Modeling the leaky pipeline in hierarchical professions

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Women are 46% of the workforce, but their representation falls in more senior positions.

- Managers, directors, and senior officials: 33%
- Professional, associate professional, and technical jobs: 47%
- All other occupations: 54%
Many industries are structured hierarchically

- business
- medicine
- law
- politics
- academia
- education
- journalism
- entertainment

![Graph showing the fraction of women in academic clinical medicine over time.](image-url)
An insidious reason women are less likely to get a STEM doctoral degree than men

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Working Women Often Underestimate Motherhood Costs

Why leaving the workforce after having kids is an unexpected, reluctant choice for some

The Stubborn Culture of Harassment in America’s Medical Schools

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The Price All Women Pay For Gender Bias
An insidious reason women are less likely to get a STEM doctoral degree than men

How Stereotypes Can Drive Women To Quit Science

Why Do Women Bully Each Other at Work?

Research suggests that conditions in the workplace might be to blame.
“Leaky Pipeline” Model

Shaw & Stanton (2012)
“Time to Parity” Model
Holman et al. (2018)

Fraction of women
Is gender parity inevitable?
Build a minimal model

Fact 1
People self-segregate (called “homophily”)
Build a minimal model

Fact 2
Bias by hiring committees exists
Build a minimal model

Both **bias** and **homophily** impact the ascension of people through professional hierarchies.
group eligible for promotion (40% women)

probability that man applies for promotion: 50%
promotion (25% women)
promotion: 25%

HOMOPHILY probability that man is promoted: 67%
probability that woman is promoted: 50%

BIAS
HOMOPHILY

- probability that man applies for promotion: 50%
- probability that woman applies for promotion: 25%

group eligible for promotion (40% women)
HOMOPHILY

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probability that woman is promoted: 50% \\
\}

group applying for promotion (25% women)

HOMOPHILY
\{ probability that man applies for promotion: 50% \\
probability that woman applies for promotion: 25% \\
\}

group granted a promotion (20% women)
Model behavior: no bias and no homophily.
Model behavior: no bias and no homophily
Model behavior: effect of bias
Model behavior: effect of bias
Model behavior: effect of homophily
Model behavior: effect of homophily
Model behavior: effect of homophily
Model behavior: effect of homophily
Model behavior: effect of homophily
What does the model say about the real world?
Data

- Academic Psychology
- Academic Math & Statistics
- Academic Computer Science
- Academic Engineering
- Academic Chemistry
- Academic Physics
- Academic Biology
- Academic Physical Sciences
- Academic Clinical Medicine
- Academic Scientific Medicine
- Academic English
- Academic Languages
- Engineering Practice
- Journalism Practice
- Medical Practice
- Nursing Practice
- Law Practice
- K-12 Education
- Politics
- Business
- Film
- Orchestras
Data

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• Academic Biology
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• Academic Clinical Medicine
• Academic Scientific Medicine
• Academic English

• Academic Languages
• Engineering Practice
• Journalism Practice
• Medical Practice
• Nursing Practice
• Law Practice
• K-12 Education
• Politics
• Business
• Film
• Orchestras
Academic
Clinical Medicine

Academic
Psychology

(a) [Graph showing the fraction of women in various academic roles over time for Clinical Medicine.]

(b) [Graph showing the fraction of women in various academic roles over time for Psychology.]
bias against women
bias against women

preference for women

average long-term x (top level)

bias b

homophily λ
Intervention: none needed
Intervention: target hiring committees
Intervention: target hiring committees
Intervention: target potential applicants
Future steps

allow bias and homophily to vary

bias

time
Future steps

- allow bias and homophily to vary
- incorporate gender differences
Future steps

- Allow bias and homophily to vary
- Incorporate gender differences
- Integrate spectrum of identities
Future steps

- allow bias and homophily to vary
- incorporate gender differences
- integrate spectrum of identities
- extend to race/ethnicity
Racial bias and homophily

Laurie Balstad
St. Olaf College
Racial bias and homophily

Hierarchy: Academic medicine in US universities
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Avi Karamchandani
(U. Arizona)
Supplemental
### Modeling bias and homophily

#### Bias

**Definition:** the fraction of those promoted who are women if the applicant pool is evenly split by gender

<table>
<thead>
<tr>
<th>Applied</th>
<th>Promoted</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Applied" /></td>
<td><img src="image2" alt="Promoted" /></td>
</tr>
</tbody>
</table>

Bias = 2/5

#### Homophily

**Definition:** the sensitivity of potential applicants to demographic deviations from their current position

\[
P(x_{i+1}, x_i) = \frac{1}{1 + e^{-\lambda(x_{i+1} - x_i)}}
\]

- fraction women in current level \(x_i\)
- fraction women in higher level \(x_{i+1}\)
- likelihood of seeking promotion \(P\)
\[
\frac{1}{R_L} \frac{dx_L}{dt} = f(x_L, x_{L-1}; b) - \underbrace{\frac{x_L}{R_L}} \quad \text{promoted from lower layer}
\]
\[
\frac{1}{R_j} \frac{dx_j}{dt} = (1 + r_j) f(x_j, x_{j-1}; b) - x_j - r_j f(x_{j+1}, x_j; b) \quad \text{retire out of layer}
\]
\[
\frac{1}{R_1} \frac{dx_1}{dt} = (1 + r_1) f(x_1, \frac{1}{2}; b) - x_1 - r_1 f(x_2, x_1; b) \quad \text{hired from general pool}
\]

\[
f(u, v; b) = \frac{b v P(u)}{b v P(u) + (1 - b)(1 - v) P(1 - u)}
\]
\[
P(u, v) = \frac{1}{1 + e^{-\lambda(u-v)}}
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>(x_j)</td>
<td>fraction of women in the (j)th level</td>
</tr>
<tr>
<td>(L)</td>
<td>number of levels in hierarchy</td>
</tr>
<tr>
<td>(R_j)</td>
<td>retirement/leave rate at the (j)th level</td>
</tr>
<tr>
<td>(N_j)</td>
<td>number of people in the (j)th level</td>
</tr>
<tr>
<td>(r_j)</td>
<td>ratio of the total retiring people above the (j)th level to the retiring people in the (j)th level (\left(\sum_{k=j+1}^{L} R_k N_k / R_j N_j\right))</td>
</tr>
<tr>
<td>(P(\cdot))</td>
<td>likelihood of seeking promotion</td>
</tr>
<tr>
<td>(f(\cdot))</td>
<td>fraction of people promoted to next level who are women</td>
</tr>
<tr>
<td>(b)</td>
<td>bias towards or against women ((b = 1/2) is no bias)</td>
</tr>
<tr>
<td>(\lambda)</td>
<td>strength of homophilic tendency</td>
</tr>
</tbody>
</table>
Model behavior: both bias and homophily