Modeling Gender Disparities in Corporate Structures

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April 3, 2025

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1 Executive Summary

1.1 Introduction

The notion of gender disparities in the corporate world has been a longstanding issue and is influenced by numerous factors, including biased hiring and promotions, skewed representation in the candidate pool, or simply systemic differences between genders. The specific factor of hiring and promotion bias, namely homophily, over time on gender disparity within corporations is explored. Homophily is the tendency for people to seek out and be attracted to those similar to themselves, which undeniably plays a role in the hiring process and promotion selections.

In this project, the purpose is to investigate the effect of a company's structure and environment on gender imbalances in the workforce when homophily is expressed. Namely, this project compares the two main company organizational structures: horizontal and vertical. A horizontal structure in an organization is also known as a flat organization, as there are minimal management layers, allowing more employee autonomy and prompting collaboration across teams. A vertical structure, on the other hand, is more hierarchical, demonstrating a pyramid structure with a top-down level of management (see Figure 1). In this structure, roles are distinctly defined and decision making follows a clear chain of command. Based on these two structures, models will be created to study the differences in gender disparities across various organizational forms over time.

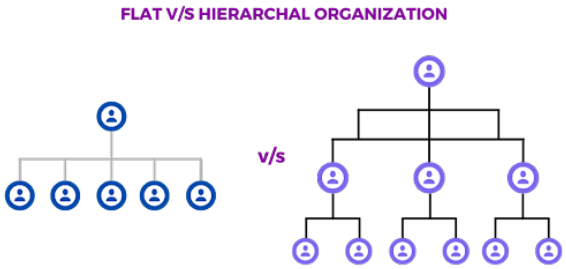

Figure 1: Horizontal (left) versus Vertical (right) Organizational Structure

1.2 Organizational Models

The fundamental model used to visualize the gender breakdown of a company included several parameters: departure rates, hiring rates, and promotional rates. Departure rates were kept constant across all organizational structures, but hiring and promotional rates favored men over women—demonstrating that men were more likely to be hired or promoted than women. Each model started with an equal number of men and women, and a new state of the model was created whenever there was a change within the company, which is usually initiated by a departure and followed with a hire and a promotion.

To differentiate between horizontal and vertical structures, the number of levels of hierarchy and promotional rates for each were different. A horizontal structure contains three levels of structure, while a vertical structure contains six levels, aligning with the definition of each of the structures. Promotional rates were also varied across the two structures, with vertical organizational structures having a higher rate of promotions than horizontal structures, as there are intuitively more opportunities for promotion in the vertical structure.

1.3 Conclusions

The models for both horizontal and vertical structures were simulated over time and visualized via a heatmap demonstrating the proportion of women and men in each level over time. Since one simulation does not fully illustrate the true effects of a model, the simulation was run 100 times and averaged out. To visualize these results, a heatmap was used.

For the horizontal structure (see Figure 2), it is evident that the lower levels tend to be more equally distributed in terms of gender, as shown by the grey. However, as employees get promoted

and increase in level, the proportion of females in the workplace decreases, meaning that a higher proportion of executives tend be male.

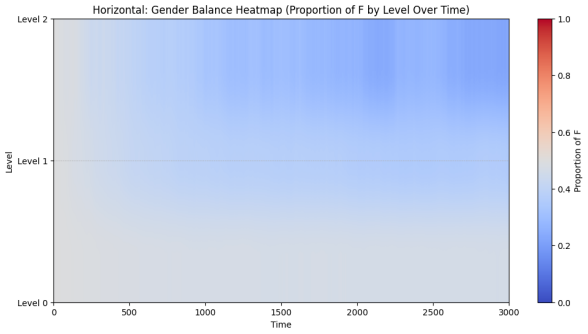

Figure 2: Horizontal Structure: Gender Balance Heatmap (Proportion of F by Level Over Time)

For the vertical structure (see Figure 3), it appears that the overall proportion of males and females are imbalanced across all levels of the company. There appears to be a slightly higher proportion of males than females in companies using the vertical structure.

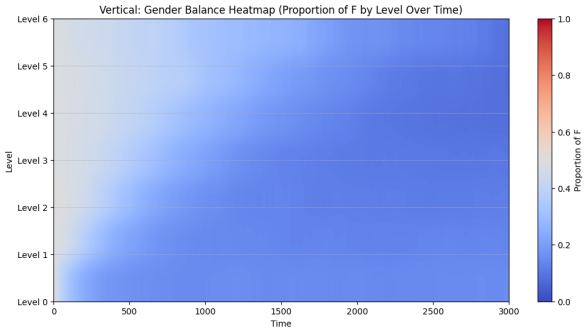

Figure 3: Vertical Structure: Gender Balance Heatmap (Proportion of F by Level Over Time

After comparing the gender disparities within horizontal and vertical structures, each company structure has their advantages and disadvantages. The horizontal structure tends to be more equal overall, but is skewed towards males at the higher levels. The vertical structure, however, is overall more male dominant across all levels.

To further investigate this concept, companies can be separated into different industries, as some industries tend to be more male or female dominant than others. Additionally, this model and simulation could also be run utilizing real-world data gathered from companies.

2 Main Body

2.1 Overview of Modeling Approach

2.1.1 Motivation and Context

In contemporary workplaces, identity disparities in representation and advancement remain critical issues, influenced by organizational structures and systemic biases. This study seeks to investigate whether the structure of a company, categorized as either vertical or horizontal, impacts the persistence and magnitude of these disparities.

Organizational structures directly influence promotion dynamics, decision-making authority, and employee career trajectories. Vertical structures, with their incremental hierarchies, might propagate subtle biases through repeated promotions, entrenching disparities over time. Conversely, horizontal structures, with fewer levels, concentrate the effects of hiring and promotion decisions, potentially amplifying disparities more quickly.

Through simulation modeling, this project aims to uncover the underlying dynamics of identity representation in these structures and evaluate how hiring, promotion, and departure patterns shape disparities. The findings will not only provide theoretical insights but also inform practical interventions for fostering equitable representation in diverse organizational contexts.

2.1.2 Description of the Base Model

The base model simulates the dynamics of a corporate workforce using a Continuous-Time Markov Chain (CTMC) framework. It represents the flow of employees through organizational levels via departures, promotions, and new hires, with parameters capturing hiring and promotion biases.

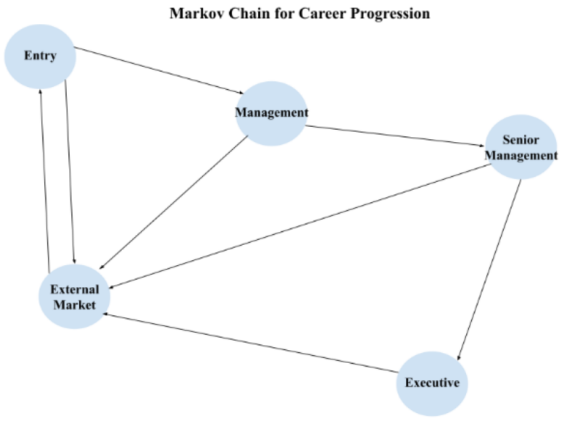

Figure 4: Markov Chain Illustrating Transitions Across Organizational Hierarchy Levels

In our model, we assume that departure rates decrease as individuals move up the organizational hierarchy, reflecting the inverse relationship between an employee's level and their likelihood of leaving the organization. This assumption aligns with the idea that individuals at higher levels often have more invested in their roles.

Promotion rates in the model are influenced by both promotion weights and the current workforce composition at each level. These rates are dynamically calculated, incorporating the concept of homophily, where individuals are more likely to promote those who share their identity. This mechanism introduces a realistic bias into upward mobility and allows the model to investigate how promotion practices impact disparities across different structures.

Hiring rates, in contrast, represent the likelihood of individuals entering the organization at the base level. These rates are determined by hiring weights, which reflect recruitment preferences or pipeline biases.

Together, the hiring, promotion, and departure dynamics interact to simulate the evolution of workforce composition within vertical and horizontal structures, offering insights into the mechanisms that drive identity disparities.

2.2 Detailed Overview of Vertical and Horizontal Variants

2.2.1 Defining Vertical and Horizontal Structures

In this study, two organizational structures are explored: vertical and horizontal. The vertical structure represents a traditional, hierarchical organization with many levels, each offering narrowly defined roles and incremental promotions. Employees in this structure move step-by-step through seven levels, with decision-making authority concentrated in the uppermost tiers. This setup mirrors industries where specialization and a clearly defined chain of command are essential.

In contrast, the horizontal structure reflects a flatter organization with fewer levels, promoting broader roles and greater autonomy at each stage. With only three levels, career progression involves larger jumps, and decision-making is more evenly distributed. This structure aligns with modern, agile workplaces that prioritize collaboration and flexibility. By examining these two contrasting models,

we can evaluate how structural design impacts identity disparities, particularly in hiring, promotion, and overall workforce composition.

2.2.2 Model Implementation for Vertical and Horizontal Structures

The implementation of both the vertical and horizontal models focuses on simulating workforce transitions through hiring, promotion, and departures, with a key emphasis on how homophily shapes promotion dynamics. Unlike predefined promotion rates, the models intentionally compute promotion probabilities dynamically, allowing them to reflect real-time workforce composition at each level. This approach ensures that the likelihood of promotion for an individual is directly influenced by the proportion of their identity group at the preceding level, as well as the promotion weights assigned to that identity. For example, the probability of promoting a female employee depends on both her representation at the prior level and the relative weight assigned to her group, capturing the effects of homophily—the tendency to favor those who share similar characteristics.

This dynamic formula for promotion rates is integral to the model, as it allows identity disparities to emerge and propagate based on the structural and procedural design of the organization. In the vertical model, the multi-tiered hierarchy provides numerous opportunities for this mechanism to play out, with disparities potentially compounding over time as employees move through successive levels. The horizontal model, with its limited number of levels, applies the same mechanism but reduces the number of transitions, emphasizing how biases at entry or during early promotions can have a more immediate and sustained effect on overall representation.

Departures are governed by fixed rates that vary by level, with higher levels experiencing lower departure probabilities. This assumption reflects the idea that individuals in senior positions are less likely to leave due to their investment in the organization and their role. Hiring, on the other hand, is modeled at the entry level, with static hiring weights determining the probability of recruiting individuals from different identity groups. While hiring weights are not dynamic, their effects are mediated by the promotion process, which acts as a filter for workforce composition as individuals advance.

2.3 Analysis and Results

2.3.1 Impact of Hiring and Promotion Bias

Understanding the mechanisms through which hiring and promotion practices shape identity representation is critical to addressing workplace disparities. Both hiring and promotion processes are key drivers of workforce composition, influencing who enters an organization and who progresses through its ranks. In this section, we explore how biases in these processes affect identity representation within two vertical and horizontal organizational structures.

The question we aimed to address is: How do hiring and promotion biases contribute to gender disparities in vertical vs. horizontal structures?

2.3.2 Model Analysis: Basic Model

We slowly built our model up to examine whether a company's organizational structure impacted gender imbalance while homophily and a slight gender bias is present in the workplace. As detailed previously, we first modeled homophily into a generic workplace structure. To best visualize the situation, we created several plots and data visualizations. First, we wanted to examine the overall measure of men versus women in the workplace (Figure 5).

This graph clearly demonstrates how homophily and a slight hiring bias quickly exacerbates the issue of gender inbalance in the workplace. This plot makes a lot of logical sense because each time step, we are forced to either hire either a man or a woman, so the lines are mirror images of each other. This plot was great for examining the overall populations in the workplace; however, does not demonstrate whether this inequality comes from the lower or higher levels. So, we plotted the various levels by line graph (Figure 6) and heatmap (Figure 7).

From these two plots, one can clearly see that this imbalance is prevalent in all the levels. However, it is much more intense in the higher levels. This could be explained by the higher promotion rate for men due to a greater gender bias in management levels.

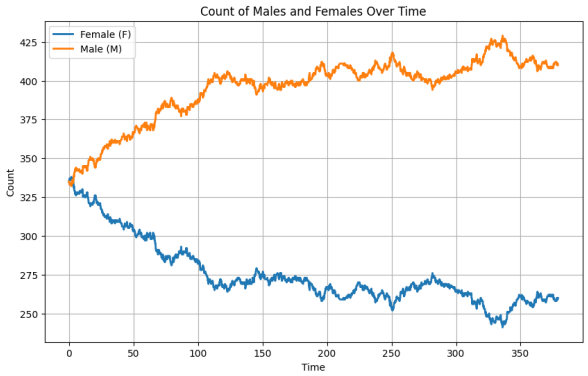

Figure 5: Basic Model with Homophily

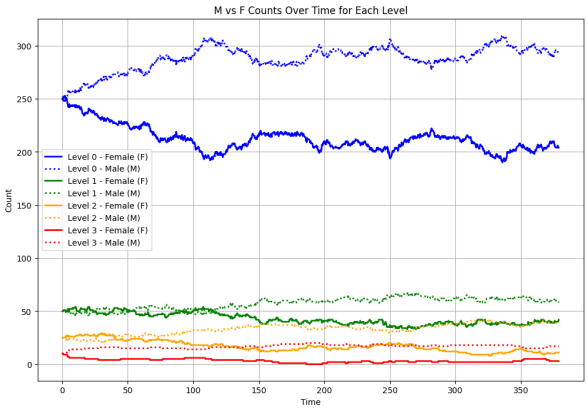

Figure 6: Basic Model with Homophily: Divided into Levels

2.3.3 Model Analysis: Horizontal vs. Vertical

Now that the proper background has been set and the basic model has been discussed, we will get into the model analysis for the horizontal and vertical model implementations. Out of the three different plots we created for the first model, the heatmap was most comprehensive and easy to understand. In order to achieve the "true" value of the model, we ran each simulation 100 times and plotted the average proportion of females across all simulations. Figures 8 and 9 are the heatmaps for such simulations.

The difference between the two simulations is quite stark, with the vertical simulation being much more heavily male dominated in all levels, very quickly; whereas the horizontal one has a bit more equality in the lower levels. We concluded that this result was from the vertical structure having more promotions and mobility through the levels. More mobility results in more chances for the slight gender bias to play an integral role in the process, which results in more male hires and promotions, which in turn also causes homophily to play a larger role in future hirings and promotions. This highlights a pro of the horizontal company structure — less gender inequality if one looks at the company as a whole.

One interesting thing to note is that horizontal company structure also seems to have a higher likelihood to produce instances where the top level is heavily skewed one way or the other. When we ran the simulation in single iterations, there were times, we would get all female leadership and times we would get all male. Figures 10 and 11 are two separate runs of the simulation for horizontal company structure that resulted in very different gender proportions.

This variation was very interesting because it showed how the horizontal company structure allowed for a higher chance of women being in leadership positions, but still maintained the male dominated nature of the situation.

To further investigate the question, we designed an experiment comparing the effects of biased

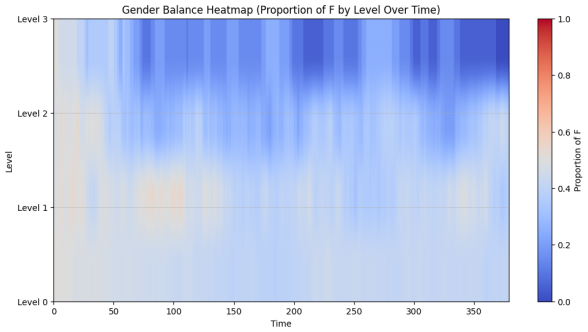

Figure 7: Basic Model with Homophily: Heatmap

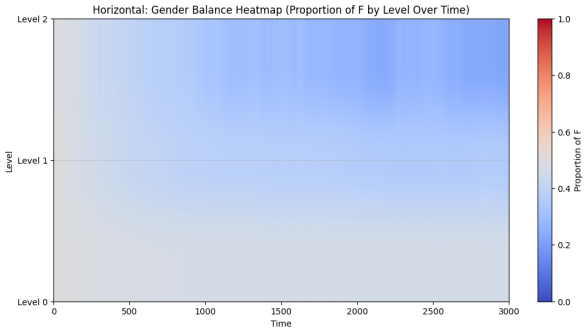

Figure 8: Horizontal Company Structure Heatmap

and unbiased hiring and promotion practices in both vertical and horizontal organizational models. Specifically, we constructed four key scenarios to isolate the impacts of these practices. In the first scenario, hiring was unbiased, maintaining an equal gender representation at the point of entry (50/50), while promotions were biased towards males (60/40). This allowed us to examine how promotion biases influence identity representation without the confounding effects of hiring disparities. The second scenario reversed this setup, introducing a hiring bias favoring males (60/40) while keeping promotions unbiased (50/50). This scenario helped isolate the impact of hiring practices, ensuring that promotion decisions did not exacerbate the disparities introduced during recruitment. These two scenarios were then applied to both vertical (Figure 12) and horizontal (Figure 13) structures to explore how biases interact with organizational hierarchies.

These heatmaps show the importance of unbiased promotion. While unbiased hiring is a step in the right direction in terms of principle, it does very little in both horizontal and vertical companies in terms of ensuring gender equality at the highest levels. An interesting thing to notice about these simulations is that with unbiased promotions, the vertical company actually mitigates gender disparities better. The horizontal company structure still ends with a majority of men in the higher positions; whereas, the vertical structure ends with almost an ideal 50-50 split at the top. This highlights a pro of the vertical model. Essentially, if we are to ensure that promotions are unbiased, the vertical model will successfully mitigate gender disparities in leadership, though they may still exist in the lower and mid-levels.

2.3.4 Long-term Steady-state Disparities

Does the organizational structure lead to significantly different steady-state identity distributions?

Figure 14 clearly demonstrates the contrast between the steady-state distributions between the two company structures. Vertical companies tend to have a significantly higher portion of men than horizontal companies do. However, a common theme is that both companies do have their highest level being the most dominated by men. Again, this visualization suggests that vertical structures tend to lead to more gender imbalance in all levels and to a higher degree than in a comparable horizontal company.

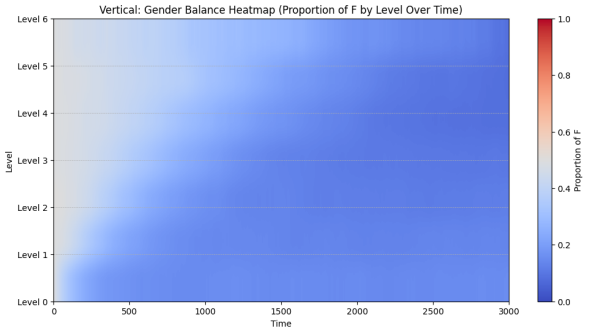

Figure 9: Vertical Company Structure Heatmap

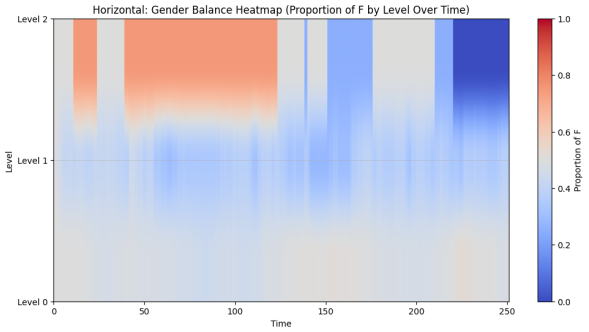

Figure 10: Horizontal: Female

2.4 Conclusions

As a brief recap, the overarching goal of this report is to answer the question: How do hiring and promotion biases contribute to identity disparities in vertical vs. horizontal structures?

From our simulations and visualizations, we have concluded that this question is not as ambiguous as we originally thought. It was fairly clear that with homophily and a slight bias towards men over women, the vertical company structure contributed to more gender disparities than the horizontal company structure did. Overall, this was a direct result of the vertical company structure having many more promotions because of their numerous levels. Even from the start where both genders were equally represented (homophily played no role), a man held a slight advantage due to the slight implicit bias many companies hold. Then, as slightly more men are hired/promoted, homophily begins to play a role in the further hirings/promotions, and so on. This system is clearly exacerbated by a vertical company structure where there are more promotions/hirings.

Though, generally speaking, a horizontal company structure is favorable in minimizing gender disparities company-wide and within each company level, an interesting thing we discovered is that ensuring the promotion rate unbiased completely flips the situation. This actually allows a vertical company structure to have an equal distribution of men and women at the highest level, whereas the horizontal company structure still had more men at the highest level. Clearly, there are many factors that contribute to the gender disparities that occur, and it would be a good idea to explore other factors further to see how they may affect company demographics.

Lastly, it is important to point out that while a horizontal company structure may seem favorable in minimizing gender disparities in companies, there are many other factors that go into how companies chose their structure. There are key differences in productivity, departure rates, and overall satisfaction that may cause a company to choose one structure over another. In our model, we drastically simplified our assumptions to create a model to best answer our question at hand, but this question may just be one of a multitude of questions that real companies must consider.

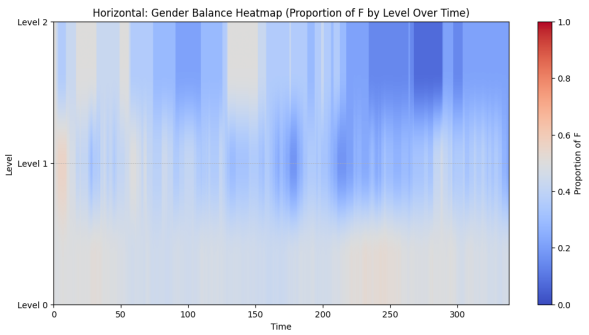

Figure 11: Horizontal: Male

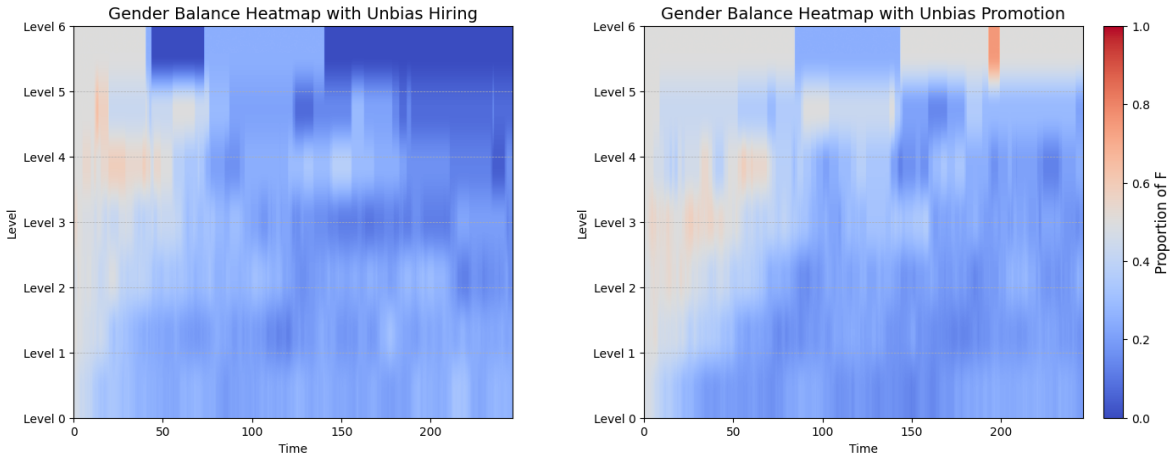

Figure 12: Gender Balance Heatmap's in a Vertical Organizational Structure

3 Technical Appendices

3.1 Effect of Homophily on Identity Representation

How does homophily influence identity representation and disparities within structures?

Another question we explored was the effect of the homophily parameter on the number of promotions for men vs. female in horizontal vs. vertical companies. In Figure 15, a homophily increment of X means the rate of hirings and promotions for men increases by X/2 and the rate for women decreases by X/2. So, a homophily increment of 0 would be representative of the Basic Model and a homophily increment of 0.2 means the male rate increased by 0.1 and the female rate decreased by 0.1. This plot makes it quite clear to see that as the difference between the male and female rate increases in the vertical company, the gap between their promotions do as well. However, the horizontal company maintains a fairly steady number of promotions regardless of the difference. This provides even further justification to support the argument that horizontal is much less sensitive to perturbations in changes in the homophily. Even as you increase the difference in homophily, the horizontal model is still constant.

3.2 Implementation of Homophily

- The promotion probability for a female employee at level l where $l > 0$ is calculated as:

$$P(\text{promote F at level } l) = \frac{\text{promotion\_weight}_{l,F} \cdot \text{num\_F}_{l-1}}{\text{promotion\_weight}_{l,F} \cdot \text{num\_F}_{l-1} + \text{promotion\_weight}_{l,M} \cdot \text{num\_M}_{l-1}}$$

- This dynamically adjusts to both promotion weights and real-time representation at the preceding level, ensuring promotion reflects structural composition at any given moment.

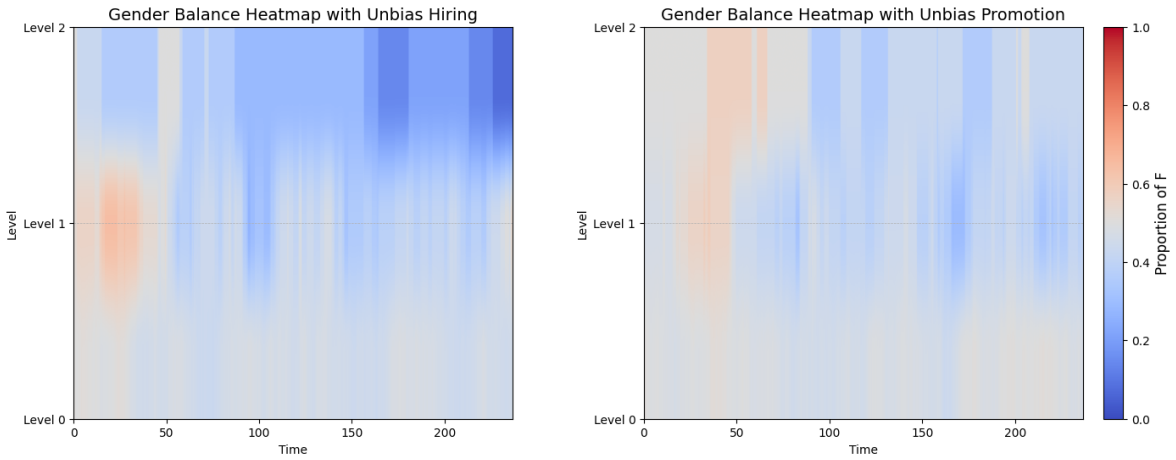

Figure 13: Gender Balance Heatmap's in a Horizontal Organizational Structure

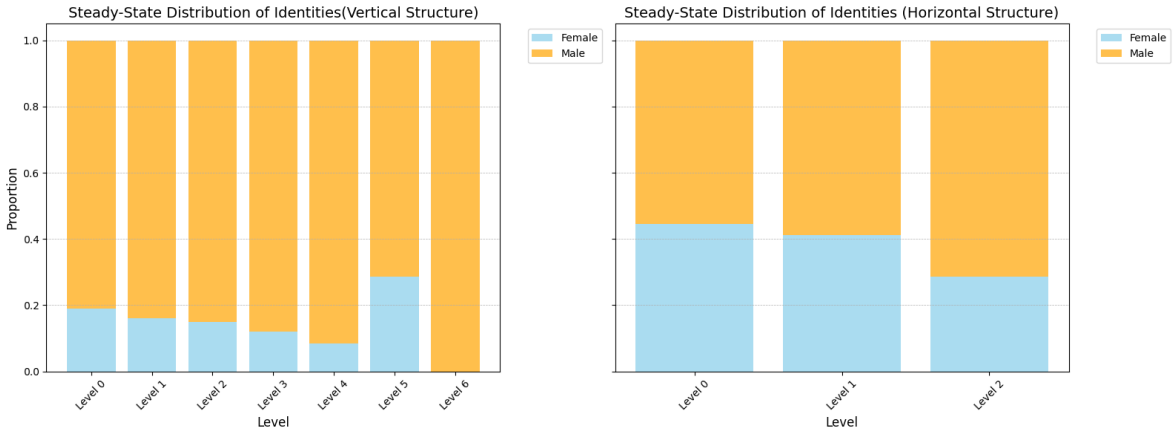

Figure 14: Steady-state Vertical vs. Horizontal

3.3 Supporting Conclusions

The findings are influenced by several underlying dynamics that go beyond the main conclusions. The vertical structure's susceptibility to exacerbating disparities is not only due to its multiple levels but also the cascading effect of homophily and promotion biases over successive transitions. Each level provides an opportunity for slight imbalances in promotion probabilities to compound, reinforcing disparities as individuals progress through the hierarchy. Additionally, even with equal initial representation, vertical structures amplify the impact of small biases in hiring and promotion, creating disparities that may not emerge in horizontal structures.

In contrast, the horizontal structure's limited levels reduce the opportunities for compounding effects, making initial hiring practices a dominant factor in determining overall disparities. However, because there are fewer promotion events, horizontal structures may struggle to correct initial imbalances, leading to persistent disparities even with unbiased promotion rates. The finding that unbiased promotions favor parity in vertical structures stems from their ability to counteract imbalances across multiple levels through repeated opportunities for correction, a mechanism absent in horizontal structures.

These insights suggest that disparities are not only a function of explicit biases but also the structure of the organization itself, highlighting the complex interaction between processes like hiring, promotion, and departure. Factors like turnover rates and external hiring pools, though fixed in the model, could further influence outcomes if varied dynamically, potentially altering the observed trends. This underscores the importance of examining structural and procedural factors together when addressing disparities.

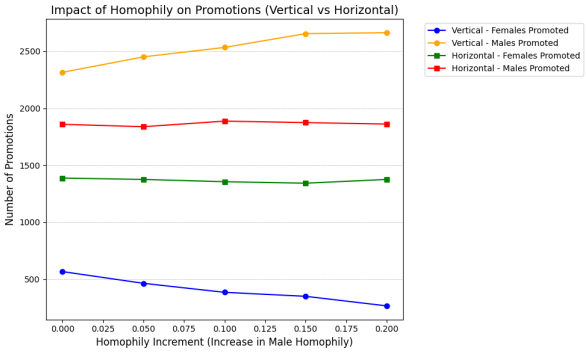

Figure 15: Homophily's Effect on Disparities

3.4 Effect of Departure Rates on Gender Representation

Figure 16 is a plot showing the effect of varying departure rates, which we held constant throughout our main analysis. While the magnitude of disparities changes, the consistent trend of reduced female representation at higher levels is consistent with our conclusions.

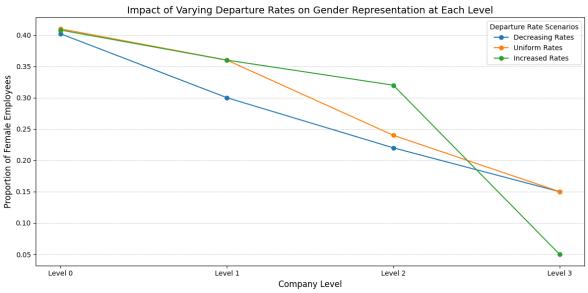

Figure 16: Impact of Varying Departure Rates on Gender Representation Across Levels

3.5 Inconclusive Rate Plots

The following four plots (Figures 17, 18, 19, and 20) are all attempts at plotting the rate of change in the male and female populations over time. Originally, we were hoping that these plots may show a trend in the rate of change getting faster or slower as the population became more male-dominated. However, the rate fluctuation was so intense, that it was quite useless to attempt to pull a trend. Thus, we attempted to use various filtering techniques, such as the Savitzky–Golay Filter or bins to help minimize the noise and find a trend. However, even with such strategies, the plots were inconclusive.

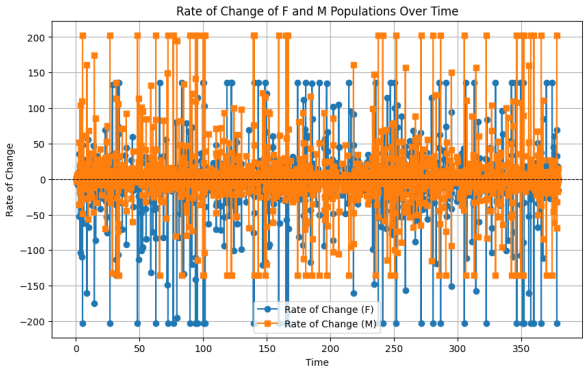

Figure 17: Messy Rate Plot

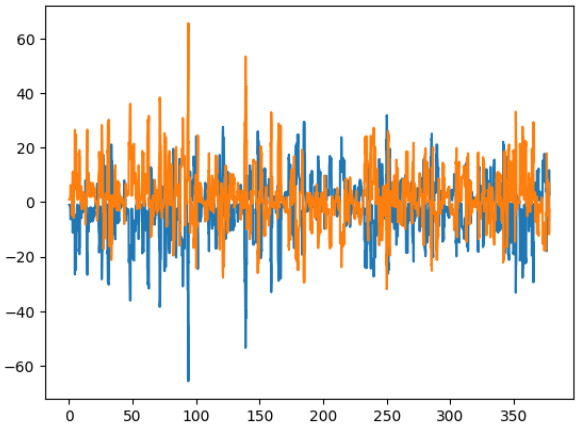

Figure 18: Less Messy Rate Plot

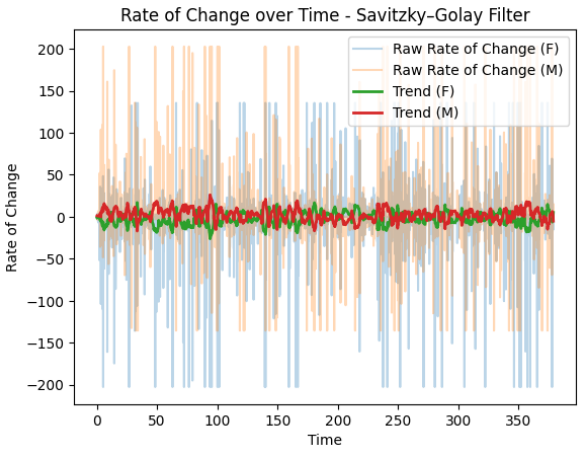

Figure 19: Savitzky–Golay Filter Rate Plot

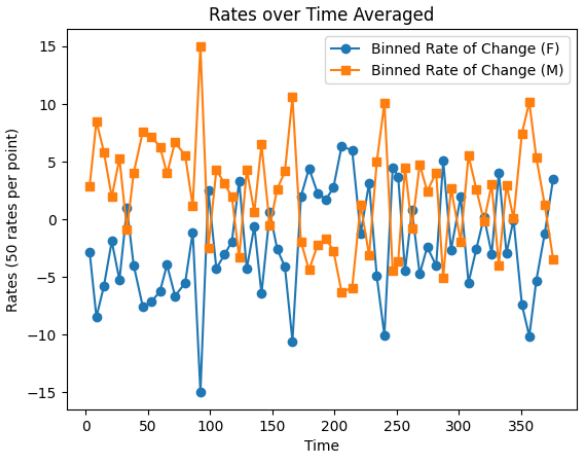

Figure 20: Binned Rate Plot