Sex Bias in Graduate Admissions: Data from Berkeley

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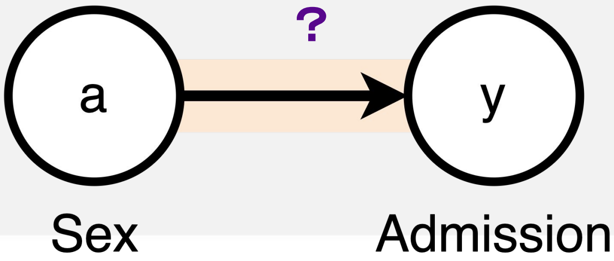
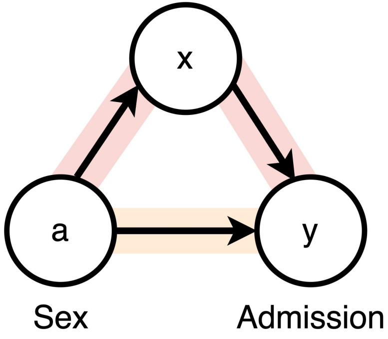


Bias vs. Discrimination

Bias is a pattern of association between a particular decision and a particular sex of applicant, of sufficient strength to make us confident that it is unlikely to be the result of chance alone.

Discrimination is the exercise of decision influenced by the sex of the applicant when that is immaterial to the qualifications for entry.



Background

- UC-Berkeley 1973 Fall Grad School Admission
  - 12763 completed applications
  - Sex (F/M), Department (101), Admission Outcome (Yes/No)
- Sex Bias?
  - **44%** of the male applicants got admitted (8442 total)
  - **35%** of the female applicants got admitted (4321 total)
- Men and women applicants should have equal chances of admission to the university.

Applicants	Outcome				Difference	
	Observed		Expected			
	Admit	Deny	Admit	Deny	Admit	Deny
Men	3738	4704	3460.7	4981.3	277.3	− 277.3
Women	1494	2827	1771.3	2549.7	− 277.3	277.3

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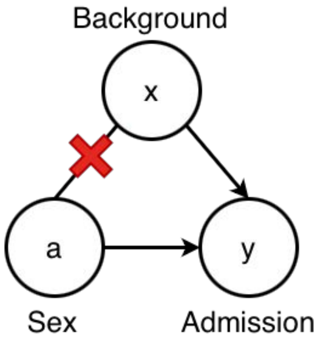
Discrimination Against Women?

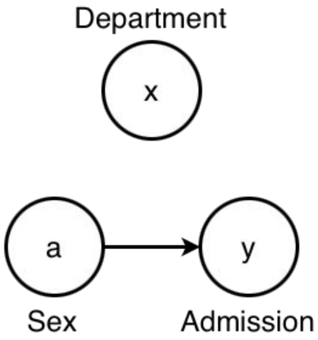
Assumption 1: Exchangeability

Male and female applicants do not differ in intelligence, skill, qualifications, promise, or other attribute that impacted the admission decision.



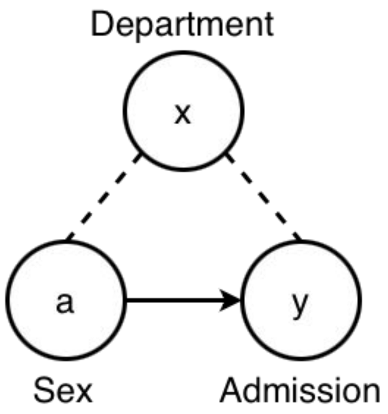
Assumption 2: Department Not A Mediator Or Confounder

The sex ratios of applicants to the various fields of graduate study are not importantly associated with any other factors in admission.



When Examining By Departments…

- Individual department did not show consistent bias against women.
- Excluding 16 that either had no women applicants (positivity) or denied admission to no applicants of either sex (no association between a, y).
- From remaining 85:
  - 4 show significant bias against women
  - 6 departments show bias against men.



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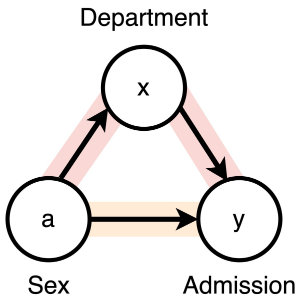
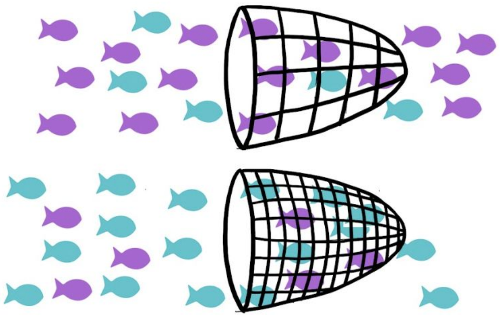
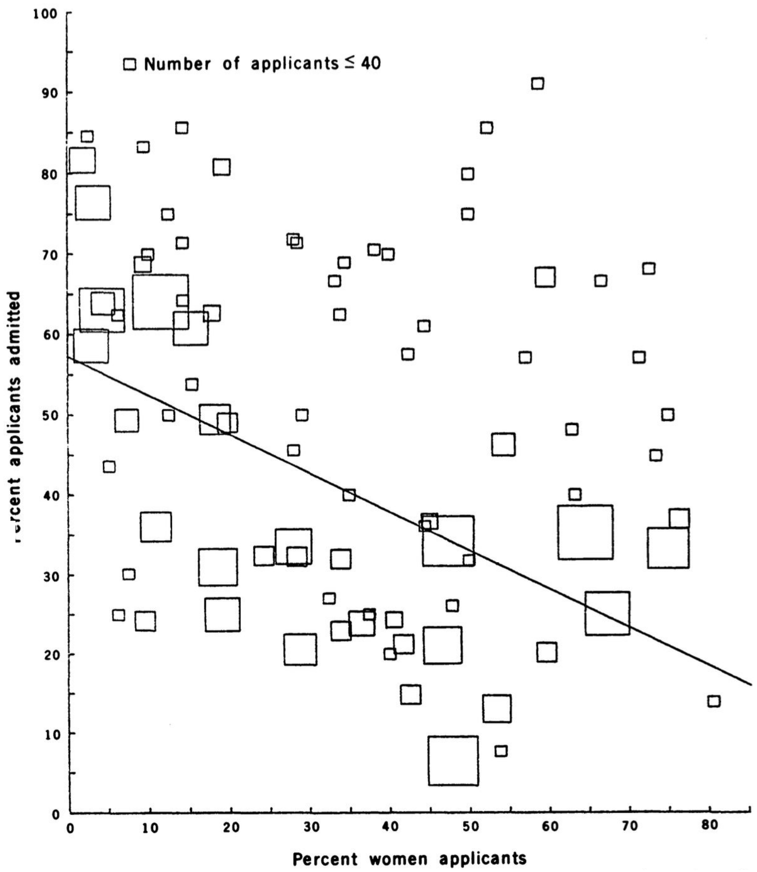
Why? Simpson's Paradox

- Women are accepted at equal/higher rate in most individuals departments.
- Men are accepted at an overall higher rate in the university.

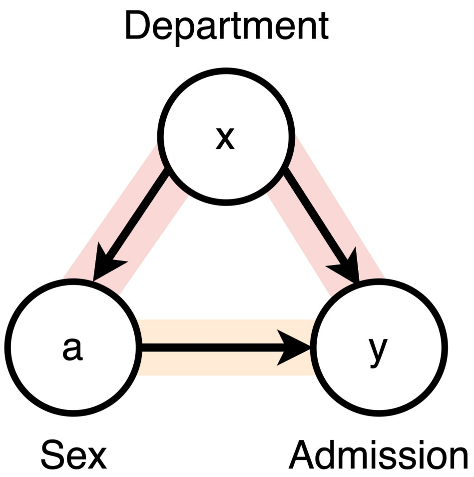
Women tend to apply to departments that are hard to get into.

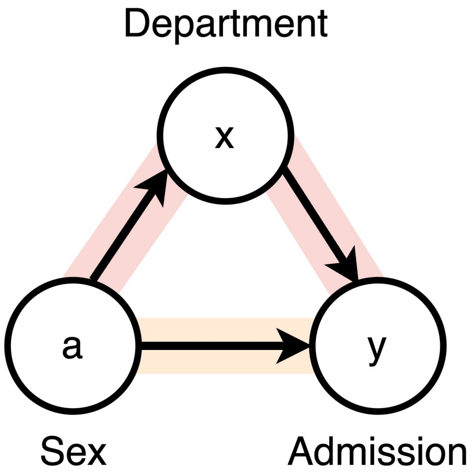






Causal Graph





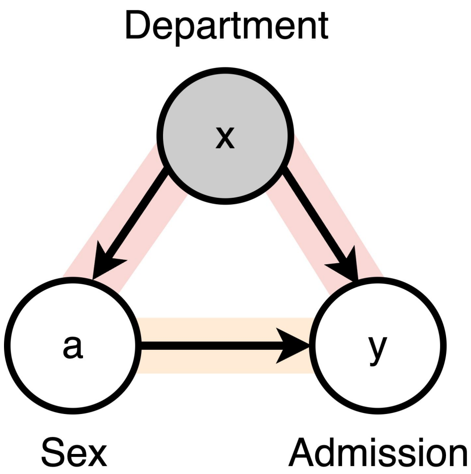
Case 1: x is an unobserved confounder

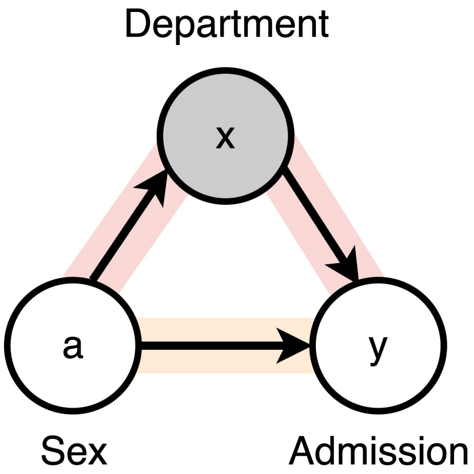
a ← x → y is an open, non-causal path
Spurious correlation (Backdoor)

Case 2: x is an unobserved mediator

a → x → y is an open, causal path
Statistical relation = Total causal relation

Causal Graph





Case 3: x is an observed confounder

a ← x → y is closed
Statistical relation = Causal relation

Case 4: x is an observed mediator

a → x → y is closed
Statistical relation = Direct causal relation

Adjusted Approach: Pooling

- Recalculating the expected admission
  - Take into account of individual department admission rate
- For each department
  - Pooled by the department admission rate instead of university admission rate
- Sum the expected number of admissions across departments
- Evidence of Bias In Favor of Women

Expected female admittees	1432.9
Observed female admittees	1493.0
Difference $(O - E)$	60.1

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Example

Originally:

Applicants	Outcome				Difference	
	Observed		Expected			
	Admit	Deny	Admit	Deny	Admit	Deny
	Department of machismatics					
Men	200	200	200	200	0	0
Women	100	100	100	100	0	0
	Department of social warfare					
Men	50	100	50	100	0	0
Women	150	300	150	300	0	0
	Totals					
Men	250	300	229.2	320.8	20.8	− 20.8
Women	250	400	270.8	379.2	− 20.8	20.8

- Overall Admit Rate:
  $(250+250)/(250+300+250+400)=0.417$
- Then, the number of expected female admittees, E_f:
  $(250+400)*0.417=270.8$
- $O_f - E_f = -20.8$

After Pooling:

- Machismatics Admit Rate:
- $(200+100)/(200+200+100+100)=0.5$
- Social Warfare Admit Rate:
- $(50+150)/(50+100+150+300)=0.333$
- E_f:

$$(100+100)*0.5+(150+300)*0.333=250$$

- $O_f - E_f = 0$

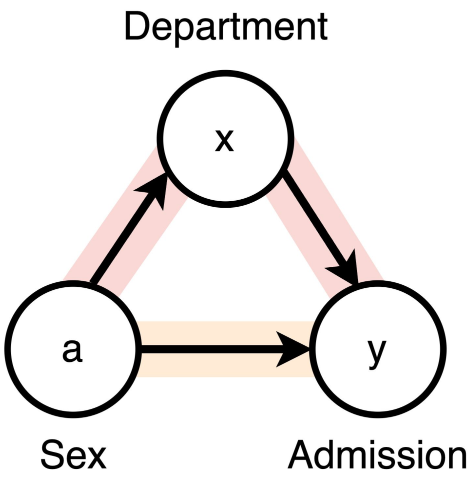
Pooling - Department as a Mediator

- Treating Department as the mediator,

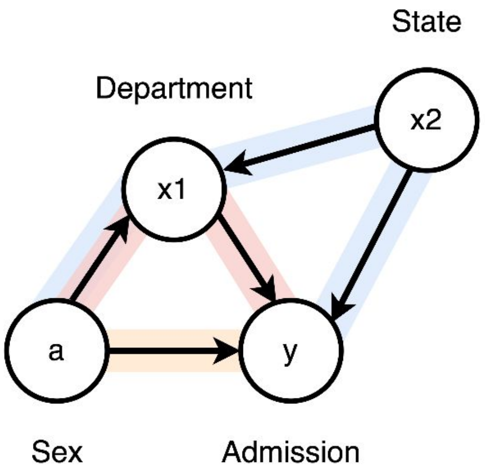
$$P(y|Do(a = female)) = \sum_x P(y|a = female, x)P(x|a = female)$$

- Let the number of female applicants be N_f. The expected count of female admittees (no bias):

$$E_f = P(y|Do(a = female)) * N_f$$
$$= \left[\sum_x P(y|a = female, x)P(x|a = female)\right] * N_f$$
$$= \sum_x \underbrace{P(y|a = female, x)}_{\text{admit rate for females in each department}} \underbrace{[P(x|a = female) * N_f]}_{\text{number of females applying to each department}} = \sum_x \underbrace{P(y|x)}_{\text{admit rate in each department (if no bias)}} [P(x|a = female) * N_f]$$

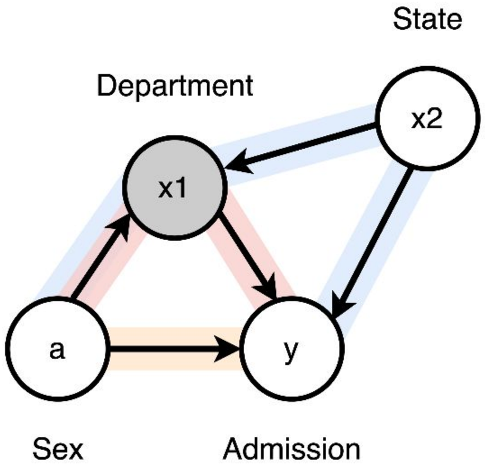


Kruskal’s Argument



x1 unobserved
x2 unobserved

a → y = Open
a → x1 → y = Open
a → x1 ← x2 → y = Closed



x1 observed
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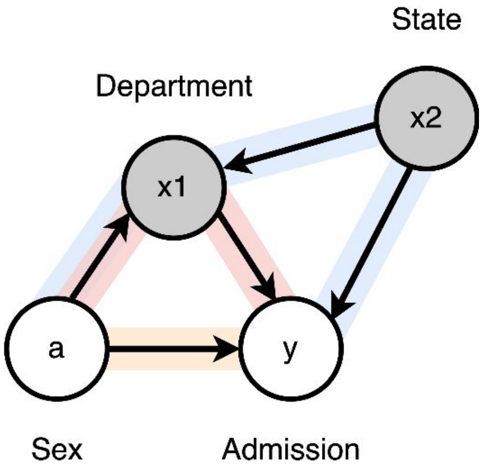

x1 observed
x2 observed

a → y = Open
a → x1 → y = Closed
a → x1 ← x2 → y = Closed

Conclusions

Simpson's Paradox Case Study

- Aggregate data suggests bias against female applicants, that reverses when data is disaggregated by departments.
- Simpson's Paradox is not solely tied to confounding variables.

Causal Effect Calculation

- Causal effect calculation largely depends on assumptions about the data generation process. For example, the department can act as a mediator or a confounder.
- The inferences must be accompanied by our assumptions about the data. For example, we must assume that we measured all confounders.

Analysis Replication

https://colab.research.google.com/drive/1ACD6BNw1AMArVXjMEtghoA2-Ap1HvilO?usp=sharing

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Thank You

Open to questions!