(Large-)team exclusion of women researchers under unequal gender ratio and homophily

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Question: Given a population (with an infinite size) of researchers exhibiting homophily with a specified gender ratio, we ask whether the expected proportion of male members in a team of a certain size differs from the global proportion of males, and how this difference varies with the parameters.

In other words, we aim to express it as a function of team size (T), gender ratio, and homophily. Formally, let the population consist of N_m males and N_f females, with corresponding proportions P_m and P_f. Assume that both males and females have the same tendency for homophily: each individual chooses to collaborate with a same-gender partner with probability s ($s > 0.5$ indicates homophily). The gender ratio is defined as $r = \frac{P_m}{P_f} = \frac{N_m}{N_f}$. We are then interested in computing

$$E\left(\frac{n_m}{T}\,\middle|\,T, r, s\right) - P_m,$$

where n_m denotes the number of male members in a team.

In the seed author model (I believe which is a **stronger** version of Guimera's team-assembly model[1], where the other members are seleted based on a random member among all existing members.), at each step we randomly select a seed author from the population, who is male with probability P_m and female with probability P_f. Next, based on the seed author's gender and the homophily parameter s, we determine the genders of the remaining $T - 1$ authors in the team: if a candidate has the same gender as the seed author, they are selected with probability $s \cdot \frac{1}{N}$; otherwise, with probability $(1 - s) \cdot \frac{1}{N}$.

Consequently, if the seed author is male, the expected number of males among the remaining

[1]Guimera, R., Uzzi, B., Spiro, J., & Amaral, L. A. N. (2005). Team assembly mechanisms determine collaboration network structure and team performance. Science, 308(5722), 697-702.

$T-1$ members is

$$(T-1) \times \frac{sN_m}{sN_m + (1-s)N_f}.$$

Including the male seed author, the expected proportion of males in a team seeded by a male author is

$$E_{mm} = \frac{1}{T}\left(1 + (T-1) \times \frac{sN_m}{sN_m + (1-s)N_f}\right).$$

Similarly, if the seed author is female, the expected number of males among the remaining $T-1$ members is

$$(T-1) \times \frac{(1-s)N_m}{(1-s)N_m + sN_f}.$$

Including the female seed author, the expected proportion of males in a team seeded by a female author is

$$E_{fm} = \frac{1}{T}\left(0 + (T-1) \times \frac{(1-s)N_m}{(1-s)N_m + sN_f}\right).$$

Therefore, in any given step, when randomly assembling a team of size T, the expected proportion of males is

$$E_m = P_m E_{mm} + P_f E_{fm}.$$

After some calculations, we arrive at the following final formula:

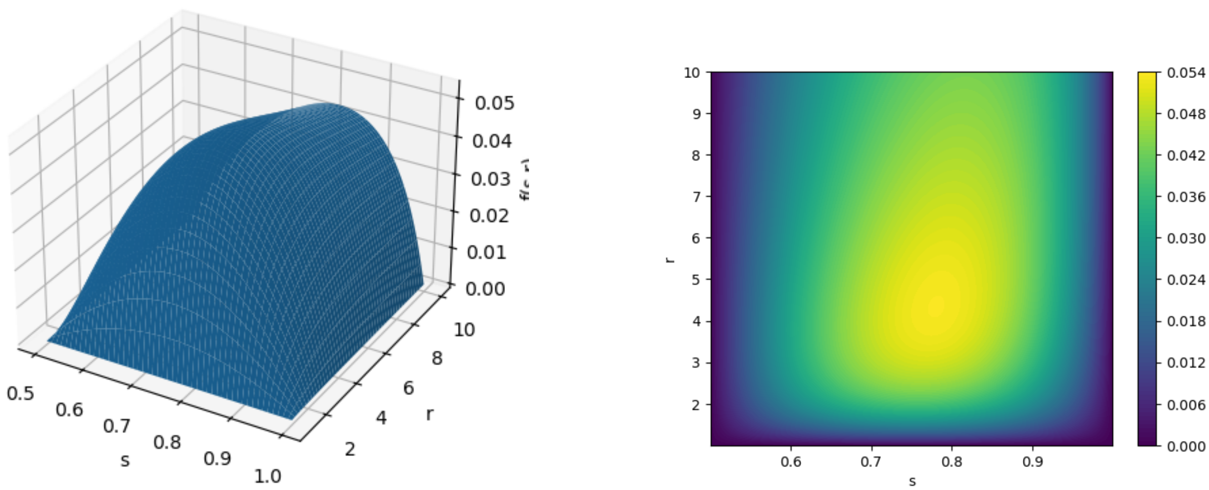
$$E_m - P_m = \frac{T-1}{T}\left(\frac{r\,(1-s)\,(2s-1)\,(r-1)}{(r+1)\,(sr+1-s)\,(r-sr+s)}\right).$$

From this expression, two observations can be immediately made:

1. This function is **always positive**. Under settings with homophily ($0.5 < s < 1$) and unequal gender ratio ($r > 1$), the numerator $r\,(1-s)\,(2s-1)\,(r-1)$ is strictly greater than zero. In other words, regardless of team size T (which is at least 2), as long as there is some degree of gender imbalance and homophily, male members are always more likely than female members to be selected into a team.

2. This function is **monotonically increasing with team size** T. That is, larger teams are more biased toward selecting male members compared to smaller teams.

As T only functions as a scaling factor, we could get rid of it and focus on the expression $(f(s, f))$ inside. As Figure 2 shows, gender disparity regarding be assembled into a team is most severely amplified in environments with moderate homophily.



(a) Surface plot of $f(s, r)$

(b) Contour plot of $f(s, r)$

Figure 1: Visualization of the function $f(s, r)$ showing (a) the 3D surface and (b) the contour representation.

Next, considering studies showing that homophily strength differs by gender, i.e., women researchers exhibit lower homophily than men[2], I allow for different homophily parameters, s_1 for men and s_2 for women. In this case, we have

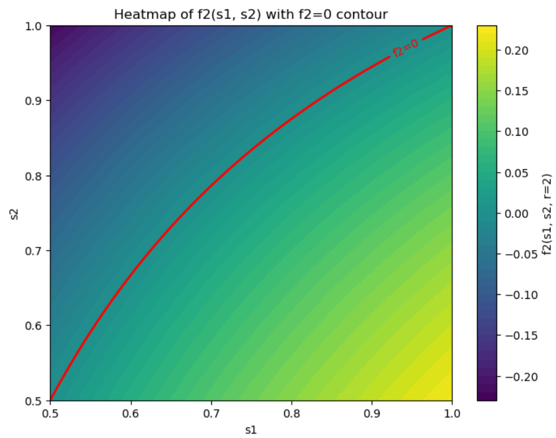
$$E_m - P_m = \frac{T-1}{T} \left(\frac{r(1-s_2)}{(r+1)(r-rs_2)+s_2} + \frac{r(s_1-1)}{(r+1)(rs_1-s_1+1)} \right)$$

In fact, the partial derivatives with respect to s_1 and s_2 are consistently positive and negative, respectively. This implies that when men exhibit stronger homophily and women weaker homophily, teams (especially larger ones) become increasingly likely to recruit male researchers. This is intuitive, since homophily only affects how the seed author selects the remaining members; given a certain gender, the optimal strategy under homophily is always to choose collaborators of the same gender.

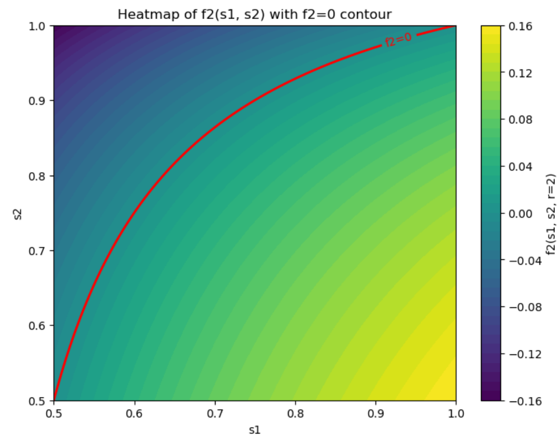
[2] Torre, M., Prieto-Alonso, J. A., & Ucar, I. (2025). The uneven effects of gender parity: Trends in gender homophily in scientific publications, 1980–2019. Social Science Research, 132, 103228.

We are however more concerned with the conditions under which gender disparity can disappear. The contour plot of $f(s_1, s_2, r)$ shows that (when $r = 2/4$), achieving balance requires women to display slightly stronger homophily than men, in other words, they would need to be more inclined to seek out female collaborators. However, as Torre et al. document, women are generally more willing than men to engage in cross-gender collaboration. Our results thus suggest that this tendency may unintentionally marginalize women's positions in collaboration networks.

Also, we notice that when r rises, women researhcers need to display a higher level of homophily to achieve gender balance.



(a) $r = 2$



(b) $r = 4$

Figure 2: Contour plots of the function $f(s_1, s_2)$ when $r = 2$ (a) or 4 (b)