristics (including gender). The “residual” is the difference between the actual $\log(\text{salary})$ and the predicted $\log(\text{salary})$. If a faculty member’s residual is .084, then using $\exp(.084) = 1.089$, we conclude that his or her salary is 8.9% higher than the center salary. If the residual is $-.042$, then $\exp(-.042) = .959$, we conclude that his or her salary is 4.1% lower than the center salary for that group.

The committee felt that each faculty member had a right to know her or his predicted value and residual. However, they want the predicted value for their rank, department, and seniority, not the predicted value for their rank, department, seniority, and gender. That is, a woman full professor doesn’t want to compare her salary to other *women* in her group, she wants to compare her salary to *everyone* in her group. Therefore, the data analysis was repeated with the gender variable removed, and the predicted values and residuals saved from this model.

I invited faculty to contact me for their residual information, and sent many people their numbers with

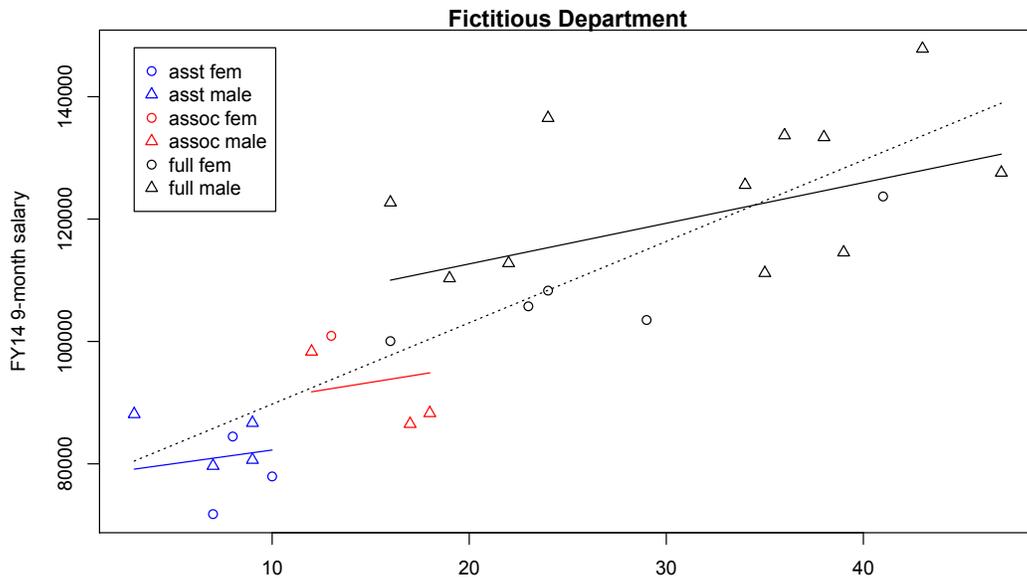
interpretation. Some time later, the IR made a web site where faculty could input a CSU ID number, and be given their predicted salaries (called “median” on the web site). However, these predicted salaries were from the analysis *with* gender. The result was that women full professors’ central salaries (given as “medians” on the web site) were many thousands of dollars less than that for men full professors, in the same department, with the same seniority. This web site was taken down shortly after this was discovered.

[Technical notes: no statistical data analysis is complete without a proper residual analysis to check the model assumptions. The residual analysis in this case found some heteroskedasticity (the assumption of equal variances for the error terms is suspect). The full professor salaries had more variance than the others’, even after the log transform. Weighted regressions were performed to correct this heteroskedasticity (once with different variances for the different ranks, once with variance increasing in years since degree), and the results concerning gender were almost identical to what has been reported. There was also evidence that the residuals from the unweighted model had a bit of a skew and heavier tails than the Gaussian distribution; this was not severe and was alleviated by the weighting.]

3. 2014-15 Individual Salary Equity Study

Every year the IR produces a salary analysis to provide information to deans and department heads, for use in determining faculty raises. In particular, the information is used to identify salaries that are low compared to peers, and these faculty might be eligible for “equity raises.”

The “old” way of doing this (in 2014 and previously) was to fit a line to salary versus years in rank, for each department separately. Some fabricated (for confidentiality) data for salaries in a department are shown in the plot below, where the dotted line represents the least-squares fit to the points. Each point represents a faculty member in the department, with color and shape of the point indicating rank and gender, respectively. These points were simulated from a subset of the predicted values from the FY2014 analysis, plus some randomly generated “error.” Thus, the patterns are typical for departments at CSU.



A single line might not be the best representation of how faculty salaries increase, as there is a bump for the two promotions. The three parallel solid lines represent the least-squares fit to the log-salaries,

converted back to the salary scale, with rank accounted for. You can see that the residuals (vertical distances from the lines) change appreciably depending on the fit. In particular, the four most junior full professors are all above the dotted line, but three are below the solid line for full professors.

The question of which variables should be used to provide “target” salaries, or measures of centers of groups, for the purposes of the annual individual salary equity studies, is important and should be carefully considered. This will reflect CSU policy for raises, and therefore should not have any implicit biases. There are also many technical issues. For example, producing these targets by considering each department separately will produce great variation in the plots. Some of the smaller departments might not have any associate professors for example, and in many cases, there are small numbers of faculty in each rank. In this case, one or two large or small salaries can change the plots drastically, sometimes resulting in negative slopes. Should the targets in these departments be decreasing in seniority? One way to ensure uniformity is to set the targets using slopes from the entire data set, or perhaps from all data within the college.

The 2014-15 Individual Salary Equity Study included the gender variable to set these targets, so that women full professor “medians” were considerably smaller (many thousands of dollars) compared to men with the same rank and seniority. After this serious mistake was discovered, the study was rescinded and the old, single regression per department plots were distributed.

This mistake caused a brief scandal, but there was a potential sub-scandal that was ignored. The Study also used the years at CSU as a factor to set the target salaries. Because the relationship between salary and years at CSU is decreasing, using this variable means having lower targets for faculty who have been here longer, all other things being equal. I believe that CSU does not want to intentionally target lower salaries for “loyal” faculty, so this variable should not be included. Further, the gender equity analysis showed that including years at CSU would also further set lower targets for women, on average, as men are more likely to switch universities. [Technical note: this inference was made from the fact that the gap in full professor salaries decreased when “years at CSU” was added to the model.]

4. Summary

Analysis of the FY2014 data for tenured and tenure-track faculty showed a significant gap between average salaries for male and female full professors. The gap for full professors persists after accounting for effects due to department and seniority. In contrast, there was no significant or substantial gender gap for assistant and associate professors, after department effects were accounted for. CSU should act to remove this gap by FY2016, by providing a pool of money from central funds, to be distributed as raises to full professor women who are below the targets for their peer groups. A careful analysis of the FY2015 data could provide the amount of money needed, and a team of faculty and administrators could collaborate on a suggested methodology for distribution, to be used as a starting point for deans and department chairs.

The results from the FY2015 data analysis were not provided to the faculty, but it can be inferred from the Study that the full professor gender gap persists, because of the substantial difference in “median” values for men and women full professors. However, as steps were taken to equalize salaries in some departments (raises were given to a number of senior women), the FY2015 gap is likely smaller than that for FY2014.

The annual salary exercise called the Individual Salary Equity Study should clearly not use gender to set “targets” to be used to compare faculty to their peer groups. Neither should years at CSU be used. The methodology for setting these targets should be carefully considered, and should reflect CSU policy and values. The details of the methodology should be made public.

5. Results and Worksheets

The estimated coefficients from the final model *without gender* in Section 2 are given here, along with some fun exercises to help you use this information to calculate your own predicted FY2014 salary.

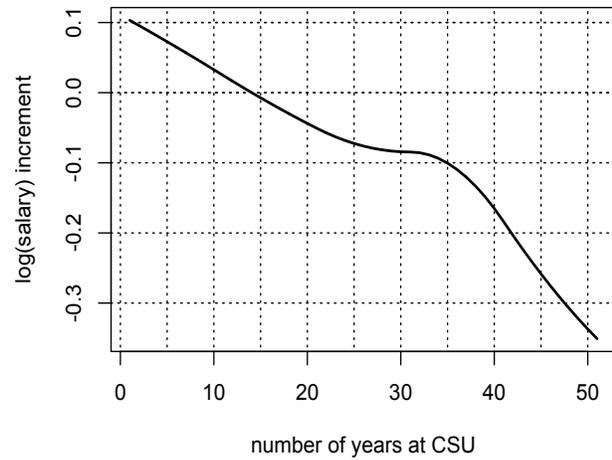
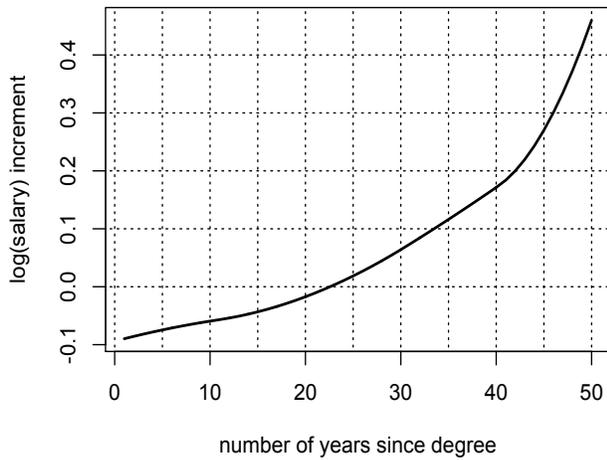
First, find your rank in the first table, then find your department in the second table. Add the coefficient for your department to the coefficient for your rank. Now, adjust for your seniority. Find the height of the curve in the first plot, for your years since degree. For ten years since degree, this number is about -.06. Next, find the height of the curve in the second plot, corresponding to your years at CSU. It's about zero for 14 years at CSU. Add these two numbers to your previous sum. Now, take $\exp(\text{sum of your four numbers})$, to get your predicted salary. It's that simple!

Coefficients for Rank

Assistant	11.3044
Associate	11.4346
Full	11.6811

Coefficients for Departments

Accounting	0.3826	Food Science and Human Nutriti	-0.1793
Agricultural and Resource Econ	-0.0688	Foreign Languages and Literatu	-0.4107
Animal Sciences	-0.0943	Forest and Rangeland Stewardship	-0.2051
Anthropology	-0.3034	Geosciences	-0.1440
Art	-0.3875	Health and Exercise Science	-0.0958
Atmospheric Science	0.1664	History	-0.3105
Bioagricultural Sciences and P	-0.1357	Horticulture and Landscape Arc	-0.2052
Biochemistry and Molecular Bio	-0.1077	Human Development and Family S	-0.1885
Biology	-0.1080	Human Dimensions of Natural Re	-0.2300
Biomedical Sciences	-0.0576	Journalism and Technical Commu	-0.2384
Chemical and Biological Engine	0.1602	Library	-0.6905
Chemistry	-0.0090	Management	0.3050
Civil and Environmental Engine	0.1238	Marketing	0.3427
Clinical Sciences	-0.0286	Mathematics	-0.1151
Communication Studies	-0.3131	Mechanical Engineering	0.1333
Computer Information Systems	0.3505	Microbiology, Immunology and P	-0.0416
Computer Science	0.1166	Music, Theatre and Dance	-0.4010
Construction Management	-0.0575	Occupational Therapy	-0.1290
Design and Merchandising	-0.2217	Philosophy	-0.3077
Economics	-0.0490	Physics	-0.0793
Ecosystem Science and Sustaina	-0.1050	Political Science	-0.2063
Electrical and Computer Engine	0.2140	Psychology	-0.1305
English	-0.3566	School of Education	-0.1908
Environmental and Radiological	-0.0269	School of Social Work	-0.2285
Ethnic Studies	-0.2277	Sociology	-0.2417
Finance and Real Estate	0.2863	Soil and Crop Sciences	-0.0905
Fish, Wildlife and Conservatio	-0.1941	Statistics	0



Here are some Fun Exercises you can do to make sure you are doing it right: (answers on next page)

1. Find the predicted salary for an associate professor in English, who is 10 years since degree and 2 years at CSU: _____
2. Suppose an assistant professor in Geosciences, who is 14 years from degree and 6 years at CSU, makes \$67,100. This is _____% less than the predicted salary.
3. Faculty in Management make about _____% more than faculty in English, all other things being equal.
4. A full professor in History who is 20 years since degree and has 20 years at CSU makes about _____% more than an associate professor in History who is 20 years since degree and has 20 years at CSU.
5. A full professor in Psychology who is 20 years since degree and has 20 years at CSU makes _____% more than an associate professor in Psychology who is 20 years since degree and has 20 years at CSU.
6. A faculty member (at any rank, in any department) who has been at CSU for all 40 years since degree makes _____% less than a faculty member at the same rank and in the same department, who has been at CSU for only year, but is 40 years since degree.

Answers to Fun Exercises

1. We start with 11.4346 for the rank, and subtract .3566 for the department. The increment for years since degree is about -.06, and the increment for years at CSU is about .09. We get $\exp(11.4346 - .3566 - .06 + .09) \approx 66703$.
2. We start with 11.3044 for the rank, and subtract .1440 for the department. The increment for 14 years since degree is about -.05, and the increment for 6 years at CSU is .07. Therefore the predicted salary is about $\exp(11.18) = 71711$. The ratio of actual to predicted is $67100/71711 = .936$, so the salary is about 6.43% less than predicted by rank, department, and seniority.
3. The coefficient for Management is .3050, while the coefficient for English is -.3566. Therefore the ratio of salaries is $\exp(.3050)/\exp(-.3566) = \exp(.3050 + .3566) = 1.938$, so the Management faculty make 93.8% more than faculty in English, at the same rank and seniority.
4. We need only compare the coefficient for full professors to the coefficient for associate professors; all the other terms will cancel. We have $\exp(11.6811 - 11.4346) = 1.280$, Therefore, full professors make about 28% more than associates, all other things being equal. (Therefore, it is important that there is no gender bias in the matter of timely promotions to full professor.)
5. Same answer as #4.
6. We need only compare the increment for 40 years at CSU (about -.17) with the increment for one year at CSU (about .1). We have $\exp(-.17 - .1) = .763$, so full professors who have been at CSU for all 40 years of their careers make, on average, about 23.7% less than full professors who have been at CSU for one year out of their 40 years since degree.