

MS137: Modeling Female and Minority Representation in Society

Organizers

Kaitlin Hill, U. of Minnesota,
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Speakers

Sara M. Clifton, U. of Illinois

Luís Amaral, Northwestern U.

S. John Hogan, U. of Bristol

Daniel P. Maes, U. of Michigan

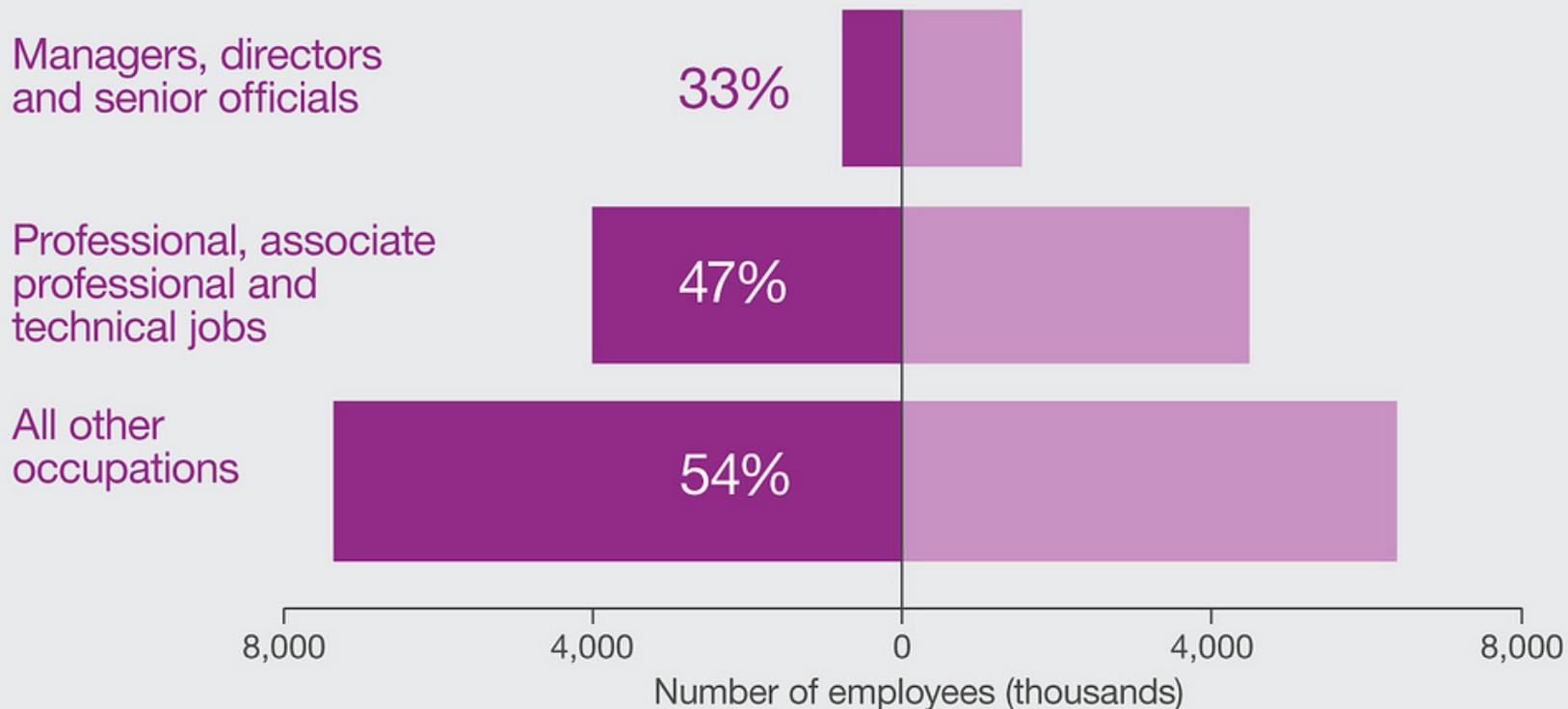


Mathematical model of gender bias and homophily in professional hierarchies

Sara M. Clifton
University of Illinois
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May 22, 2019

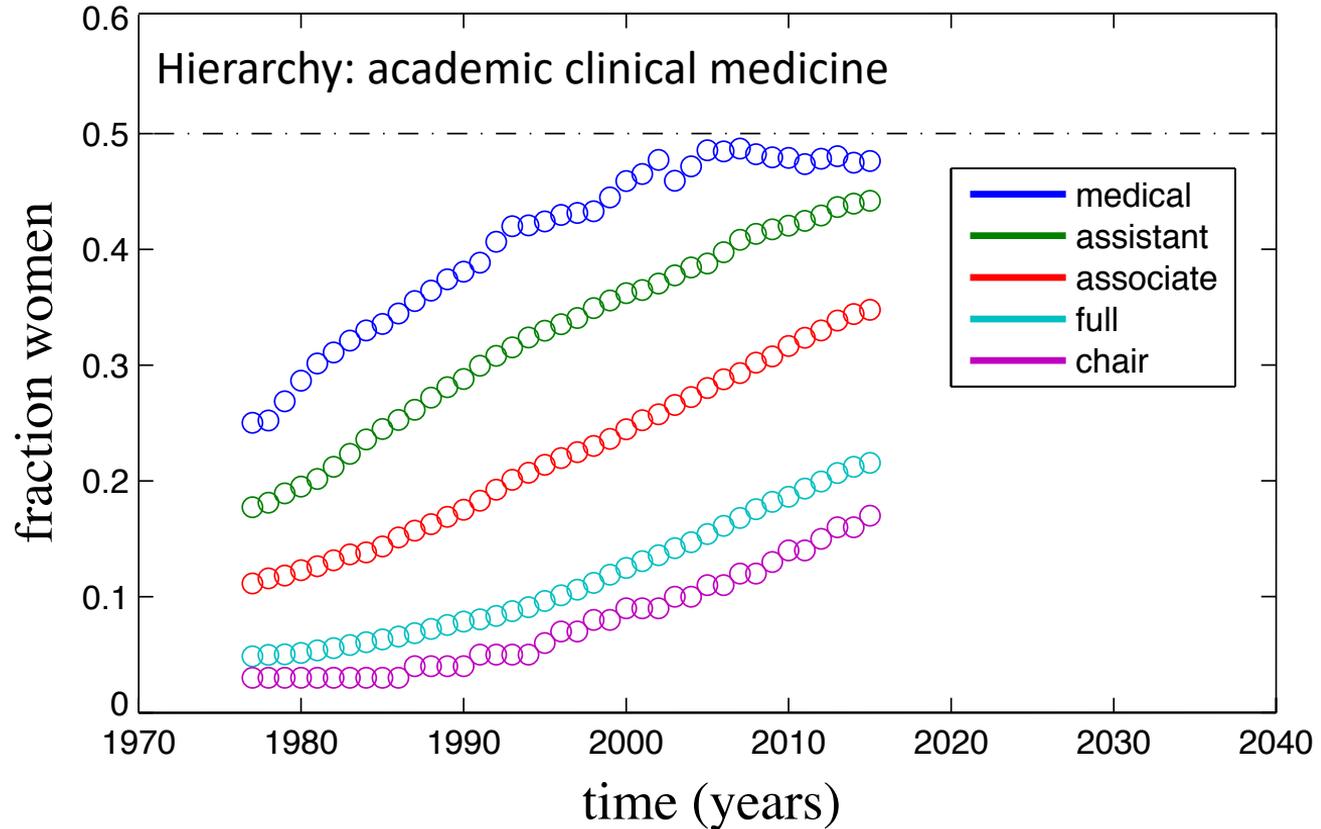
Women are 46% of the workforce, but their representation falls in more senior positions

Women Men



Many industries are structured hierarchically

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



Build a minimal model

Fact 1

People self-segregate
(called “**homophily**”)



Build a minimal model

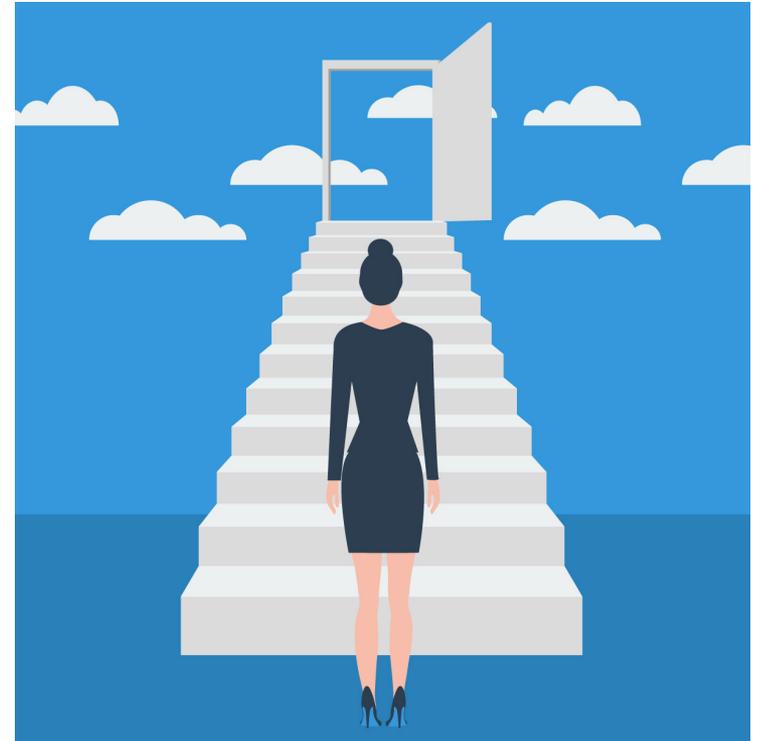
Fact 2

Bias by hiring committees exists

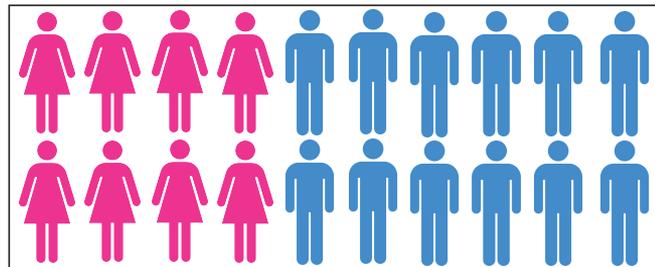


Build a minimal model

Both **bias** and **homophily** impact the ascension of people through professional hierarchies



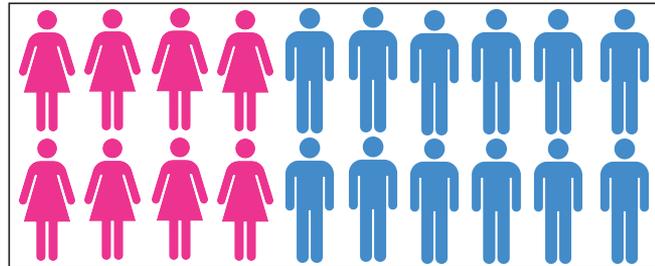
group eligible
for promotion
(40% women)

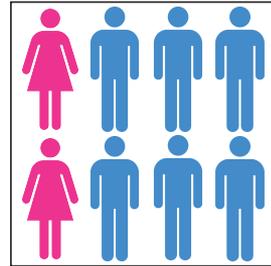




HOMOPHILY { probability that man applies for promotion: 50%
probability that woman applies for promotion: 25%

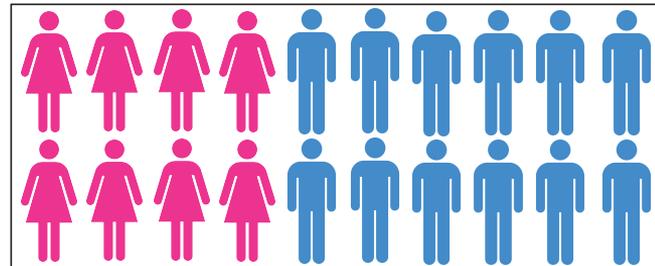
group eligible
for promotion
(40% women)





group applying for promotion (25% women)

HOMOPHILY { probability that man applies for promotion: 50%
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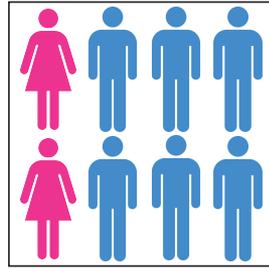
group eligible for promotion (40% women)





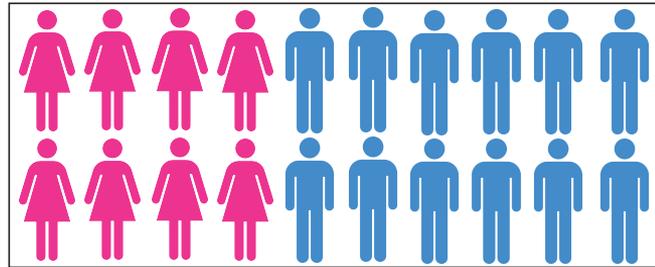
BIAS { probability that man is promoted: 67%
probability that woman is promoted: 50%

group applying for promotion (25% women)

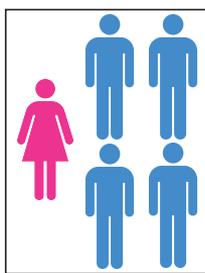


HOMOPHILY { probability that man applies for promotion: 50%
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group eligible for promotion (40% women)

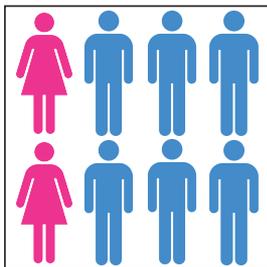


group granted a promotion
(20% women)



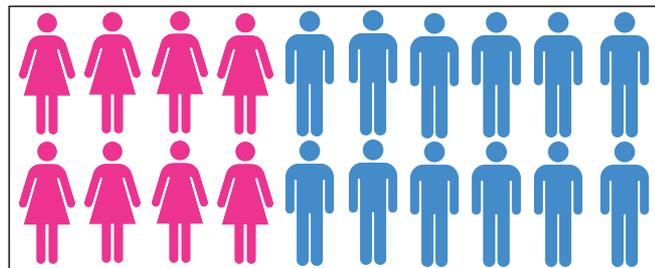
BIAS { probability that man is promoted: 67%
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group applying for
promotion (25% women)

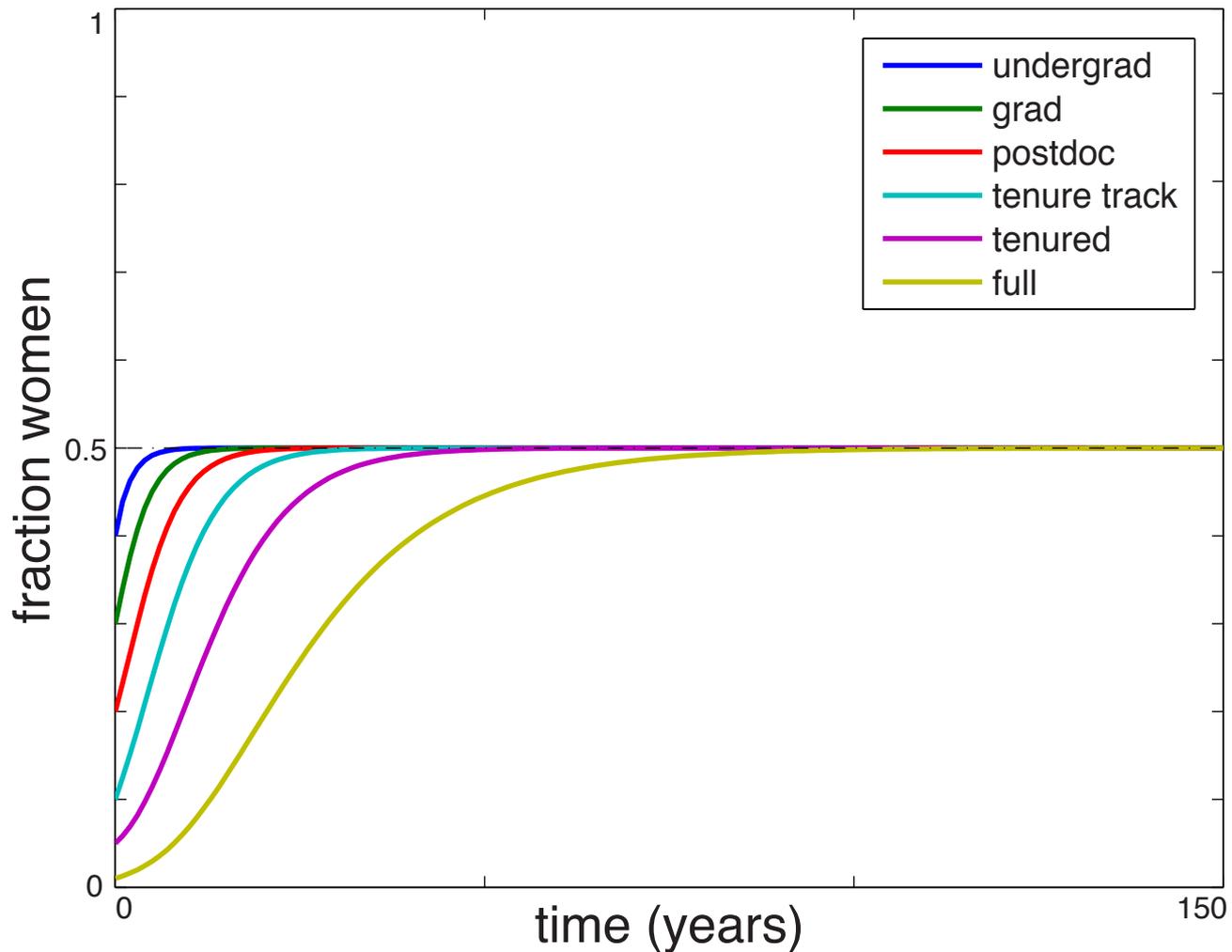


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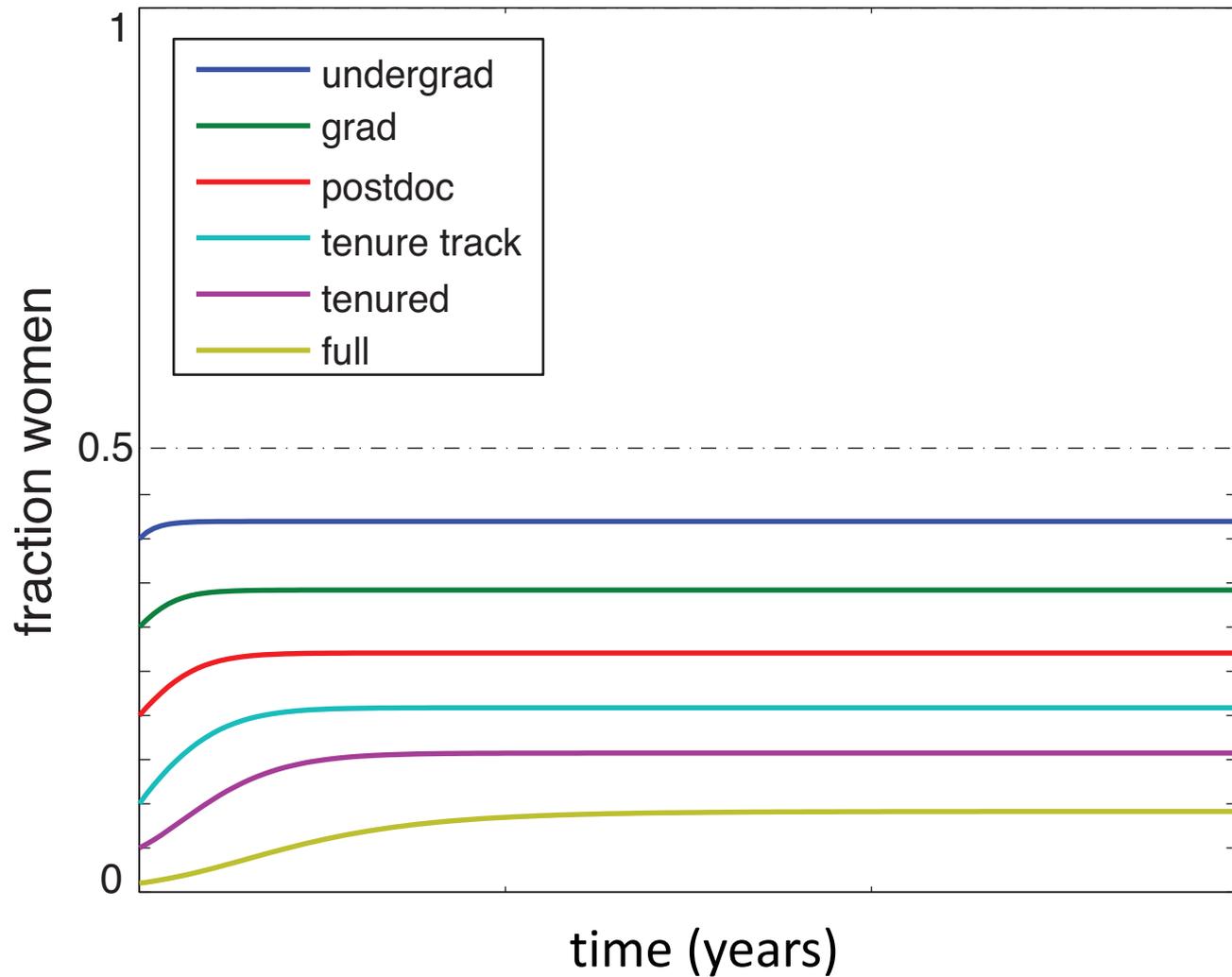
group eligible
for promotion
(40% women)



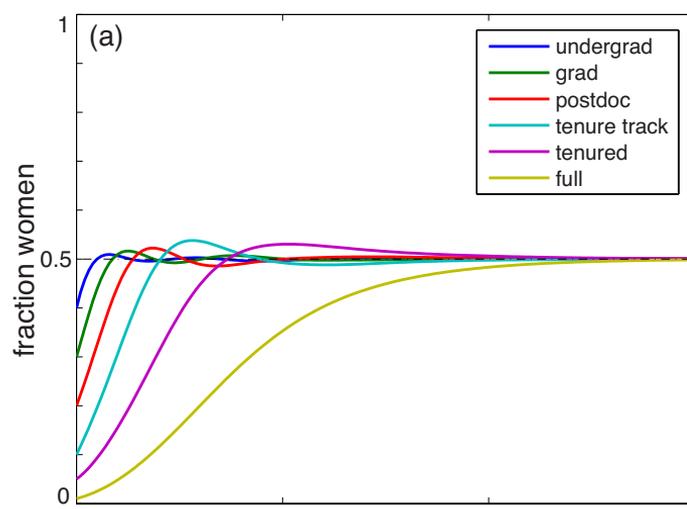
**Model
behavior:**
no bias and
no homophily



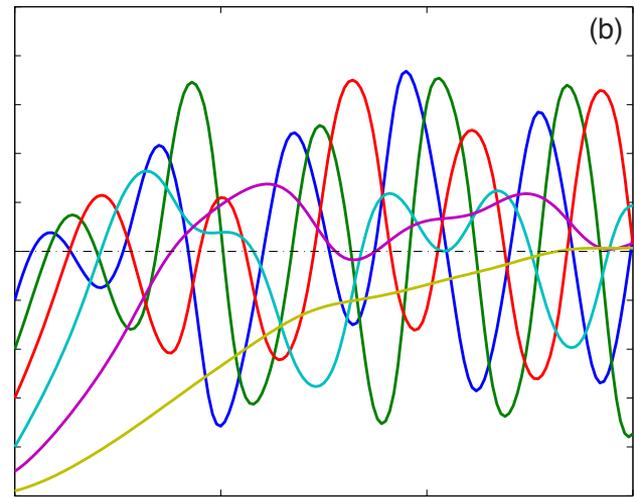
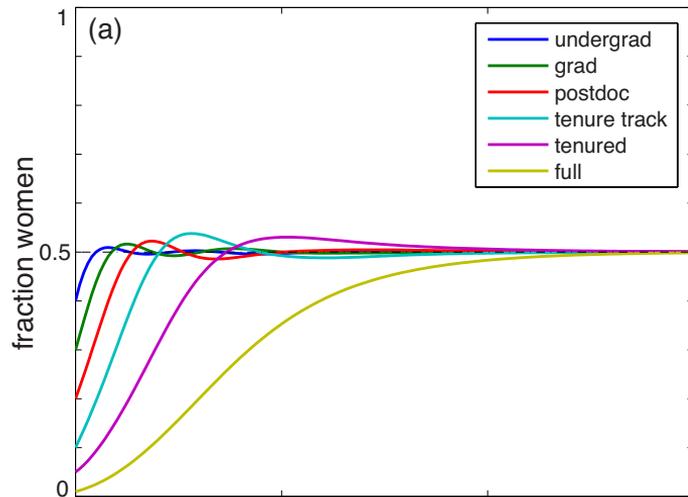
Model behavior: effect of bias



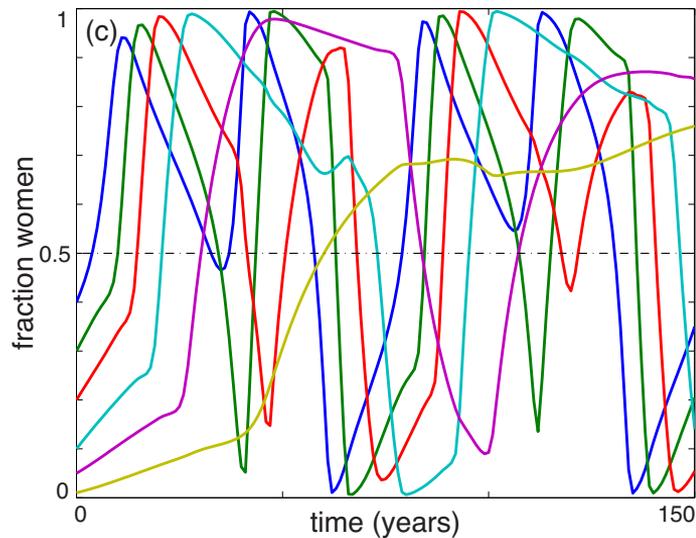
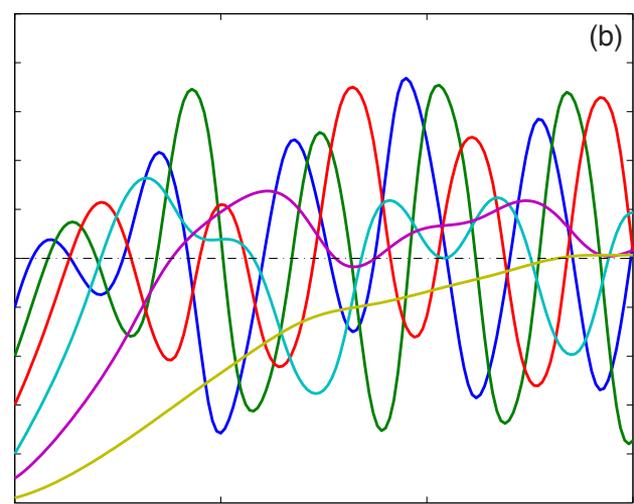
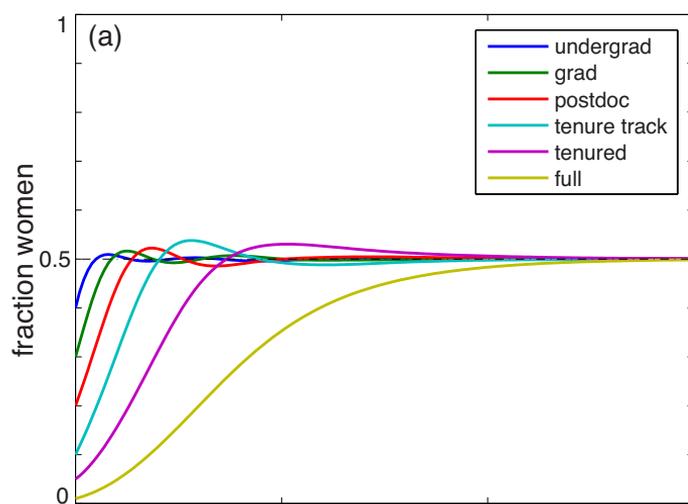
Model behavior: effect of homophily



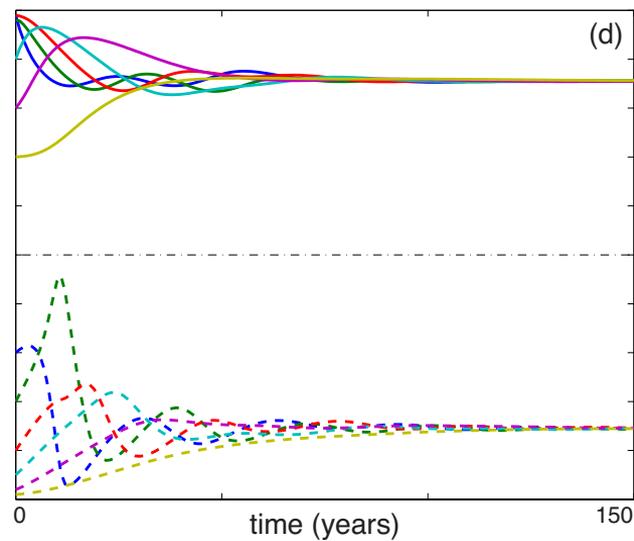
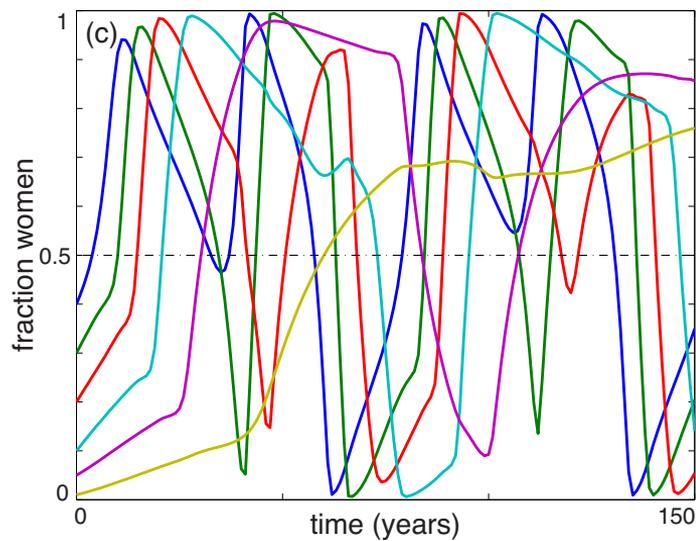
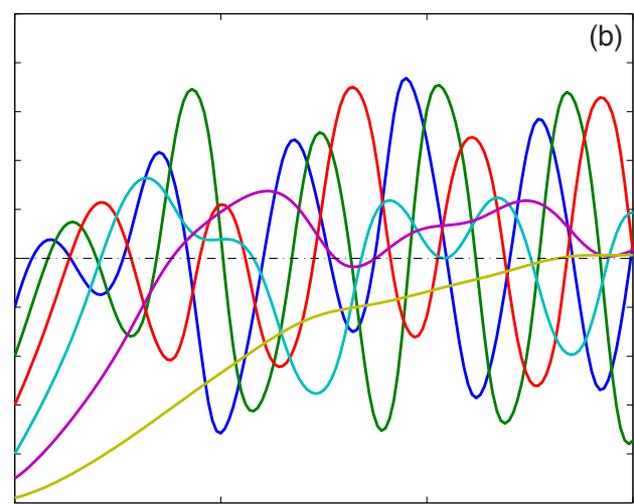
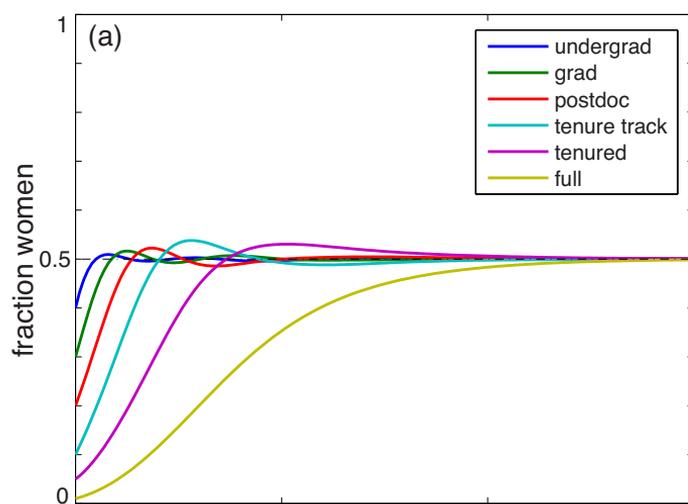
Model behavior: effect of homophily



Model behavior: effect of homophily

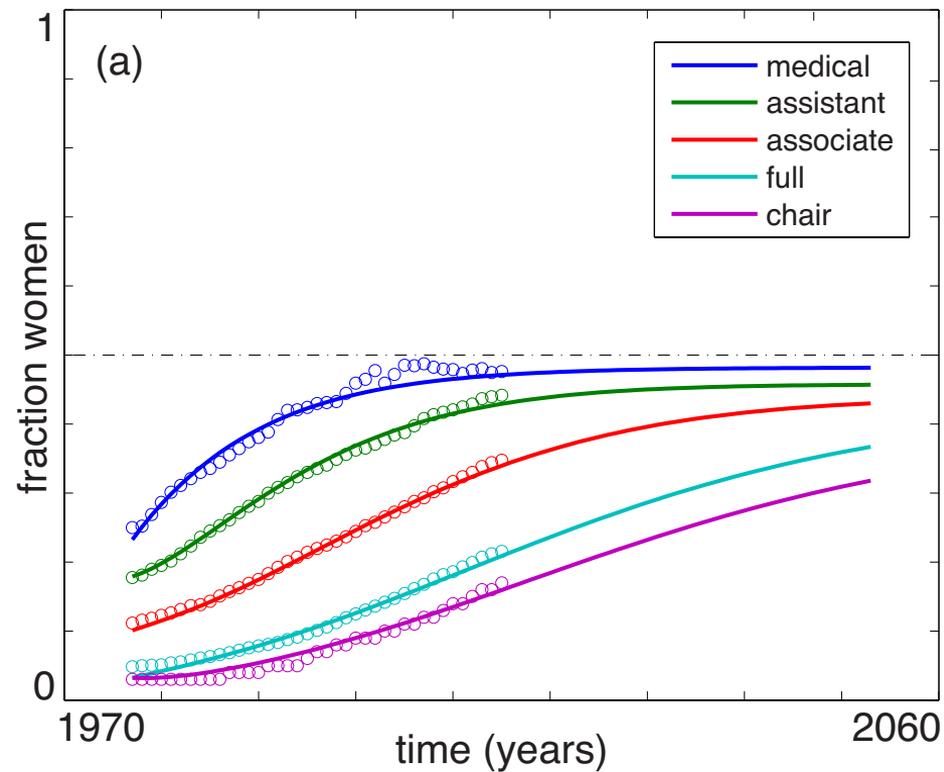


Model behavior: effect of homophily

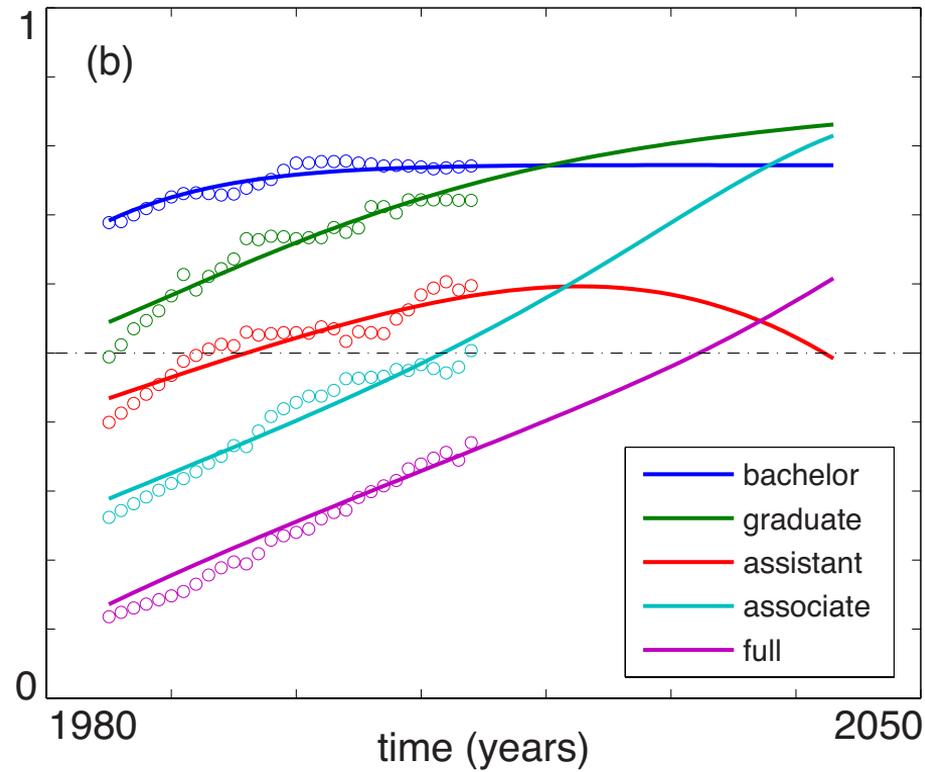


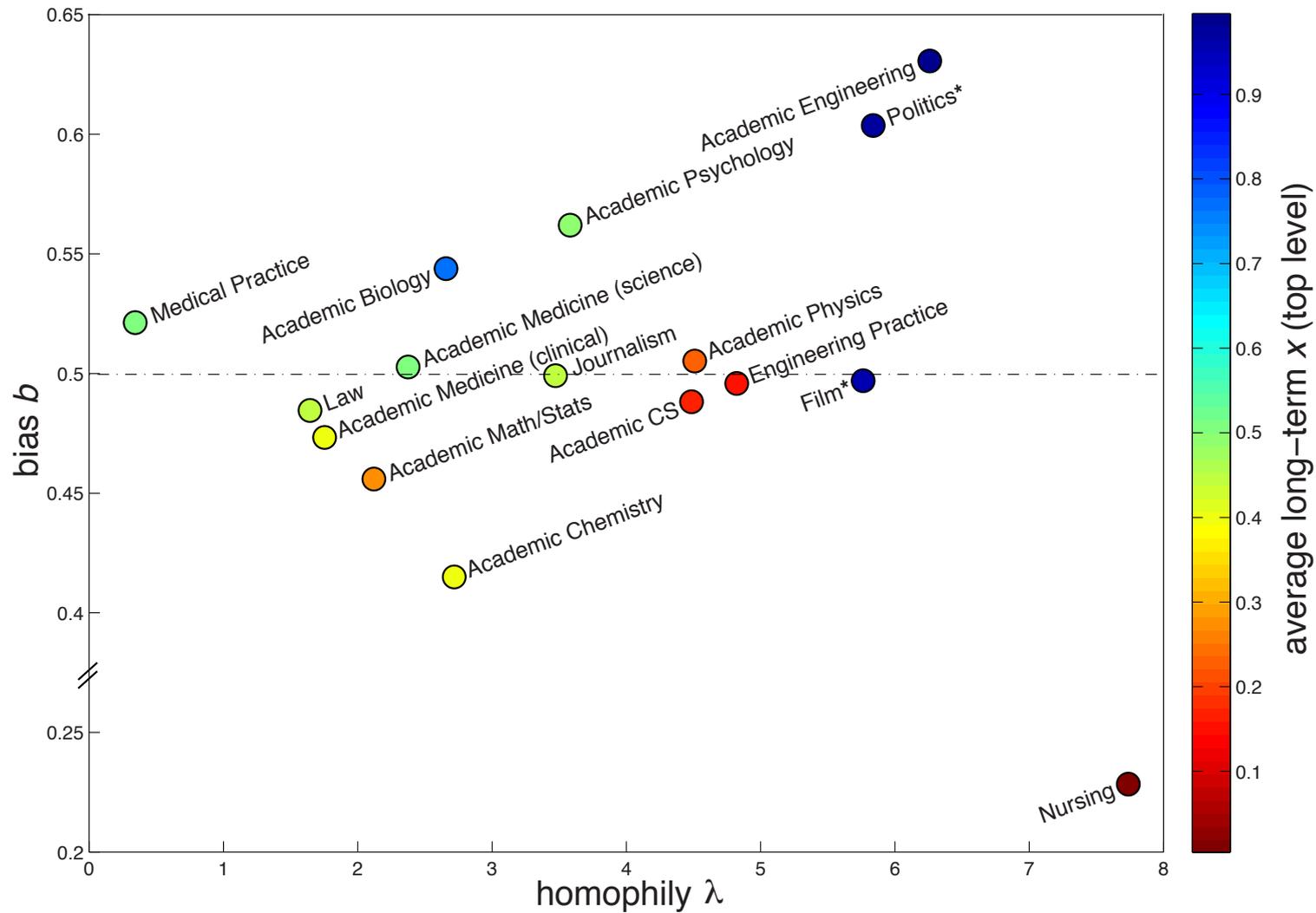
What does the model
say about the real world?

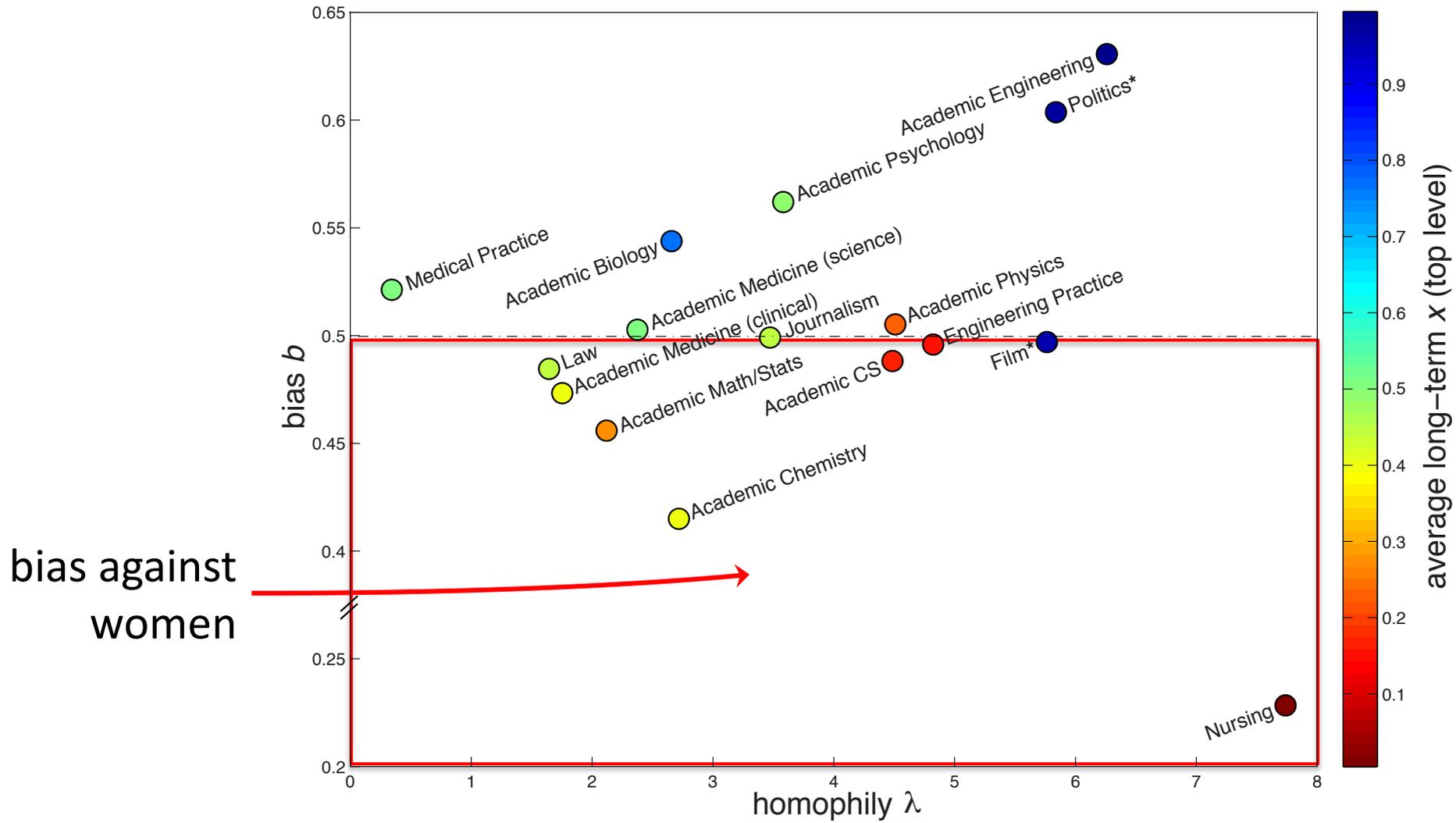
Academic Clinical Medicine

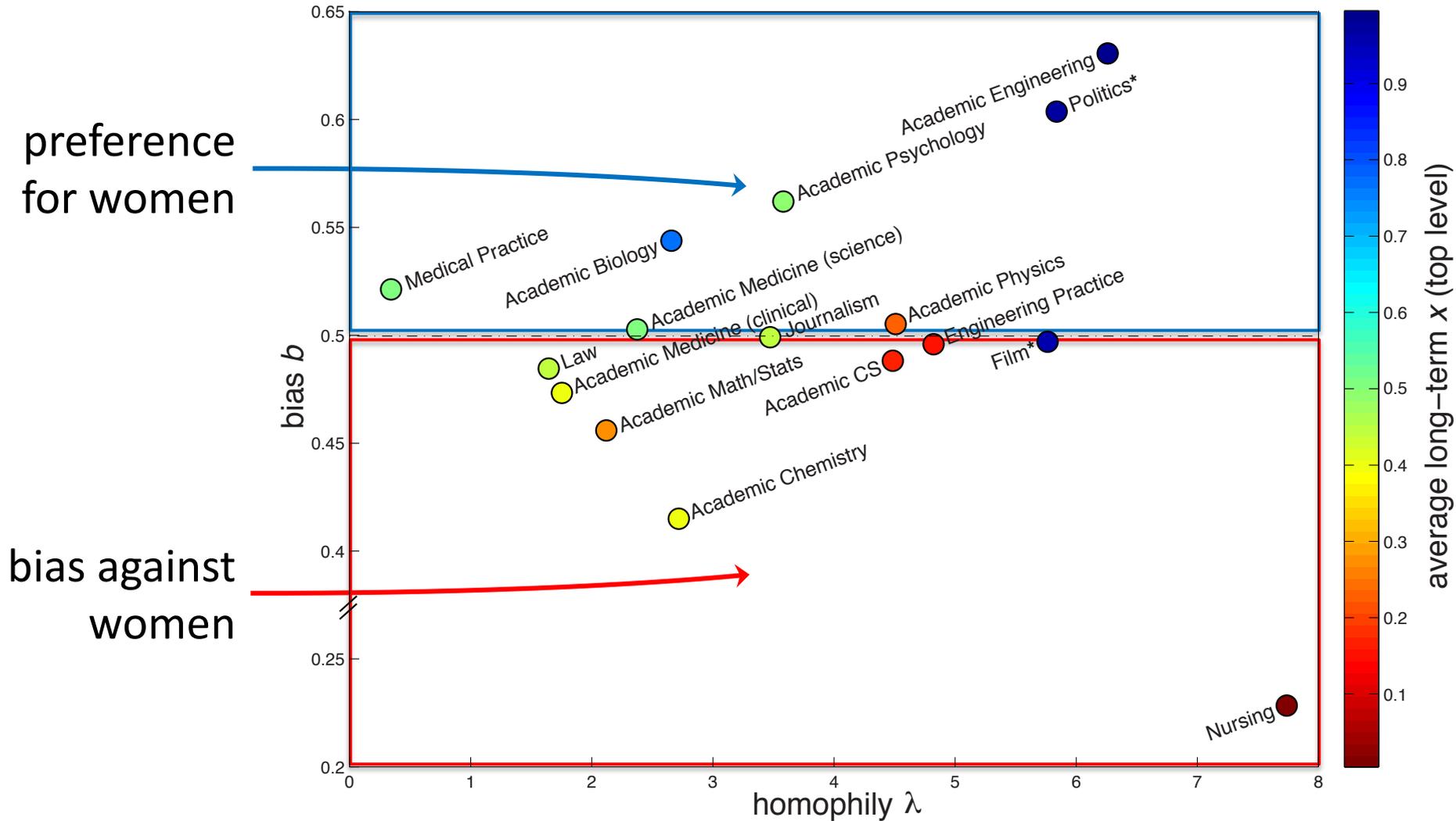


Academic Psychology

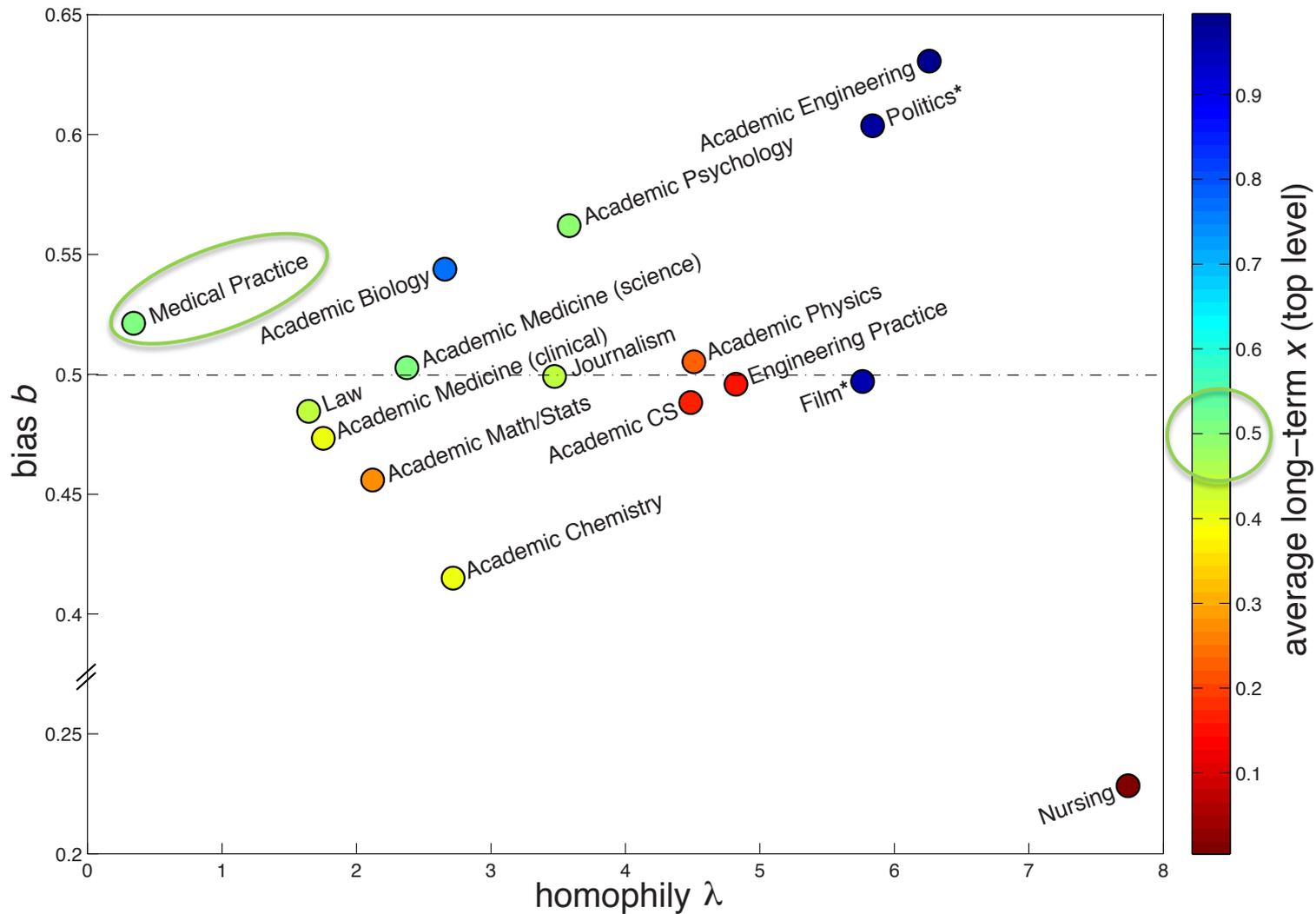




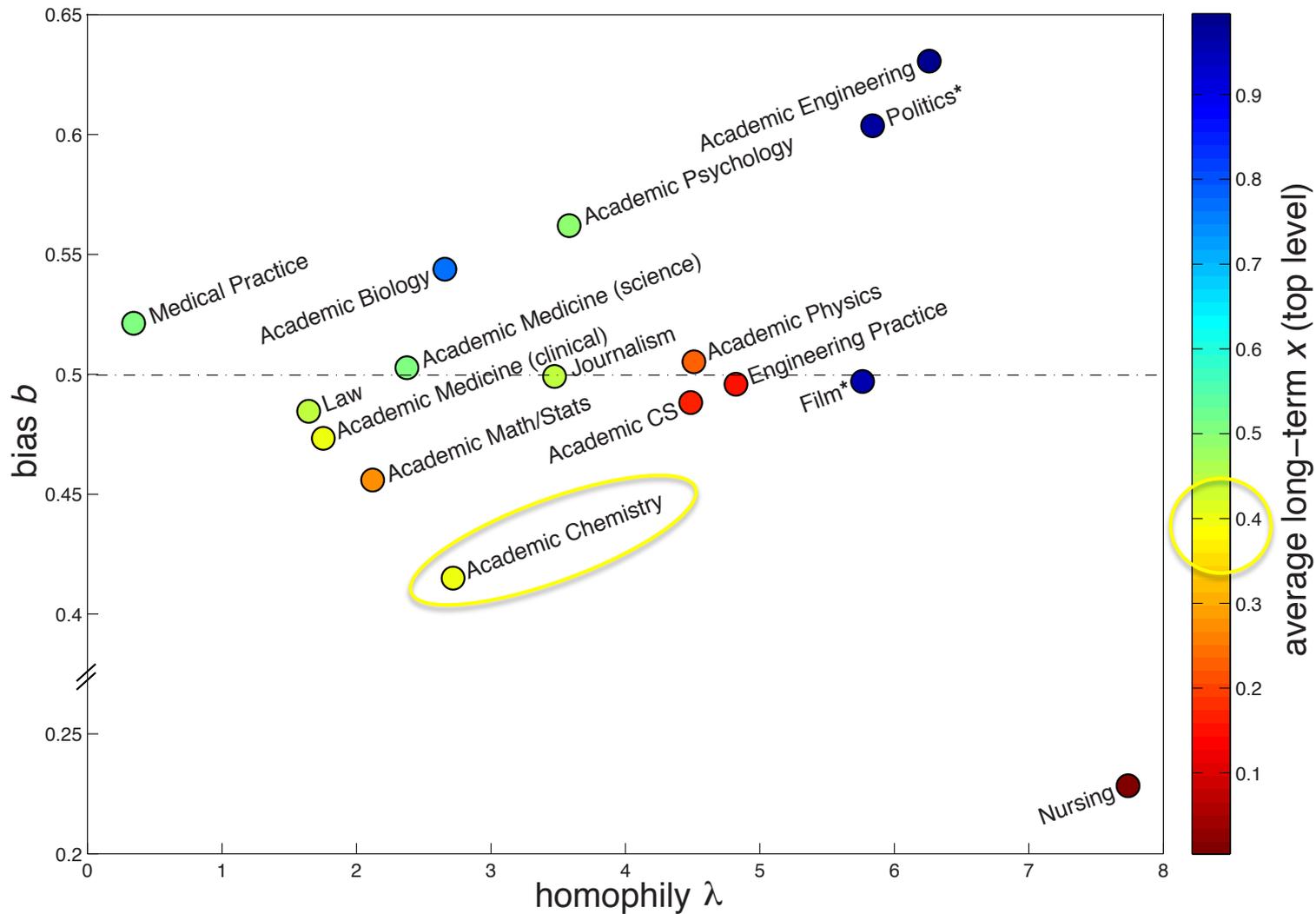




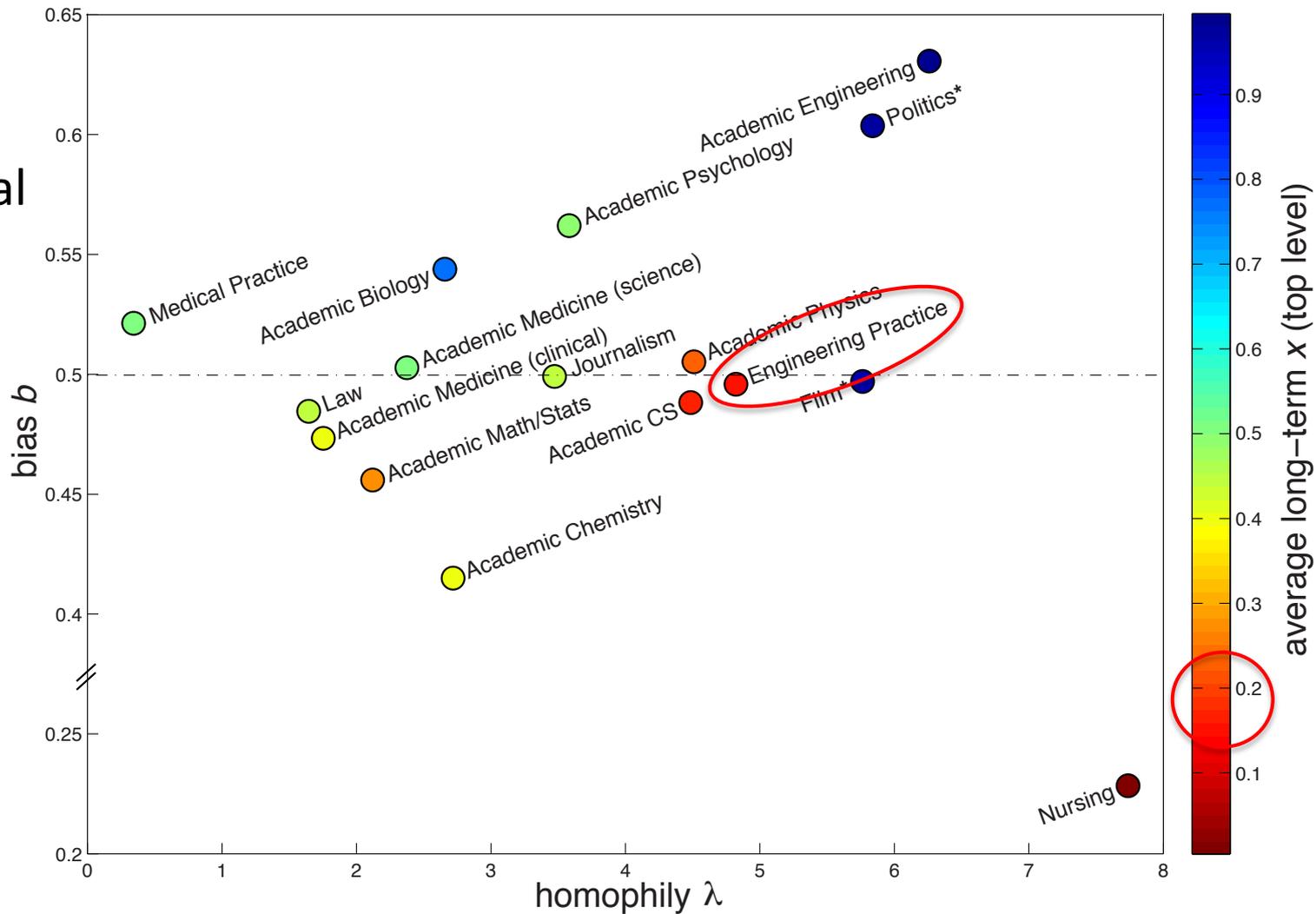
Intervention:
none needed



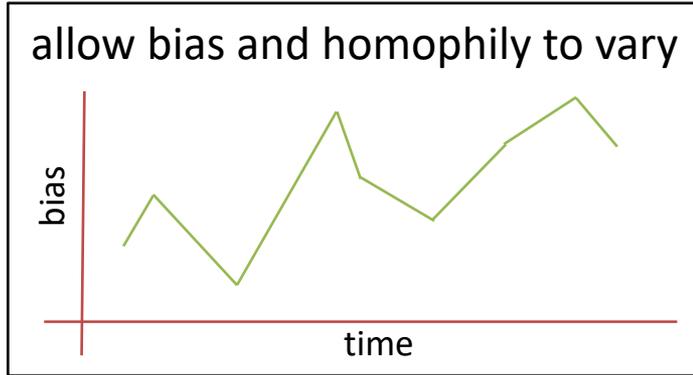
Intervention:
target hiring
committees



Intervention:
target potential
applicants



Future steps

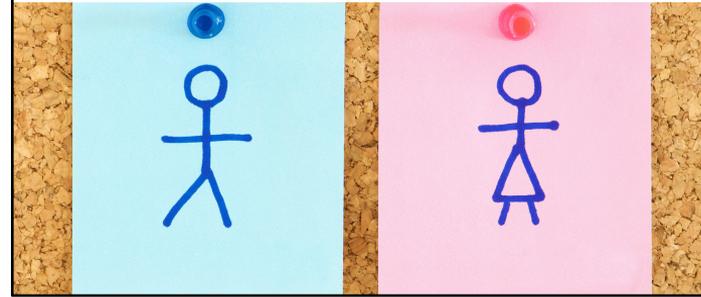


Future steps

allow bias and homophily to vary



incorporate gender differences

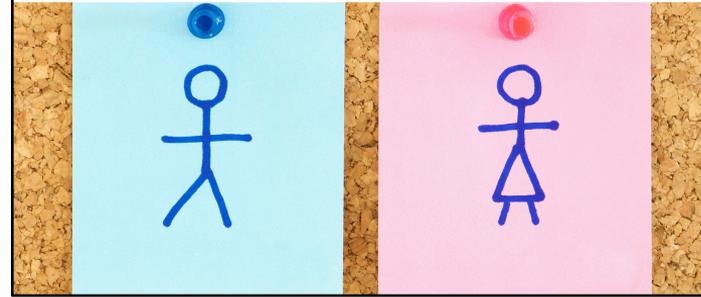


Future steps

allow bias and homophily to vary



incorporate gender differences



build in interventions

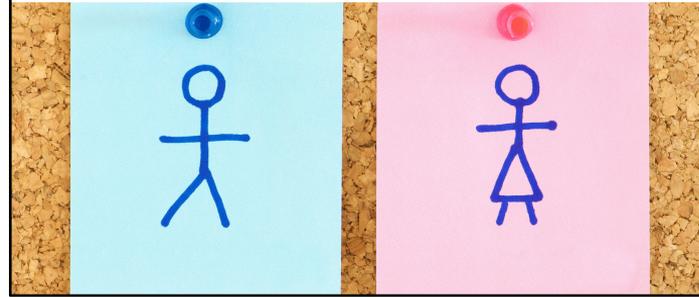


Future steps

allow bias and homophily to vary



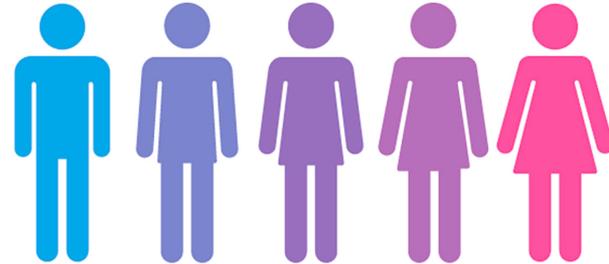
incorporate gender differences



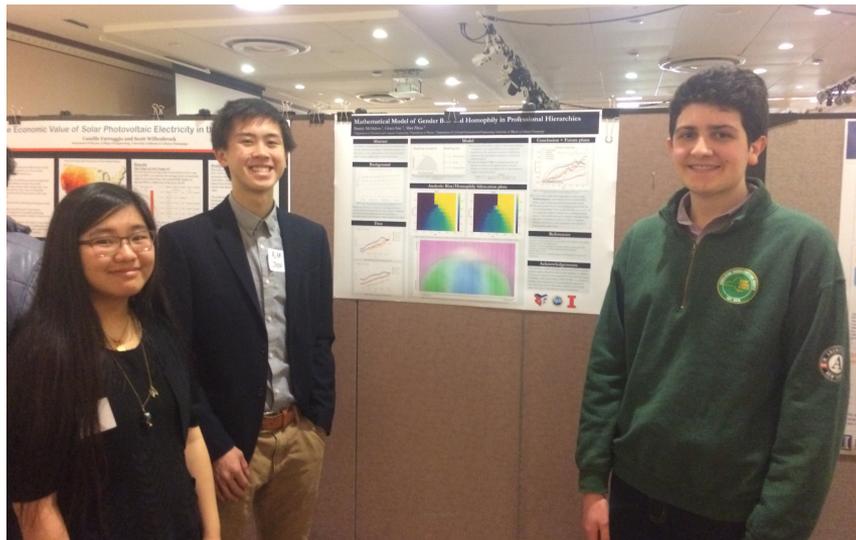
build in interventions



integrate spectrum of identities



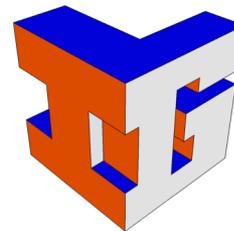
Thanks



Undergraduate researchers Grace Sun, Alan Zhou, and Patrick McMahon



Mathways grant
DMS 1449269



Illinois
Geometry Lab



Institute for the
Quantitative Study of
Inclusion, Diversity,
and Equity



Eric Autry
(Duke)



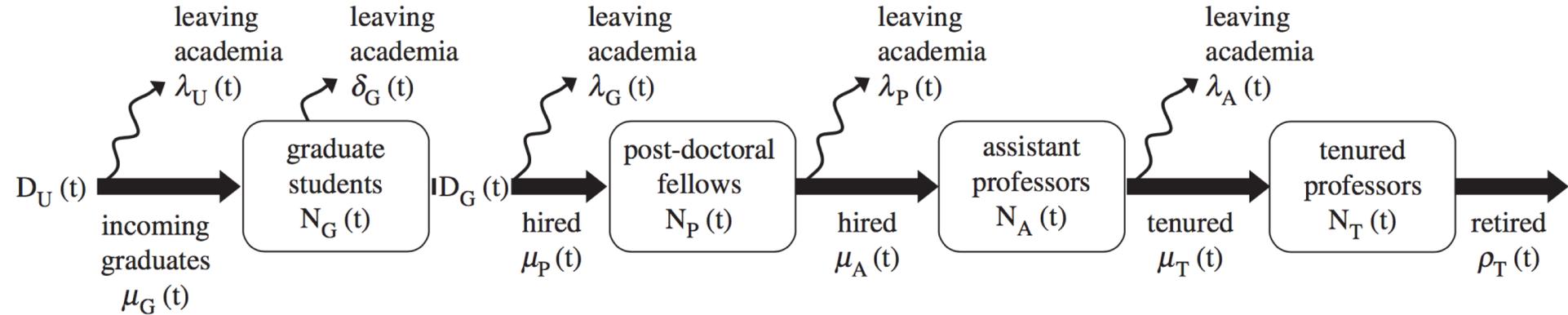
Kaitlin Hill
(U. Minnesota)

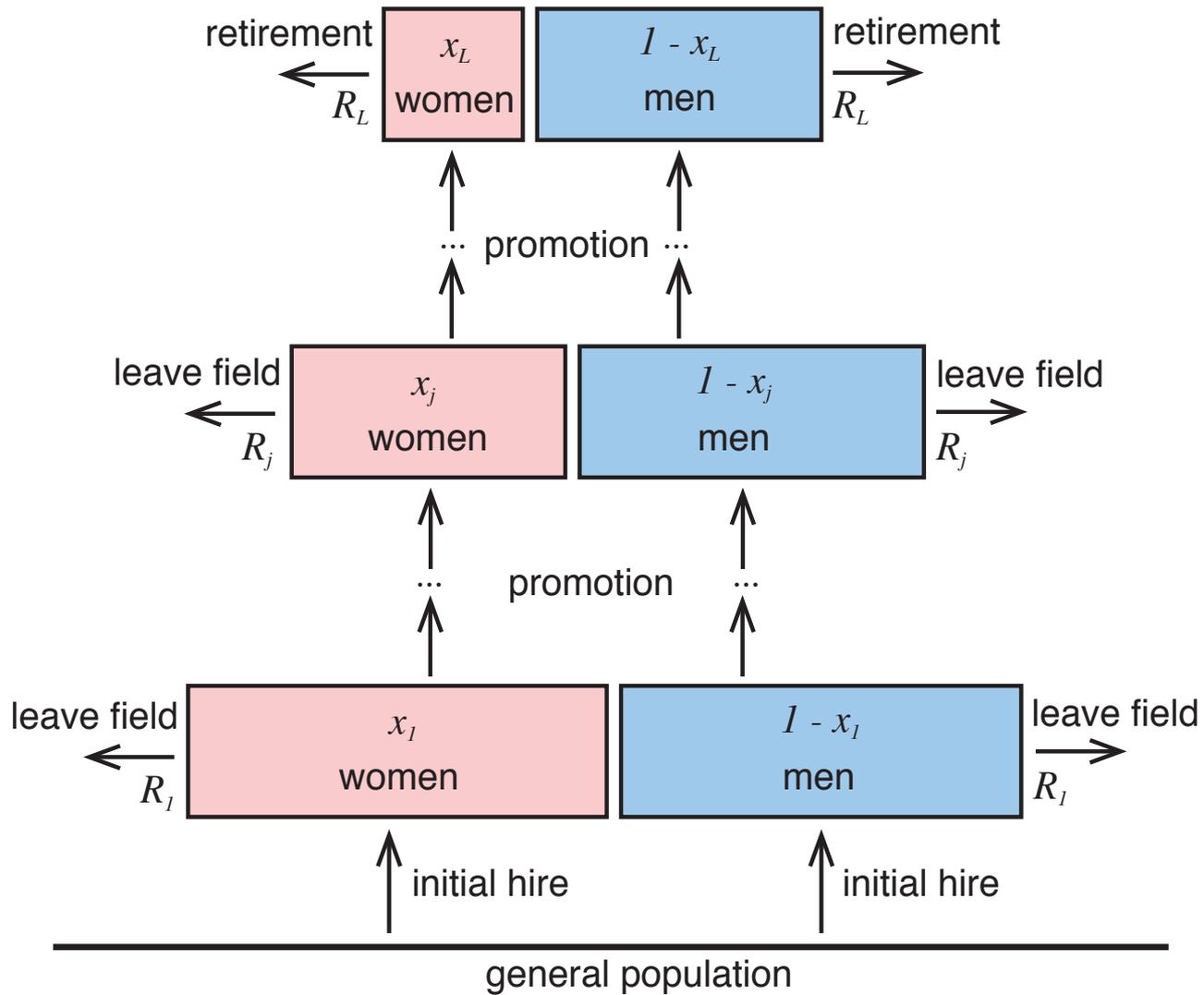


Avi Karamchandani
(Northwestern)

Supplemental

“Leaky Pipeline” Model

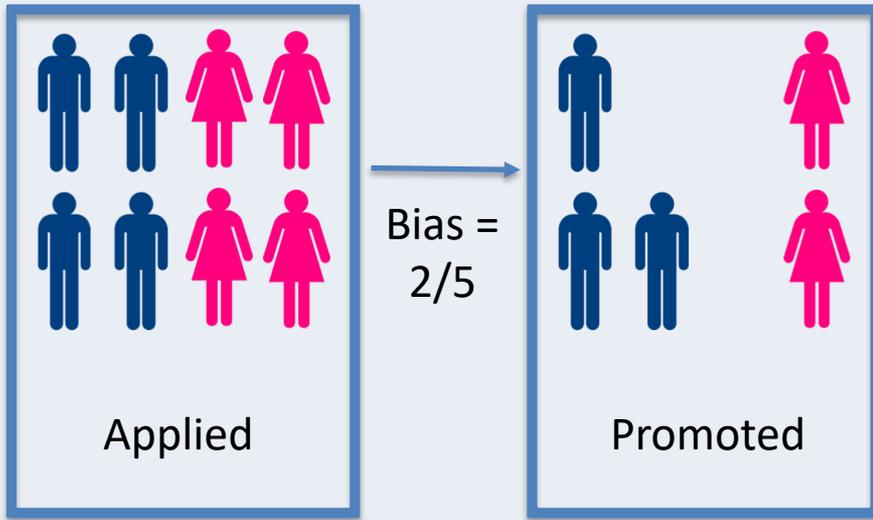




Modeling bias and homophily

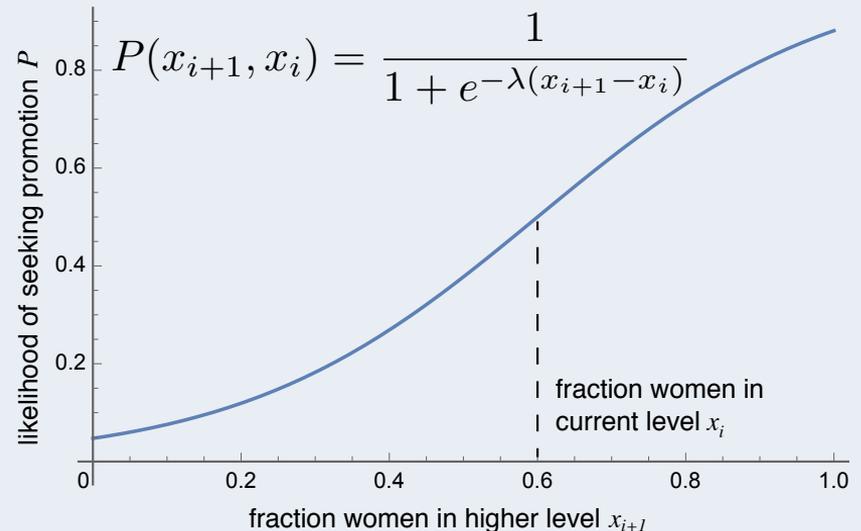
Bias

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



Homophily

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



$$\frac{1}{R_L} \frac{dx_L}{dt} = \overbrace{f(x_L, x_{L-1}; b)}^{\text{promoted from lower layer}} - \underbrace{x_L}_{\text{retire out of layer}}$$

$$f(u, v; b) = \frac{bvP(u)}{bvP(u) + (1-b)(1-v)P(1-u)}$$

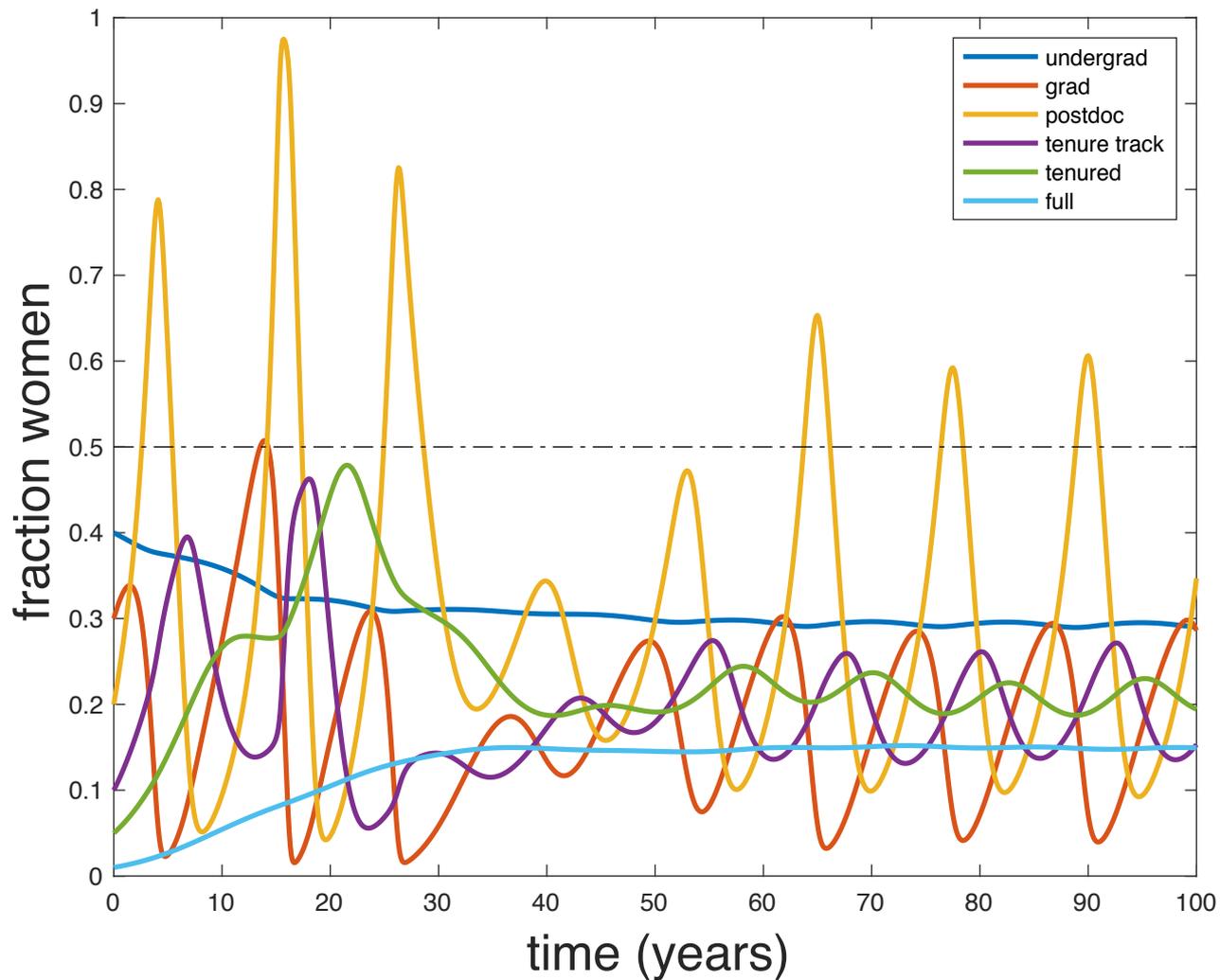
$$\frac{1}{R_j} \frac{dx_j}{dt} = (1+r_j)f(x_j, x_{j-1}; b) - x_j - r_j f(x_{j+1}, x_j; b)$$

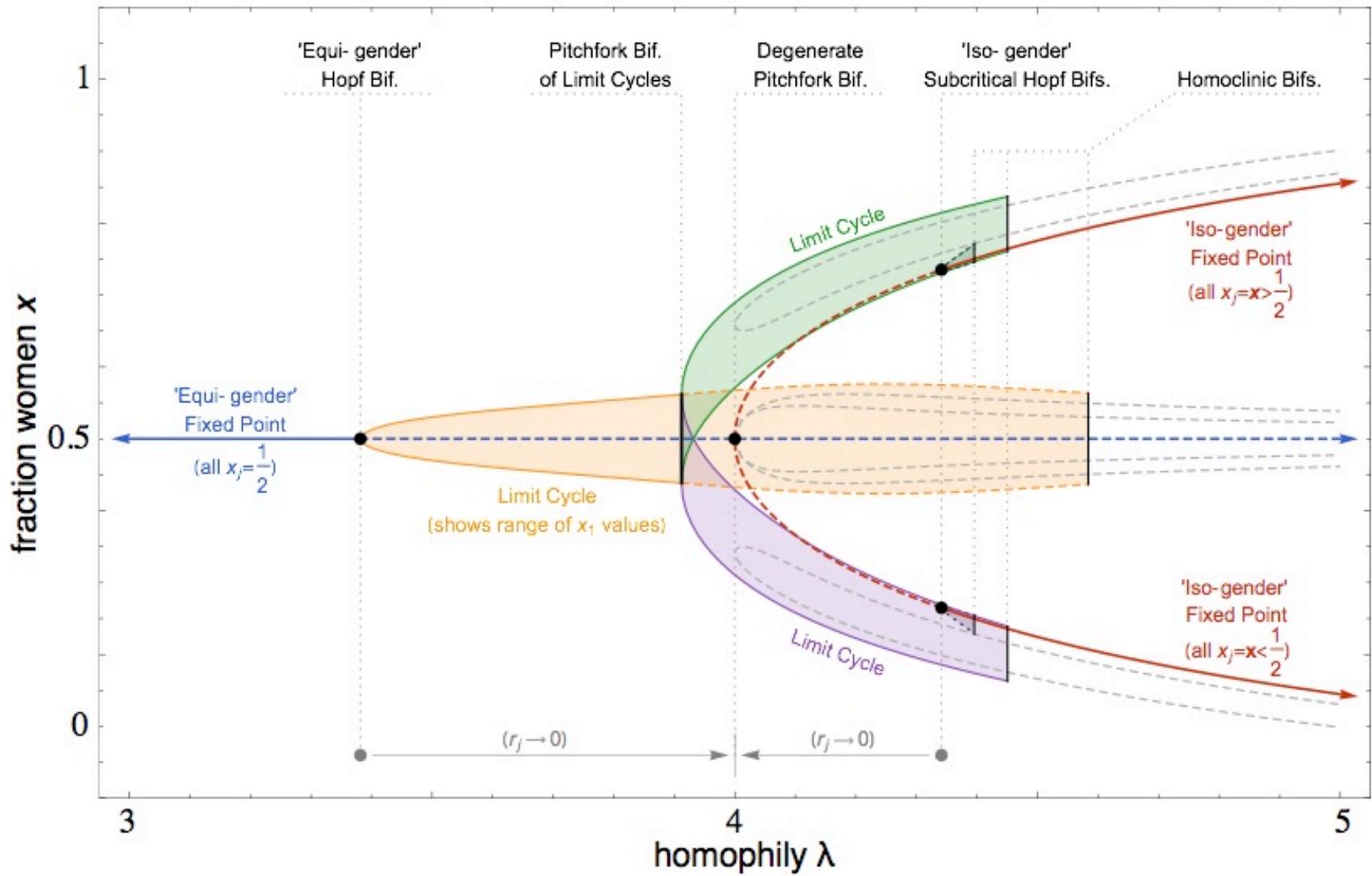
$$P(u, v) = \frac{1}{1 + e^{-\lambda(u-v)}}$$

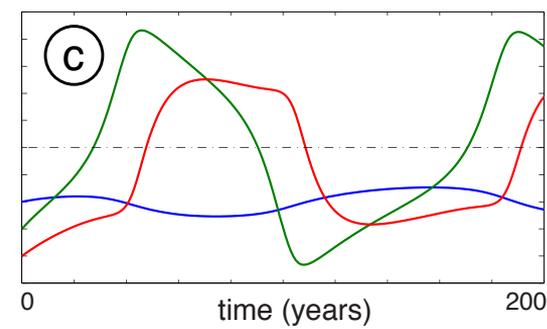
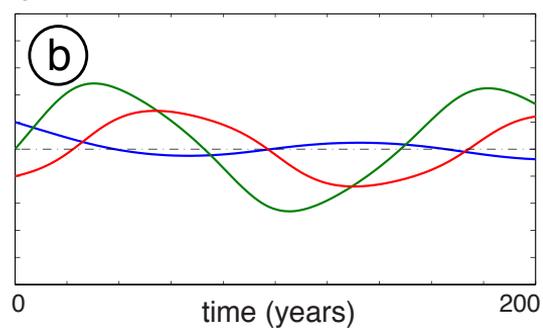
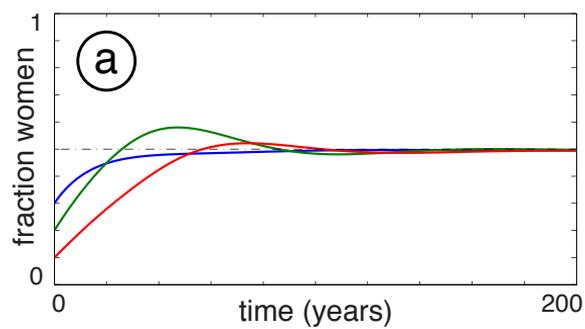
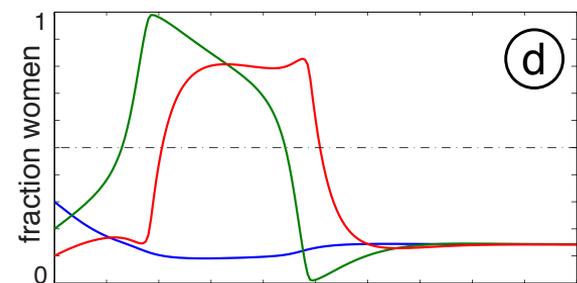
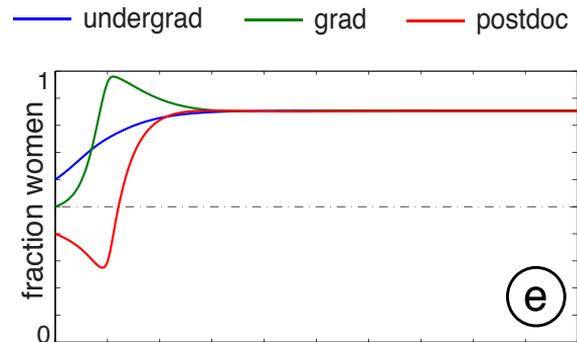
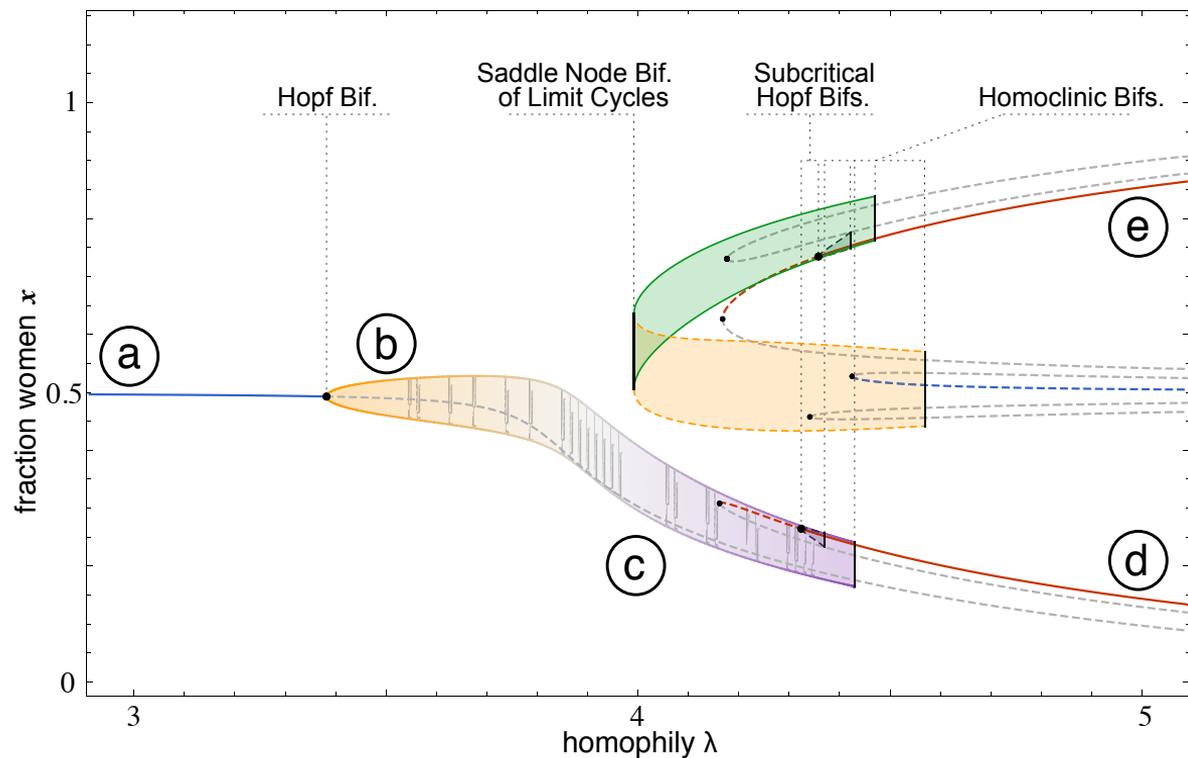
$$\frac{1}{R_1} \frac{dx_1}{dt} = \underbrace{(1+r_1)f(x_1, \frac{1}{2}; b)}_{\text{hired from general pool}} - \underbrace{x_1}_{\text{leave field}} - \underbrace{r_1 f(x_2, x_1; b)}_{\text{promoted to next layer}}$$

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

**Model
behavior:
both bias and
homophily**



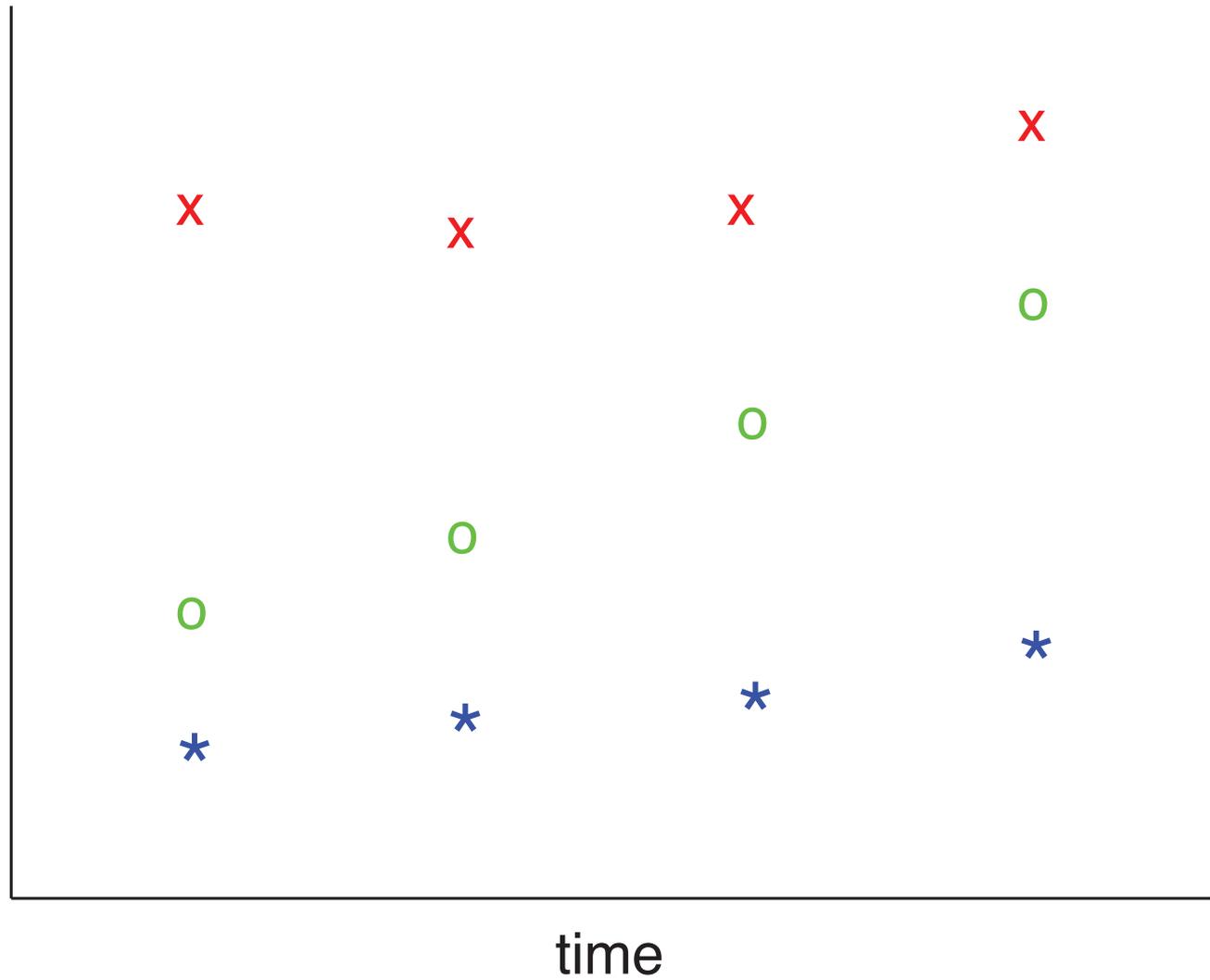




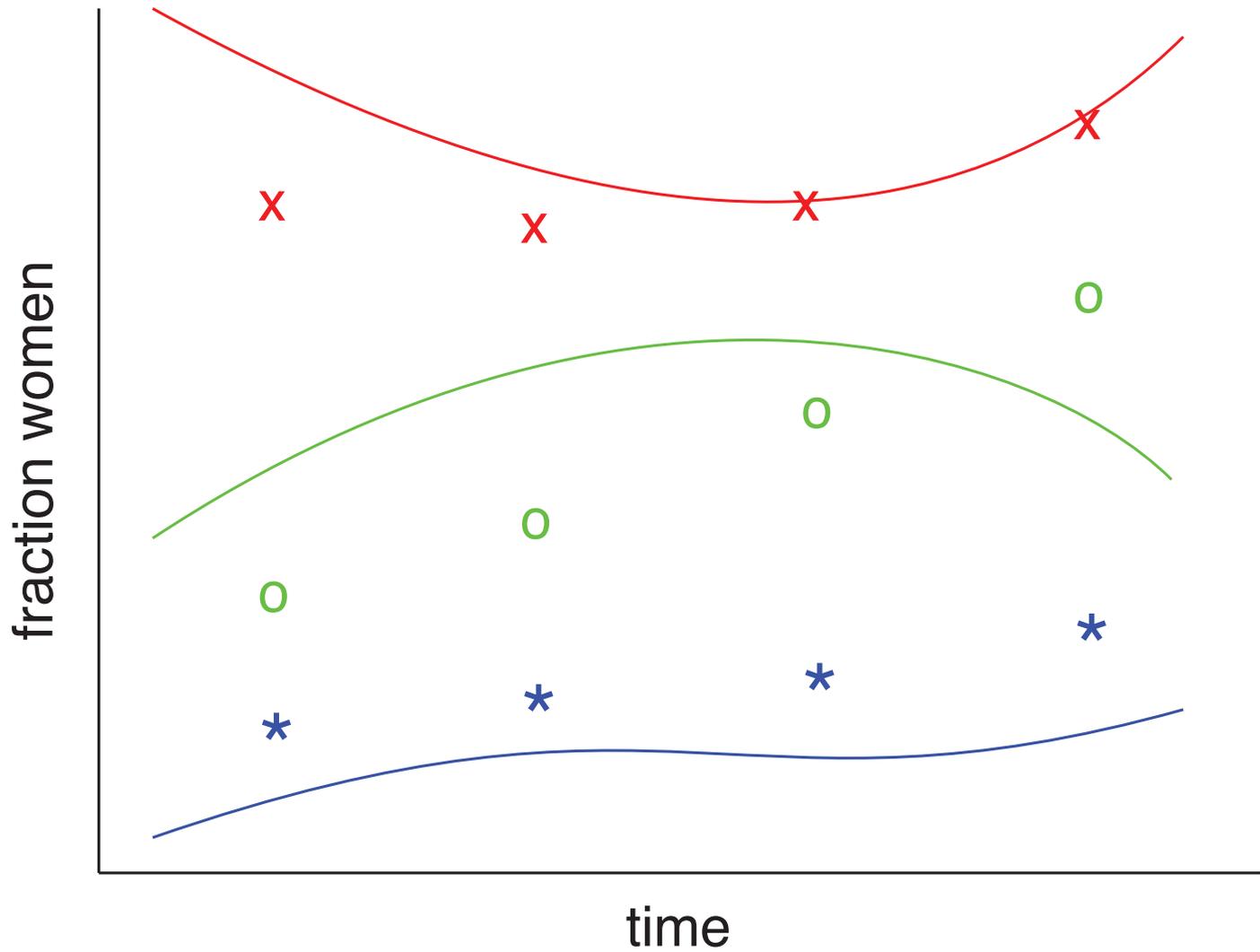
— undergrad — grad — postdoc

Fit model
to data

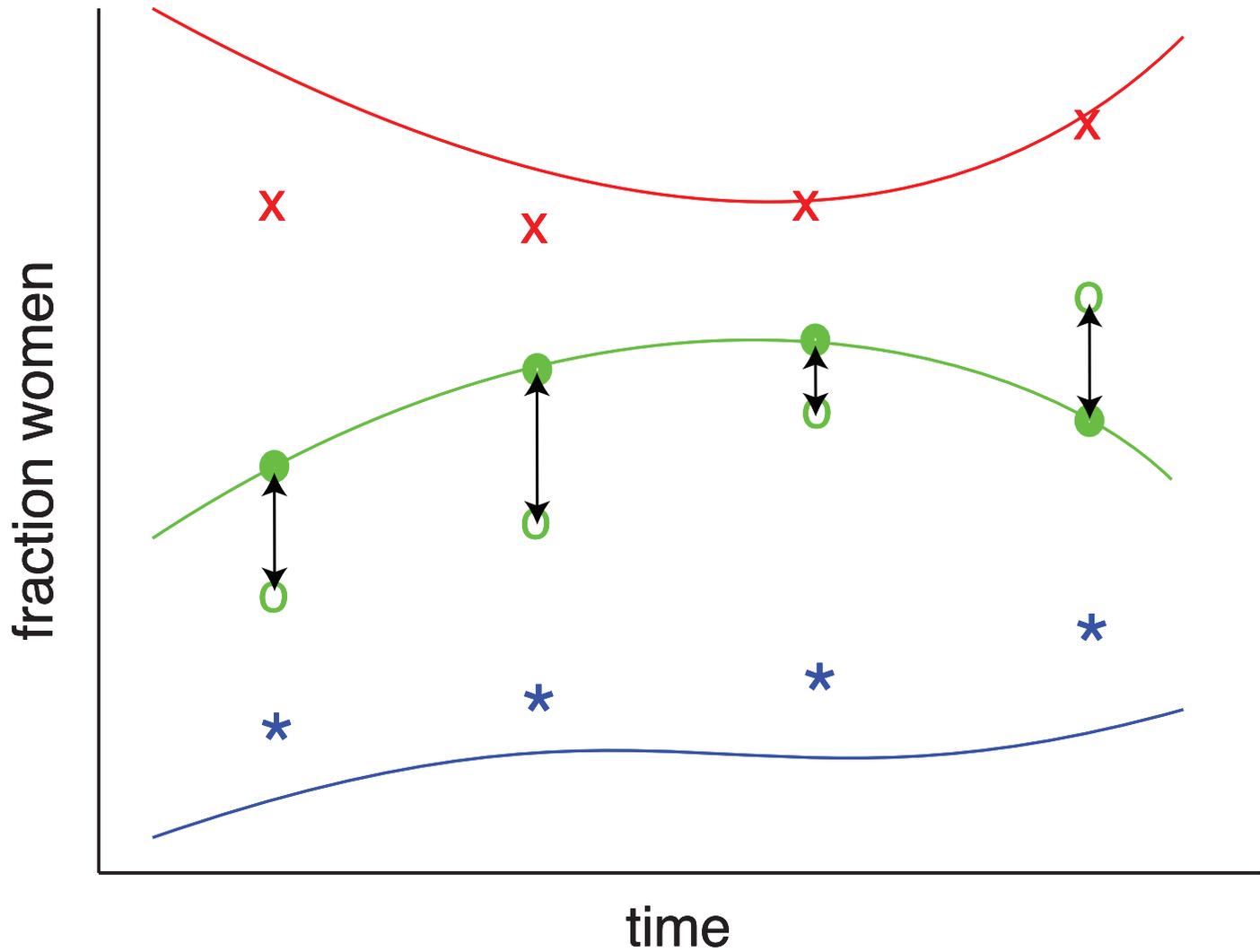
fraction women



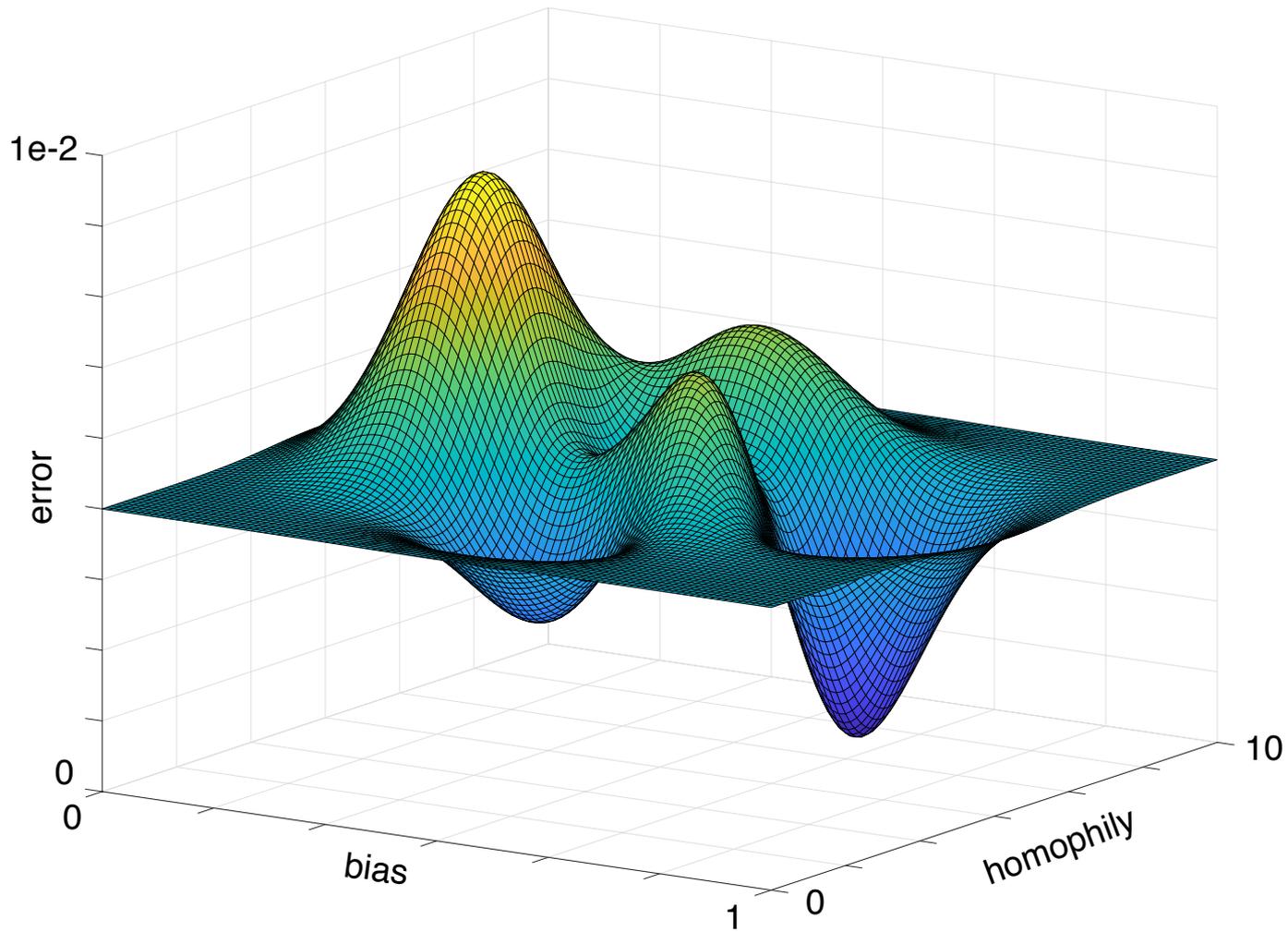
Fit model
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Fit model
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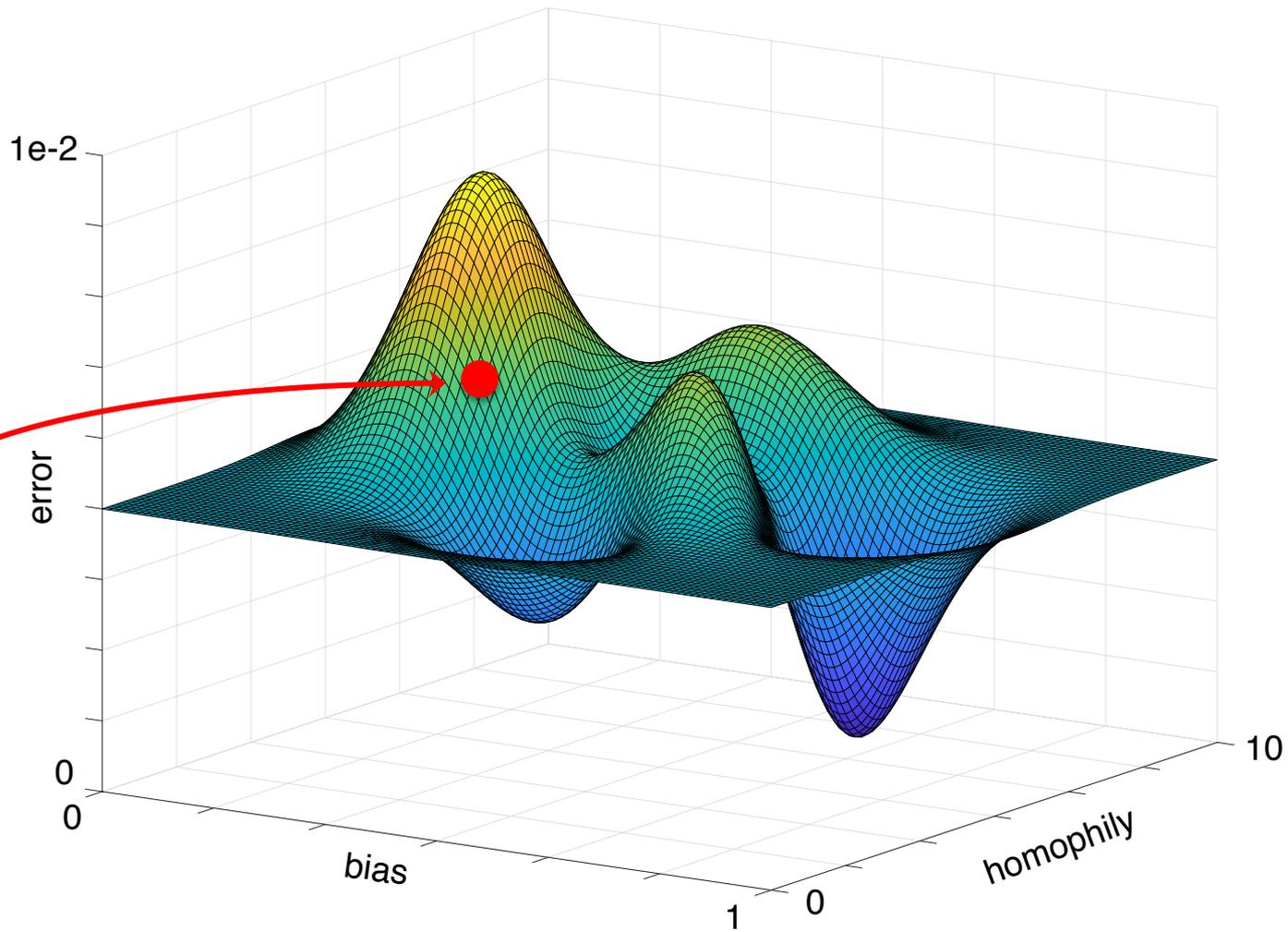


Fit model to data

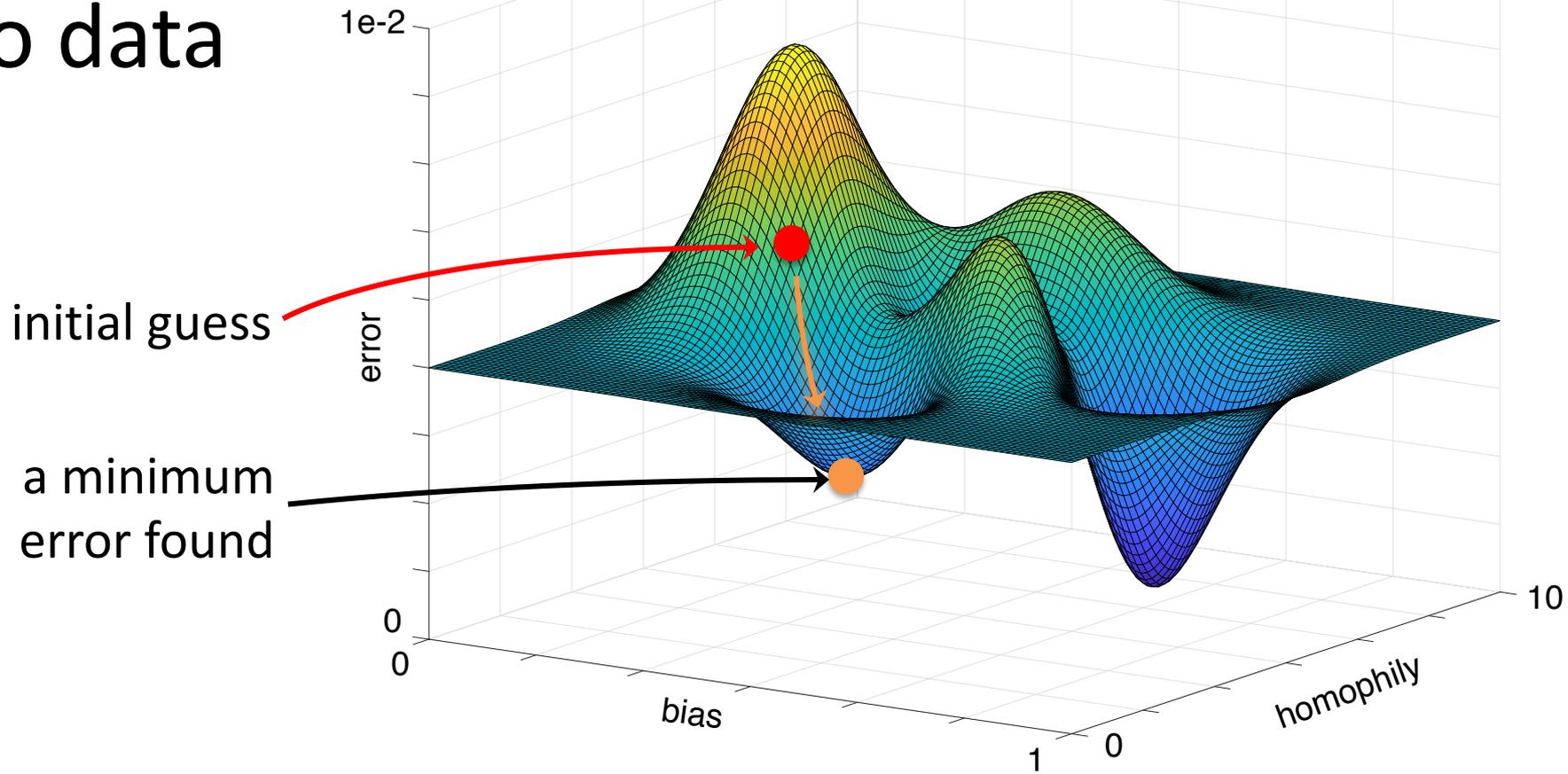


Fit model to data

initial guess

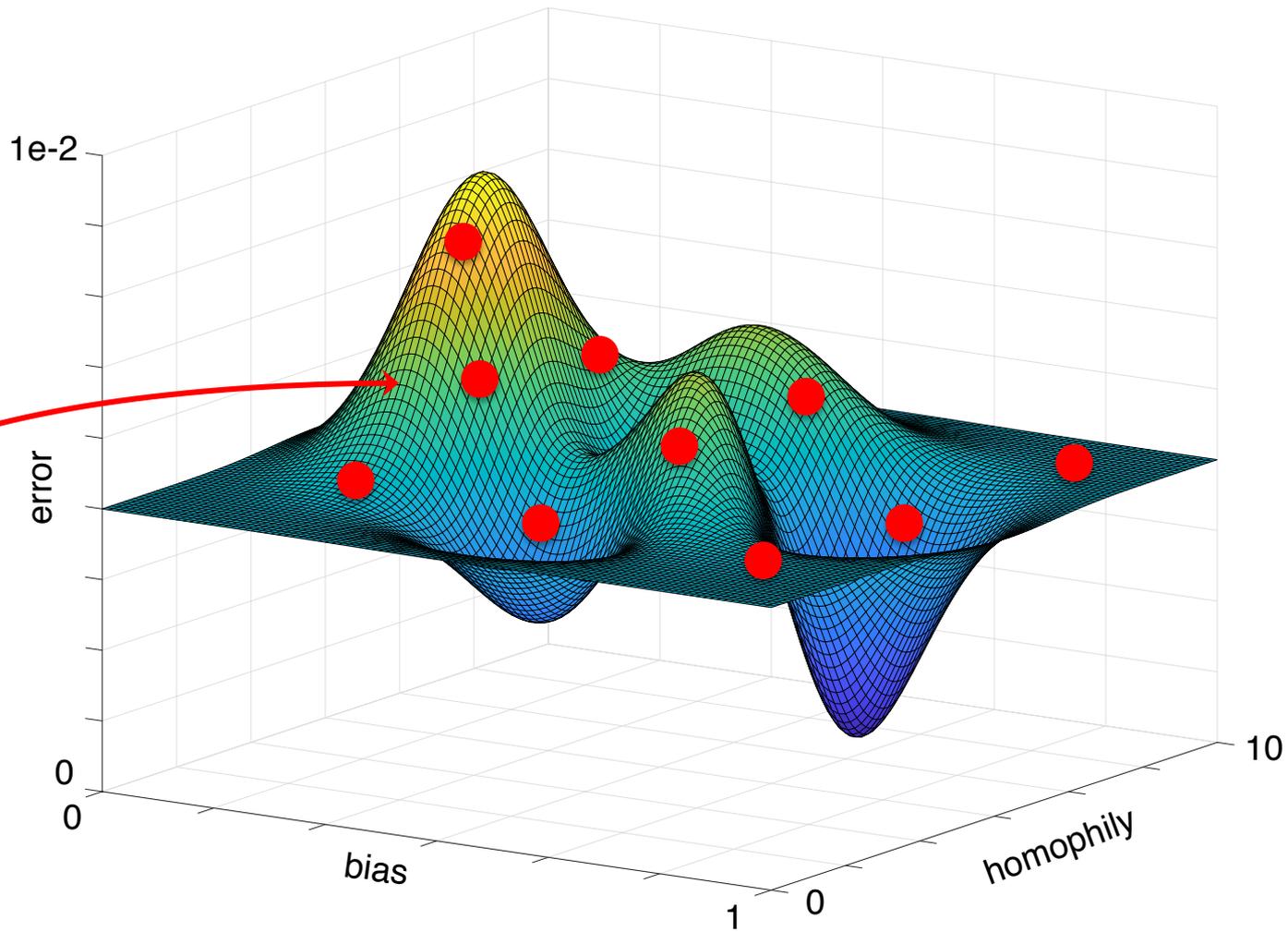


Fit model to data

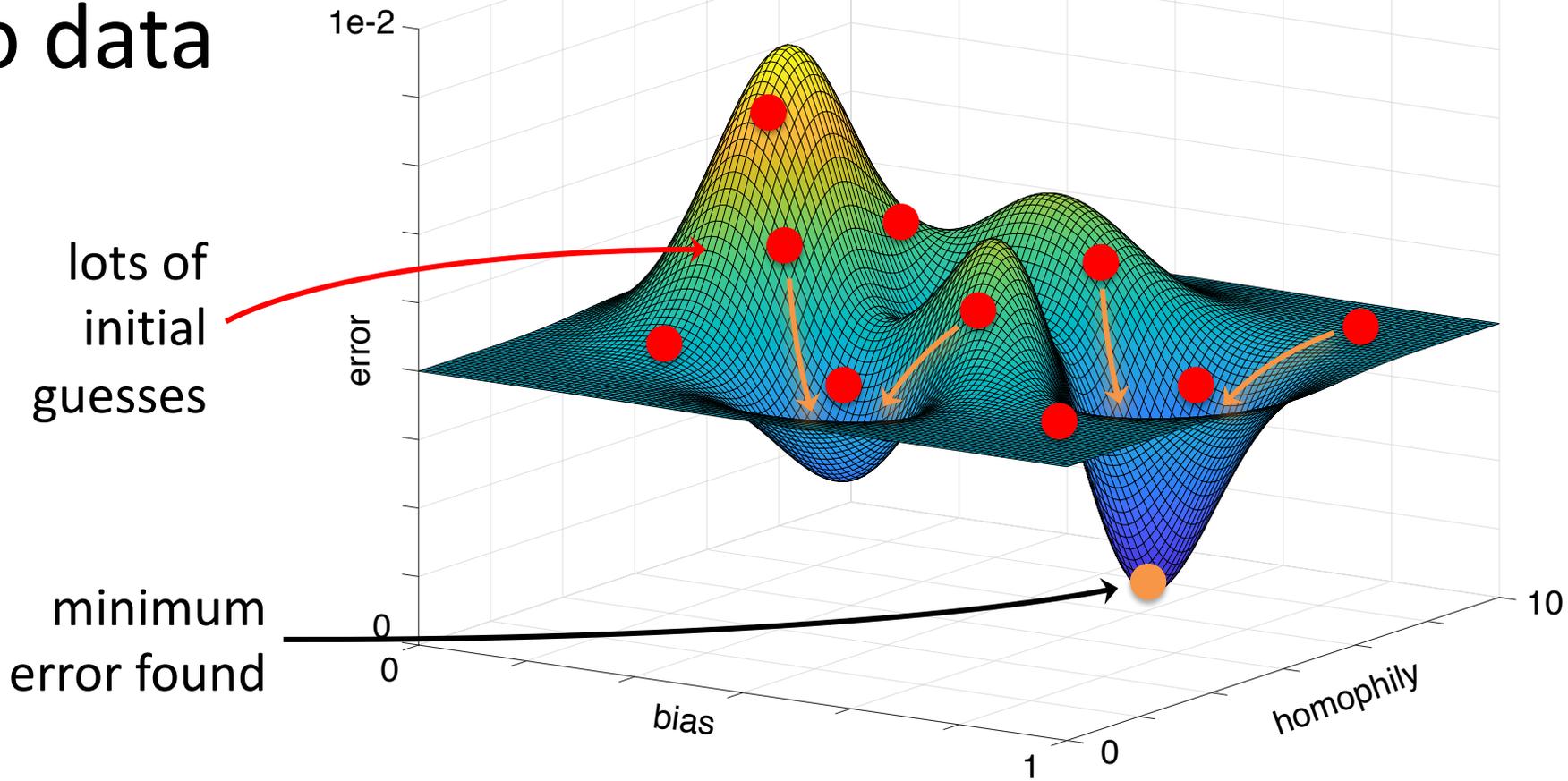


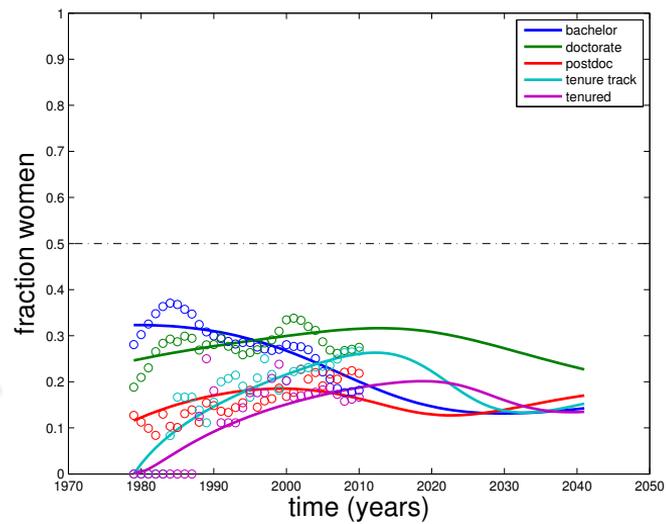
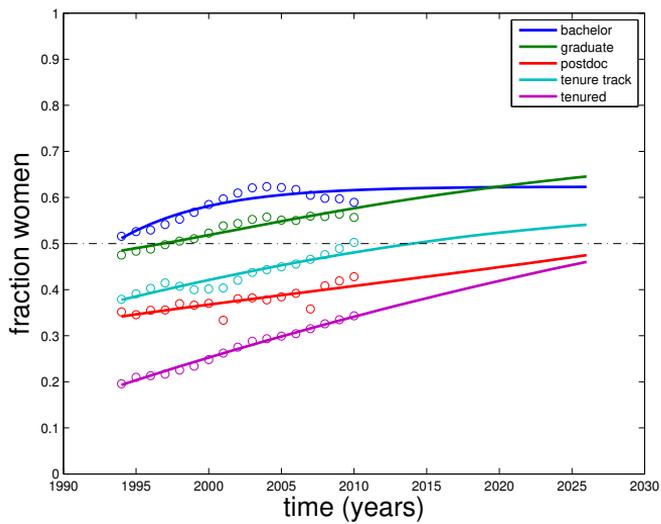
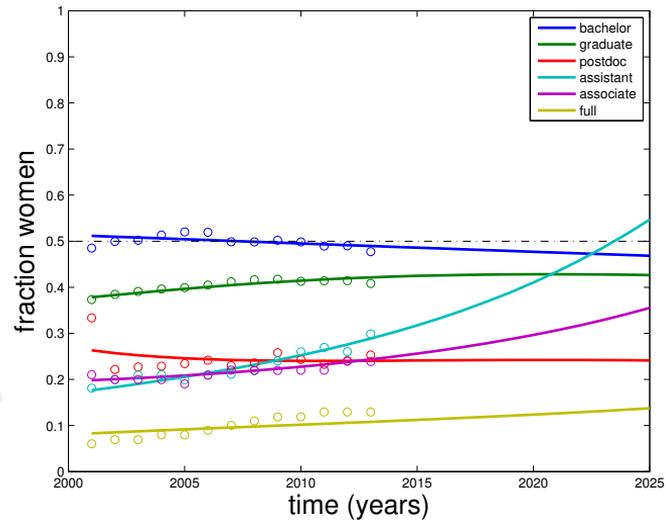
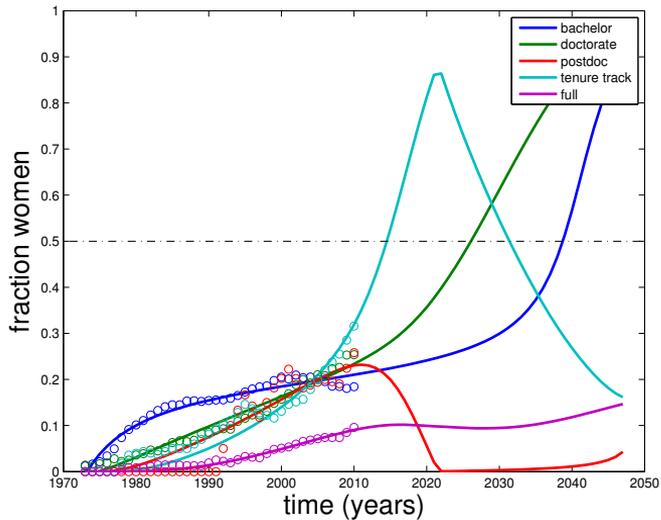
Fit model to data

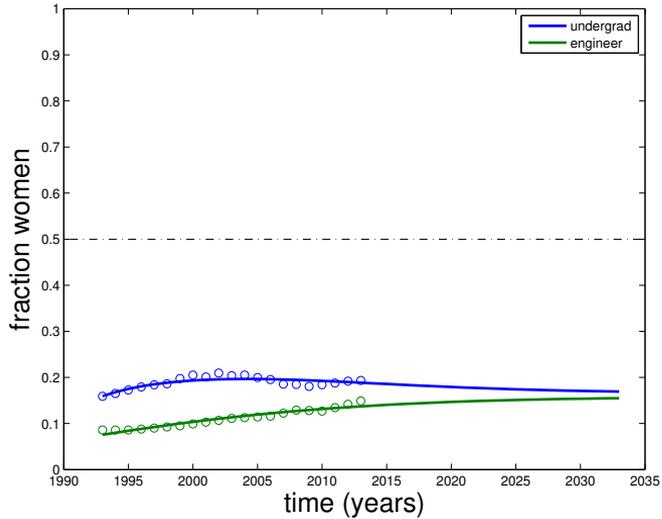
lots of
initial
guesses



Fit model to data

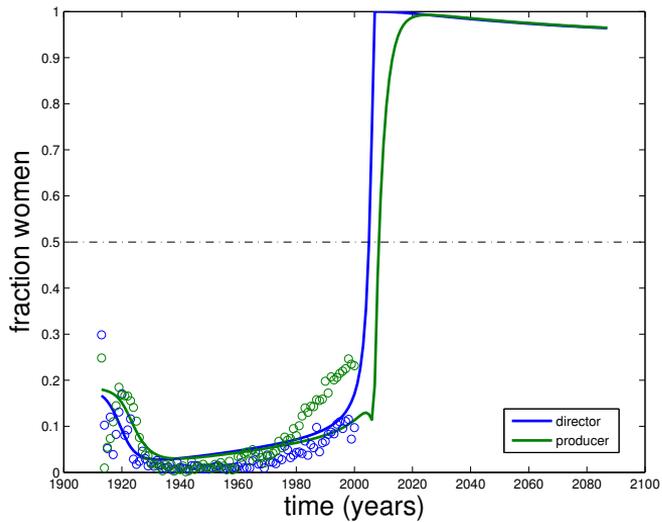
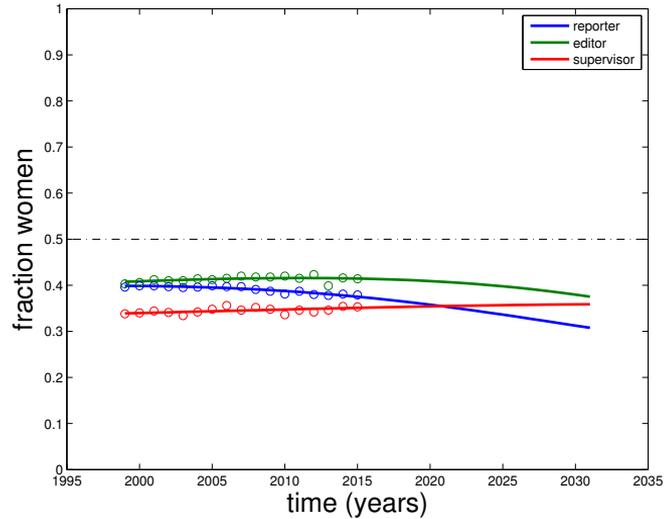






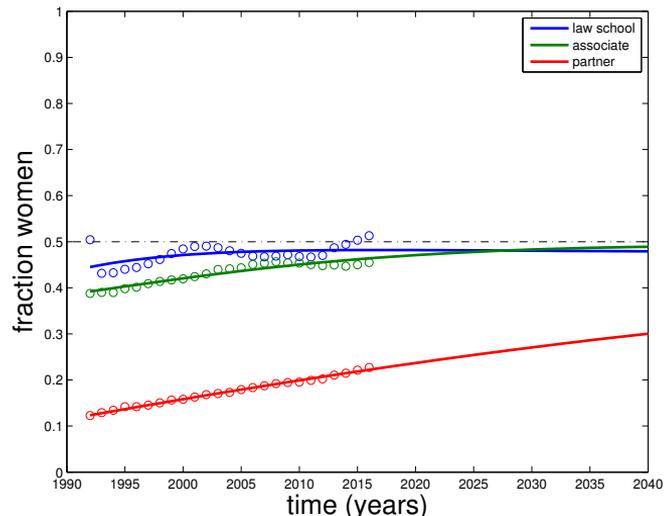
Engineering
Practice

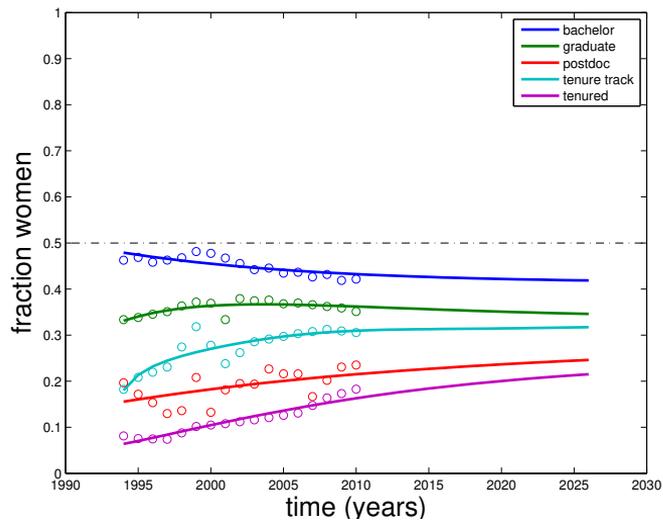
Journalism



Film

Law

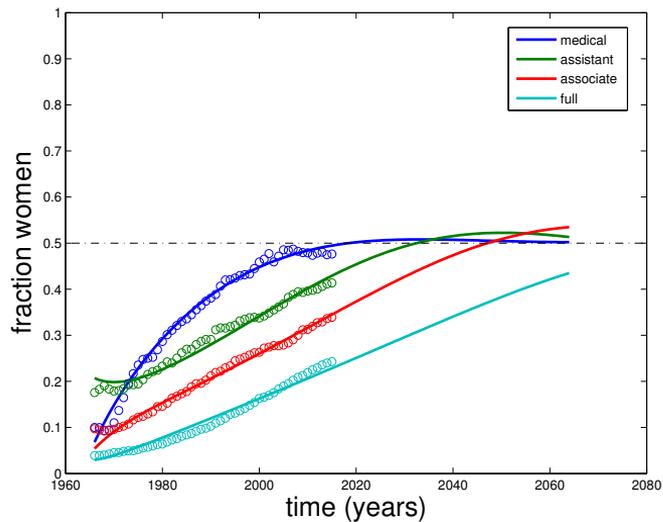
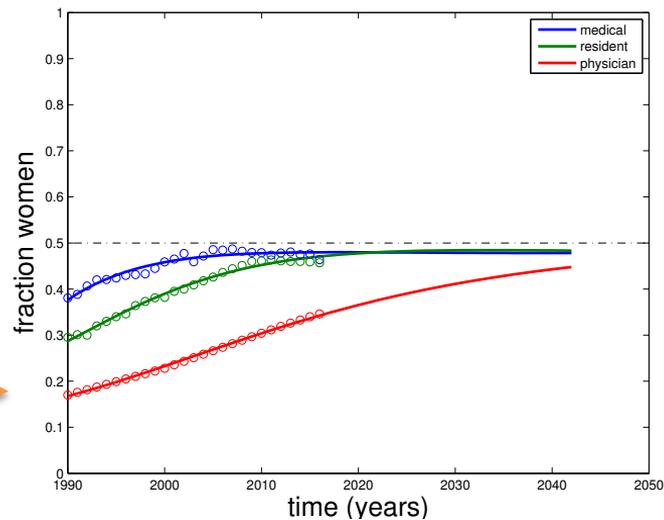




Academic
Math & Stats



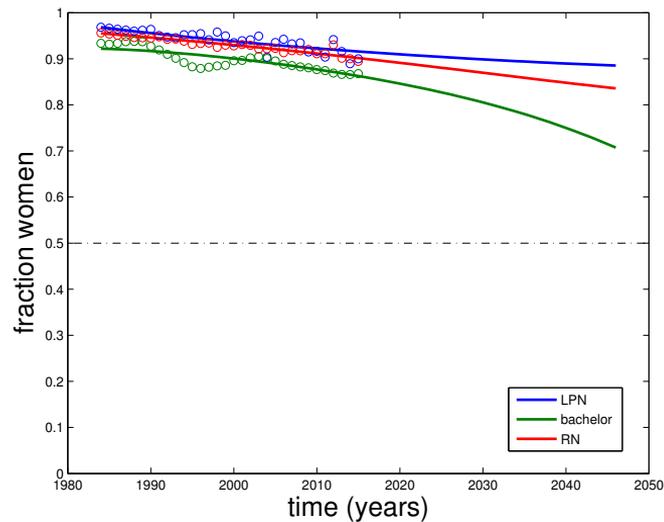
Medical
Practice

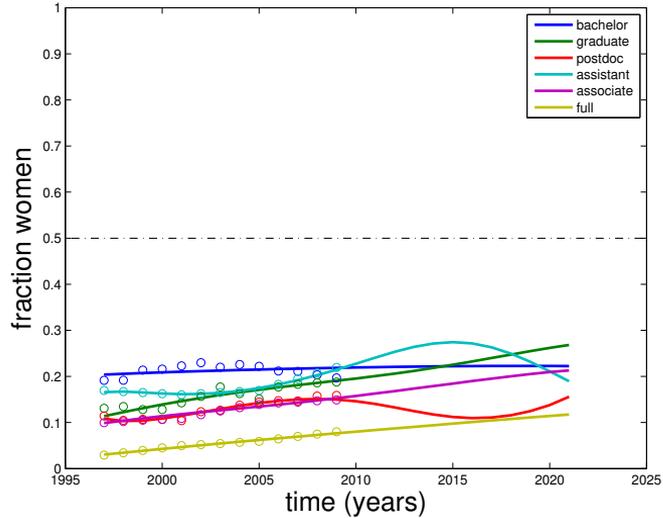


Academic Medicine
(basic science)



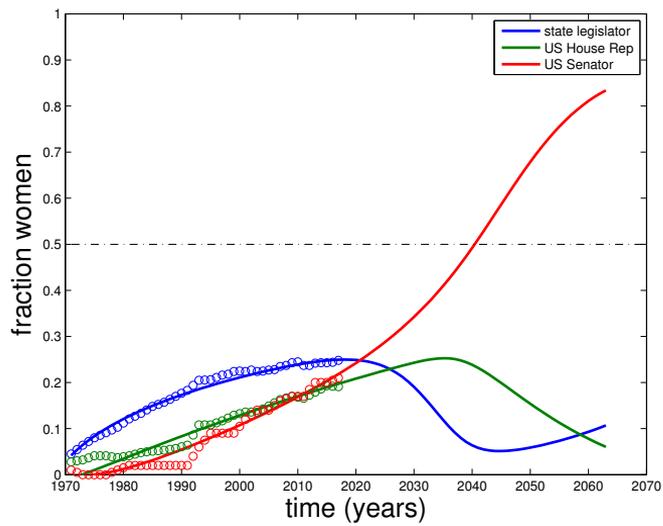
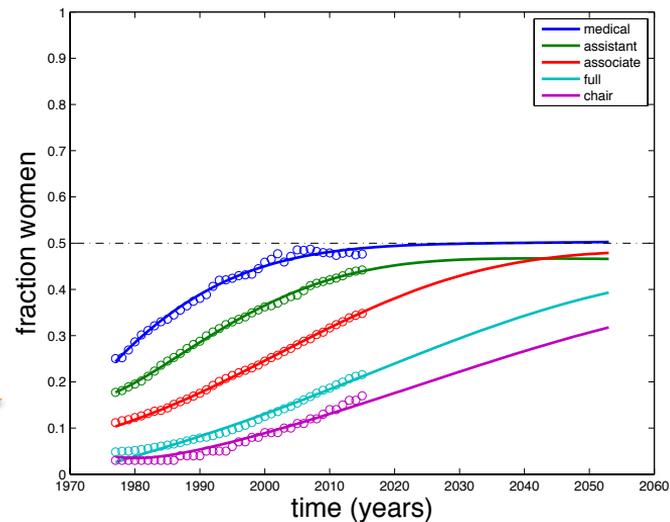
Nursing





Academic
Physics

Academic Medicine
(clinical)



Politics

Academic
Psychology

