EMTH415 Assignment 1

Recognition Bias and the Gender Pay Gap

Steven Little (49788379), Ryan Bright (11086829), Connor Thomas (97101899)

Contents

Abstract

A three DOF model is presented based on lecture content. The model describes a career through time as a system of Pay (P), Status (S), and Research (R). Looking at pay guidelines, the model baseline is determined. This baseline gives a starting pay of $78,856 and a final pay of $231,720 after a 40-year career. A perturbation analysis shows how each parameter in the model impacts the final pay. It is found that status recognition is the most impactful parameter on final pay with research recognition being the second most. To explore potential interventions that can offset the disparity between males and females over a career, a temporary increase to status recognition is modeled. This was applied across all points in a career to show when such an intervention is most impactful, occurring 6 years into the career.

Introduction

Recent research shows that there are gender disparities in pay within academia (Ann & Alex, 2020). Women are being paid significantly less over their career compared to similarly performing men. Further research shows that women's work is valued less compared to men's work (James, Buelow, Gibson, & Ann, 2024). This difference in an academic's perceived value may result in women being recognized less for their work. The effect of this recognition bias on the lifetime pay of female academics will be investigated as a cause of the gender pay gap.

Model

Our analysis assumes a career can be represented by a current state, Equation 1 and a system of ODEs, Equation 2. Additionally, lifetime pay is described by Equation 3.

$$Z = \begin{pmatrix} P \\ S \\ R \end{pmatrix} \tag{1}$$

$$\frac{dP}{dt} = \gamma * P + \alpha_S * S * P \tag{2}$$

$$\frac{dS}{dt} = (\alpha_R * R + \alpha_T * (1 - R)) * S * (1 - S)$$

$$\frac{dR}{dt} = \beta * (1 - R) * R$$

$$L = \int_0^{40} P(t)dt \tag{3}$$

Where:

$P(t) = Academic's\ Yearly\ Annual\ Salary\ at\ year\ t$

$S(t) = Academic's\ Status\ at\ year\ t$

$R(t) = Proportion\ of\ Academic's\ time\ allocated\ to\ Research\ at\ year\ t$

$L = Lifetime\ pay\ for\ a\ 40\ year\ career$

$\beta = Research\ Growth\ Rate$

$\alpha_R = Status\ Growth\ Rate\ due\ to\ Research$

$\alpha_T = Status\ Growth\ Rate\ due\ to\ Teaching$

$\alpha_S = Payrise\ recognition\ due\ to\ Status$

$\gamma = Inflation\ Rate$

Parameters and assumptions

For S and R, both are bounded by an unstable fixed point at 0 and a stable point at 1, letting them act as non-dimensional coefficients. Inflation will be set at 2% and the research growth rate will be set at 5%.

It is assumed that all academics start their careers with a status of 0.5 ($S(0) = 0.5$), to represent that they have already published a paper for their PhD. Another assumption made by this model is that academics will start their career spending an equal proportion of their time between researching and teaching ($R(0) = 0.5$).

All dollar values in this report are in NZD.

Method

To model the ODE system, Equation 2, that describes a career, a fourth order Runge Kutta numerical integrator is used. To establish a baseline of parameters, model hand tuning reduced the error between initial and final pay.

To determine what parameter is most impactful on final pay, sensitivity analysis was conducted. This was done by taking a range of percent changes to each parameter of the baseline and mapping this change to final pay. This then informed the next analysis.

Recognition bias causes a pay gap between males and females due to differences in their status recognition, α_S, or their research recognition, α_R. By applying a localized change to a given parameter, this can alter a careers trajectory. This is investigated to identify when best to provide an intervention to a female's career so they get similar lifetime pay and final pay to a male of equal work. The localized change is described by a step function acting on the parameter, Equation 4.

$$\alpha(t) = \alpha_{baseline} + A * (H(t - t_0) - H(t - t_1)) \tag{4}$$

For this report the width of this local change is one year applied at all points through a career, and the magnitude is given by 'A'. This allows for qualitative study of when such a change to a career causes the most significant change to lifetime pay.

Results

Model baseline

To refine the model, salary data from the University of Canterbury (University of Canterbury, 2024) was used to define the initial and final pay of the model. The initial state was set to [78856, 0.5, 0.5]. Parameters $\alpha_S, \alpha_R, \alpha_T$ were then tweaked so that final pay returned by the model matched the highest pay band, which is earned by a Distinguished Professor, $231,720. This assumes that after 40 years, every academic is promoted to Distinguished Professor. This resulted in a career trajectory shown in Figure 1

To provide an example of what female pay might look like compared to a male pay over their career, α_S was varied until the Lifetime pay, Equation 3, was \$400,000 less than the males total pay, which is the estimated value found in (Ann & Alex, 2020). This is shown in Figure 1.

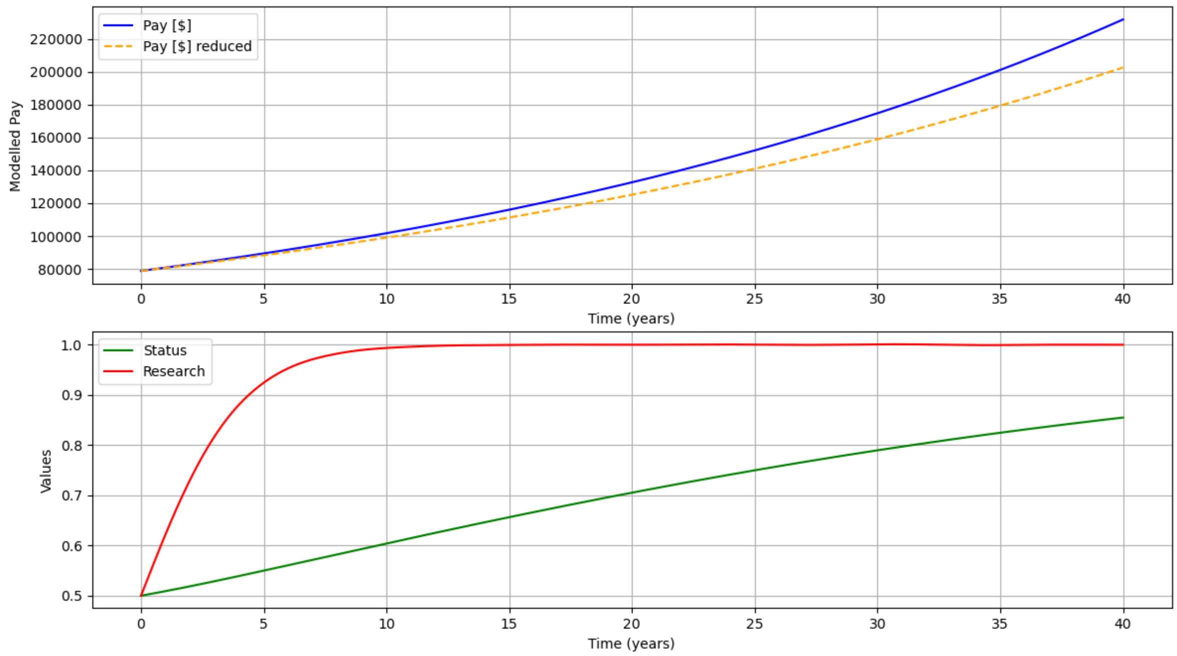

Figure 1. Above: calibrated pay model showing male (default) and female pay. Final parameters for the model are: $\alpha_S = 0.01, \alpha_R = 0.045, \alpha_T = 0.025, \beta = 0.5$. *Below: status and research models created with the same parameters.*

Sensitivity Analysis

A sensitivity analysis was carried out on important parameters: $\alpha_S, \alpha_R, \alpha_T, \beta$, to determine which of these had the most effect on final pay (pay at end of career), so that the model could be better understood. Figure 2 shows the model's sensitivity to each parameter.

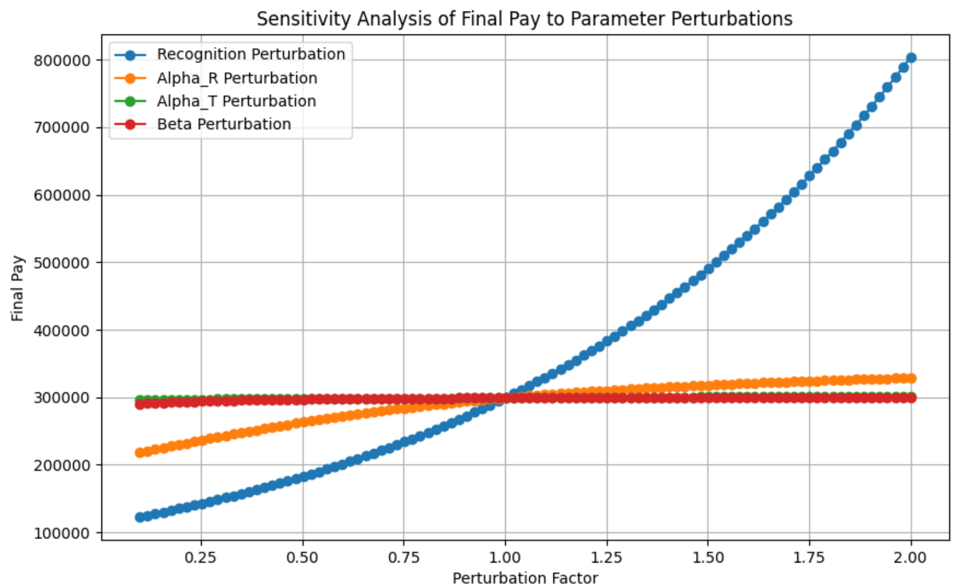

Figure 2 Sensitivity analysis for important parameters.

Clearly the model is most sensitive to changes of α_S, followed by α_R. It is for this reason that further analysis was carried out varying α_R and α_S in the following two sections, respectively.

Career intervention – Research recognition

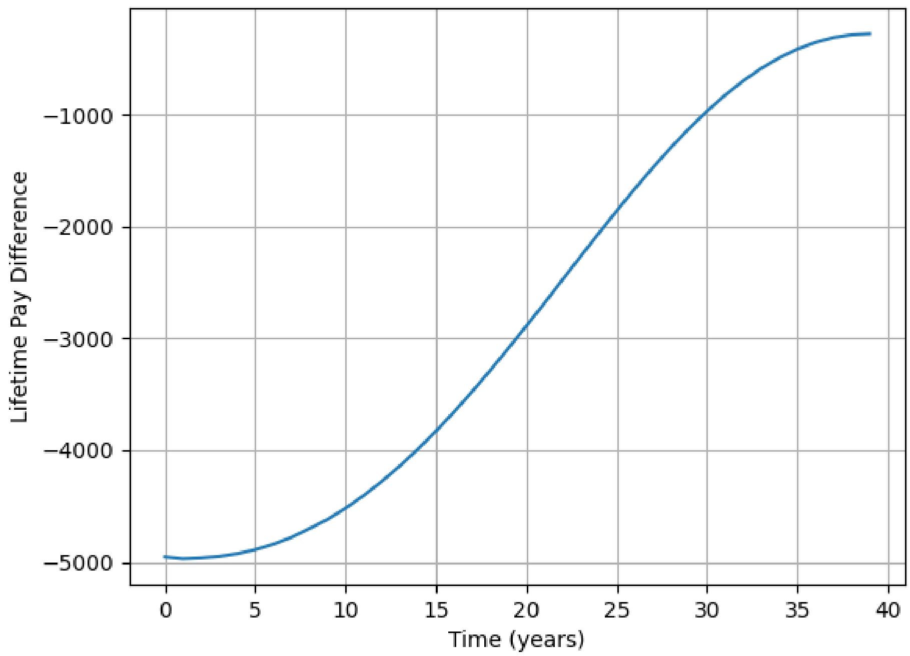

Figure 3. Total change in pay for different years of reduced research recognition

Figure 3 shows that this model predicts that reduced research recognition in an academic's early years negatively affects their lifetime pay more than having reduced research recognition in the later years of the career.

Career intervention – Status recognition

With the calculated default value for $\alpha_S = 0.01$, and using Equation 4, and setting $A = 0.1, (t_0, t_1) = (5,6)$, the effect of an intervention at this particular time can be seen in Figure 4.

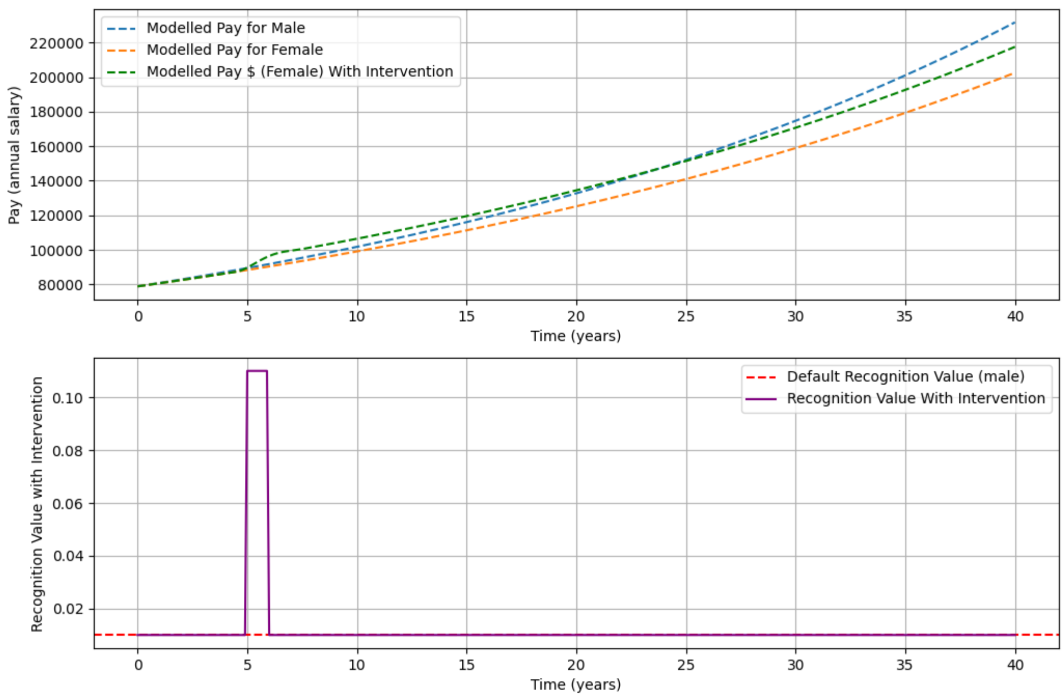

Figure 4. An example of the effect of an intervention has on one's career. Note the

Since this investigation only focusses on the relative impact that an intervention has on pay, and not the resultant change in pay, the value for A is arbitrary. To find which year in one's career is most effective, i.e., creates the biggest lifetime pay increase, a metric named 'impact' was created. This is a normalized scale of the difference in lifetime pay between male and female resulting from an intervention. This impact was plotted against the year which the intervention occurred, shown in Figure 5.

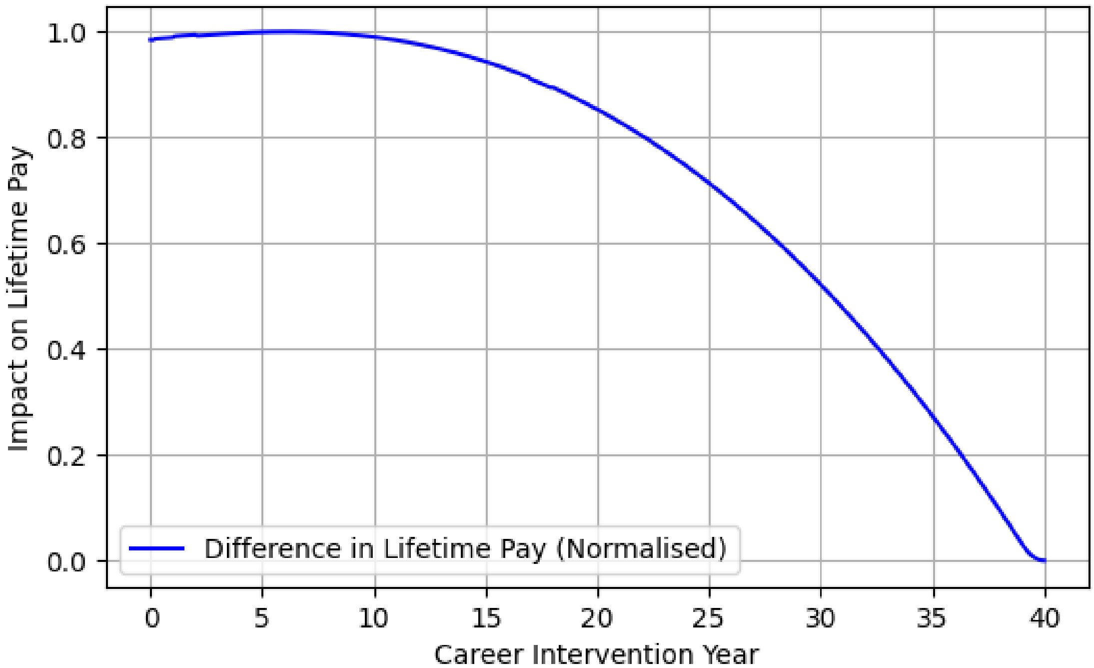

Figure 5. Impact on lifetime pay vs year of career intervention

Note that the peak occurred approximately 6 years into the career.

Discussion

Model limitations

A limitation of this model is that pay is not constrained and an academic with a status of 1 will experience a 3% pay increase on top on inflation every year, leading to an exponential pay, even in terms of the current value of money. However, since the careers simulated last for only 40 years the salary is bounded.

Another assumption that limits the model is that for calibrating the baseline model, is that an academic becomes a Distinguished Professor by the end of their career. This is unrealistic but the assumption creates a sufficiently accurate model.

Sensitivity analysis

Because the system is nonlinear, the relative sensitivity of the model using the baseline parameters won't necessarily have the same trends for different baselines. This means further analysis could be done to conduct a more thorough search for the parameter with the highest sensitivity averaged over the whole sensitivity space.

Career intervention - research

Analysis of a varied α_R showed that recognition bias present early in a female academic's career had a significantly higher effect on the lifetime pay over the career. Therefore, even if a recognition bias was fully rectified, for most female academics, the damage to lifetime pay has already been done. The older the academic, the more pronounced this effect will be. For this reason, the authors believe that to fully address the recognition bias in academia, not only should the recognition bias be closed but other interventions will be necessary to ensure lifetime pay equity between men and women.

Career intervention – status recognition

Changing the year of the academic's career in which an intervention occurs and calculating the impact shows that it is generally better to stage the intervention earlier in a woman's career. This is expected because the associated pay rise that occurs at the time of the intervention permanently increases the academic's pay for the rest of their career. This can be seen by the jump in the green curve in Figure 4. Therefore, the longer the effect is felt for, the larger difference it has on lifetime pay. The peak of the curve in Figure 5 shows the optimal time to have the intervention. According to the previous logic, the peak should lie at the very beginning of the career. The reason why this does not occur is because of how status and research are modelled (Equation 2). Figure 1 shows that the status and research vary differently over time. It is the author's hypothesis that the peak lies where there is an optimal balance of: 1) being early enough in the career for the intervention and associated pay rise to have a large effect, and 2) having a large enough status and research value as to increase the academic's pay. Further investigation is required to validate this.

Proposed Solutions

The results show that it would be most effective to stage an intervention to increase a woman's status recognition early on in their career. This intervention could look like a standardized performance evaluation for women early in their career in academia (say 5 years in), which focusses on objective, evidence-based markers of contribution/potential.

References

Ann, B., & Alex, J. (2020). Research performance and age explain less than half of the gender pay gap in New Zealand universities. *PLOS One*, https://doi.org/10.1371/journal.pone.0226392.

James, A., Buelow, F., Gibson, L., & Ann, B. (2024). Female-dominated disciplines have lower evaluated research quality and funding success rates, for men and women. *eLife*, https://doi.org/10.7554/eLife.97613.3.

University of Canterbury. (2024). *Collective Employment Agreement*. Retrieved from https://hrdocs.canterbury.ac.nz/ea/rs_cea01.pdf

CRediT Statement

Steven Little: Investigation, Writing – Original Draft, Software
Ryan Bright: Methodology, Investigation, Writing – Original Draft, Software
Connor Thomas: Investigation, Writing – Original Draft, Software