POLS 205
Political Science as a Social Science

Evaluating Causal Theories

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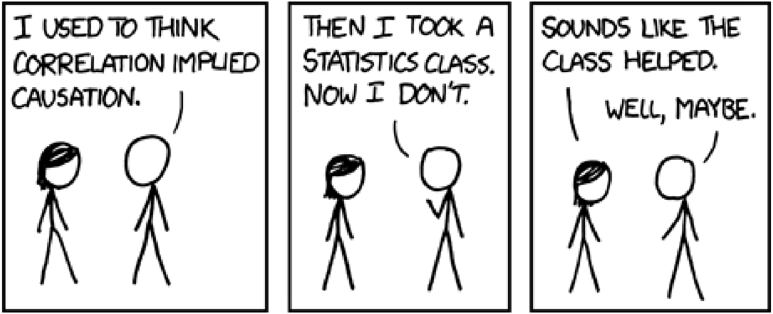
Outline

Defining correlation & casusation

Writing causal theories as models

Testing causal theories



http://xkcd.com/552/

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2. Highly misleading, under the colloquial understanding of "imply":
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   - This is FALSE. Correlation may not be sufficient evidence to conclude causation, but it is a clue!

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Hypothesis Larger fiscal stimulus lowers unemployment

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Can we test this hypothesis?

Cause and Effect

Correlation Suppose X_i and Y_i are correlated. Then:

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- when X_i is large, it causes Y_i to be large
- when X_i is small, it causes Y_i to be small
- Causation is directional. $X_i \Rightarrow Y_i$ does not imply $Y_i \Rightarrow X_i$

Signal and noise

$$Y_i = f(X_i) + \varepsilon_i$$

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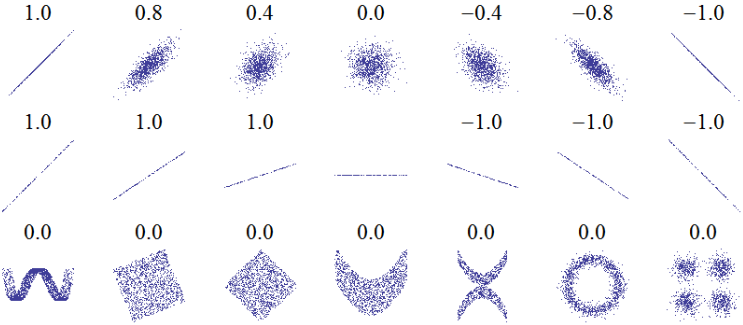
Suggests we need a lot of observations to study causality

Correlation examples



Causes and confounders

We observe a correlation between fiscal stimulus & fast recovery from recession

Could this correlation be spurious?

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How can we solve this problem?
Compare countries with similar ex ante debt levels: Control for debt

A simple causal model

Regular
Exercise

What is the
causal
relationship
here?

Health

A simple causal model

Regular Exercise

Health

What is the causal relationship here?

Which variables are correlated?

A simple causal model

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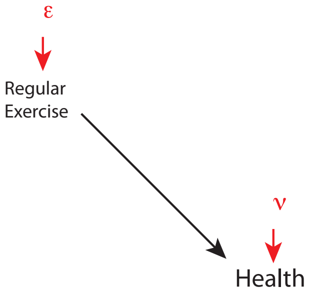
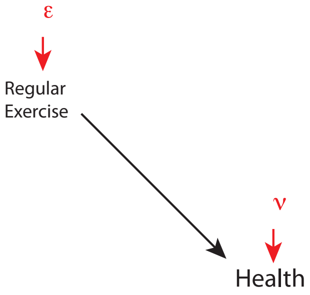
What is missing from this path diagram?

A simple causal model



We assume a random component affects each variable

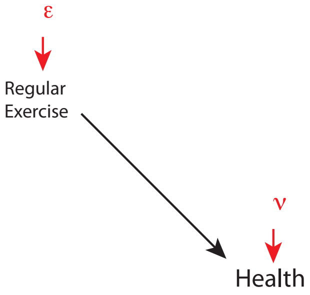
A simple causal model



We assume a random component affects each variable

Here, both exercise and health are subject to random fluctuation

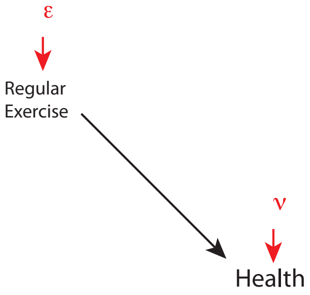
A simple causal model



These random effects are uncorrelated with Health and Exercise

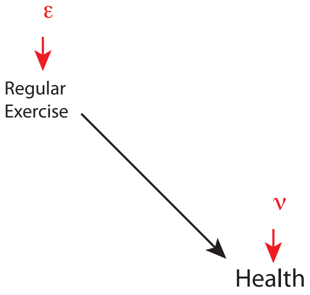
(why?)

A simple causal model



ε means Exercise varies randomly from person to person

A simple causal model



Health results from both Exercise and ν

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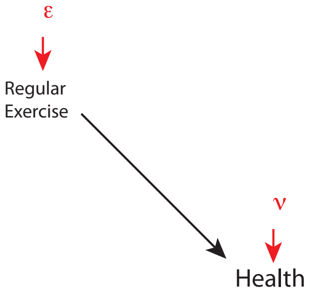
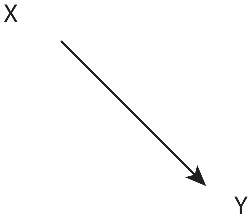


Health results from both Exercise and ν

ν makes relationship between exercise & health probabilistic, *not* deterministic

A simple causal model



In most path diagrams, we will leave out random effects to reduce clutter

What other variables might fit this pattern?

Mystery model 1

arm length

genes

leg length

What is the causal relationship here?

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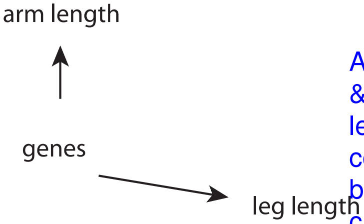
genes

leg length

What is the causal relationship here?

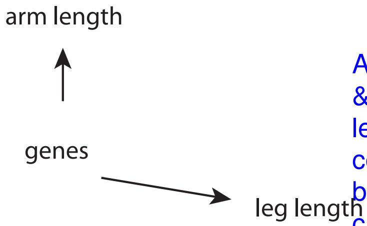
Which variables are correlated?

Common cause; spurious correlation



Arm length & leg length are correlated but not causally related

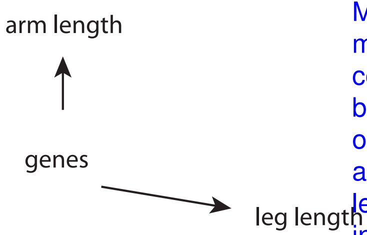
Common cause; spurious correlation



Arm length & leg length are correlated but not causally related

What if we didn't know about genes?

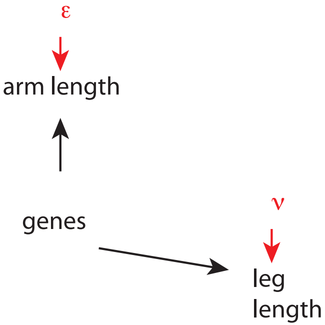
Common cause; spurious correlation



Might be misled by correlation between observed arm and leg lengths into perceiving a causal relationship

Watch out for omitted common causes!

Common cause; spurious correlation



As before, we are assuming random effects on arms and legs

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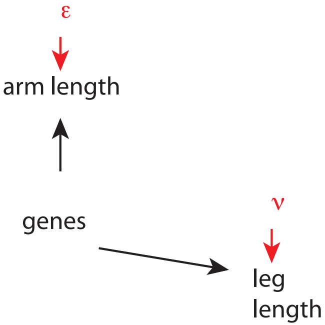

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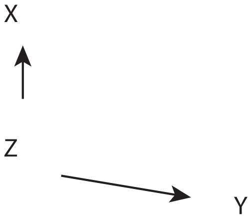
Recall that ε and ν are uncorrelated. What does that mean here?

Common cause; spurious correlation



What other variables might fit in this model?

Mystery model 2

per capita
gross domestic
product

Female
education

Fertility
rate

What is the causal relationship here?

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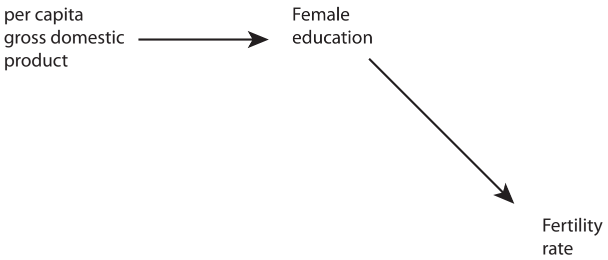
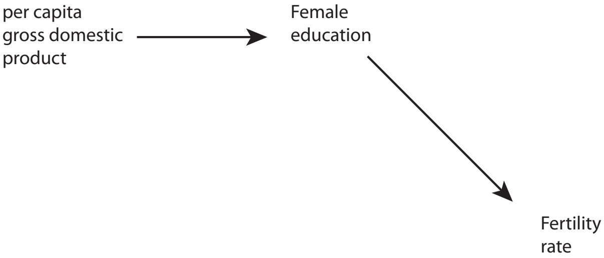
Indirect relationship



Economic development leads to female education

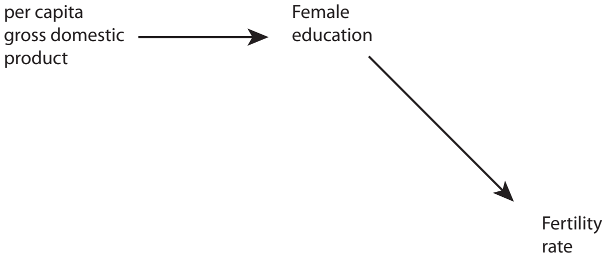
Indirect relationship



Economic development leads to female education

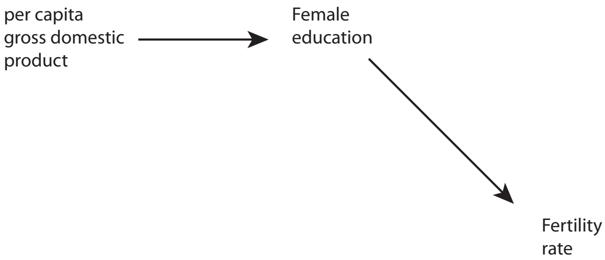
Educated females use contraception, have fewer kids

Indirect relationship



Rising GDP lowers fertility, but not directly

Indirect relationship



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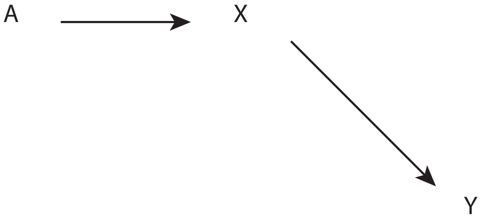
GDP and fertility are (inversely) correlated

Indirect relationship



What other variables fit this model?

Mystery model 3

Democratic
Governor

Democratic
Legislature

Welfare
Spending

What is the causal relationship here?

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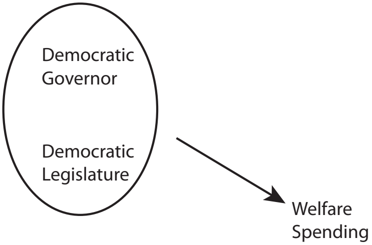
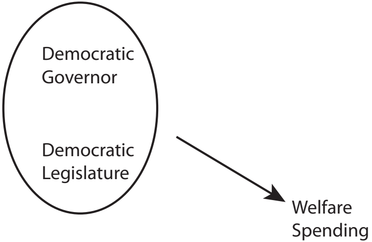
Which variables are correlated?

Conditional relationship



Effect of Democratic governors depends on party in control of leg, & vice versa

Conditional relationship



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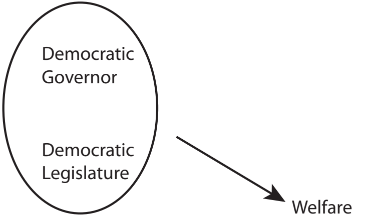
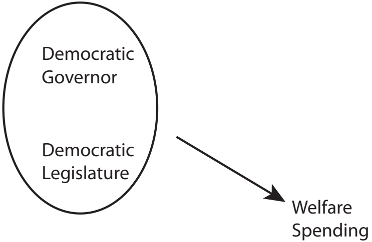
Welfare might stay low unless Democrats have united control

Conditional relationship



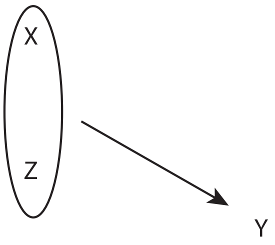
Effects of party control not additive but multiplicative

Conditional relationship



Effects of party control not additive but multiplicative
Known as an "interactive effect"

Conditional relationship



Can we think of variables that would fit in an interative model?

Mystery model 4

Campaign
Contributions

Expected
Vote
Percentage

What is the causal relationship here?

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Expected
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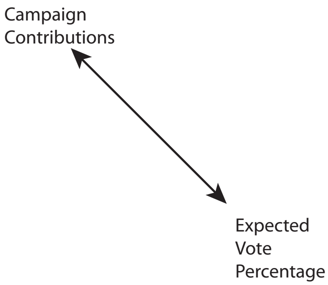
What is the causal relationship here?

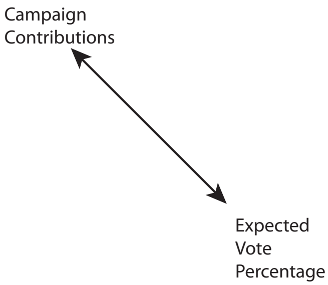
Which variables are correlated?

Reciprocal Causation



Better funded candidates do better, all else equal

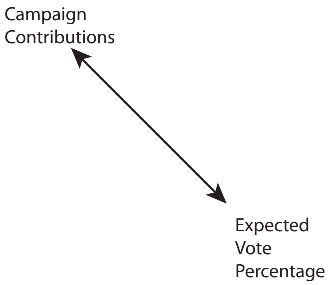
Reciprocal Causation



Better funded candidates do better, all else equal

But in close elections even losers raise a lot

Reciprocal Causation



Hard to separate these effects empirically

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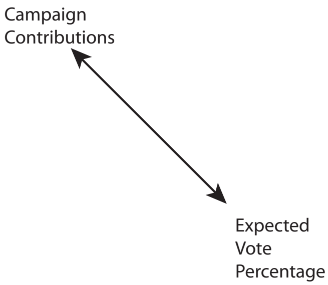
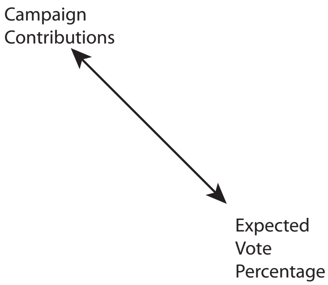


Hard to separate these effects empirically

Often people “find” campaign contributions & victory are *inversely correlated*!

Reciprocal Causation



Implies candidates should shun campaign contributions!

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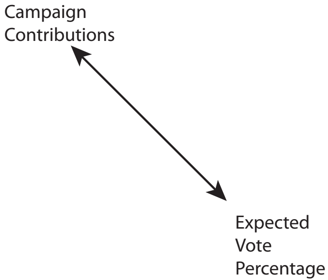

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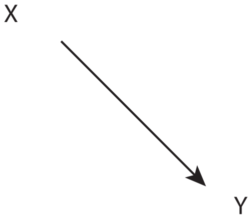
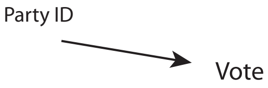
Is this a theoretically plausible causal finding?

Reciprocal Causation



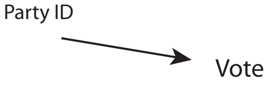
Can we think of other variables that have a reciprocal causal relationship?

A complex causal model



We'll start with a simple model of Vote Choice and build up

A complex causal model



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Strongest predictor of Vote Choice: Party identification

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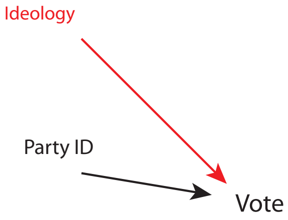
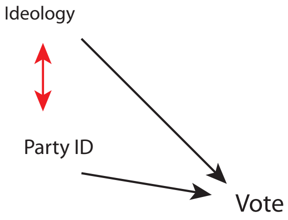


Ideology might have an inde- pendent impact on Vote

Are we missing any arrows?

A complex causal model

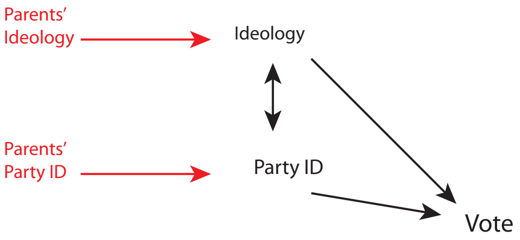


Ideology and Party ID surely influence each other

Reciprocal causation again!

What else is missing?

A complex causal model

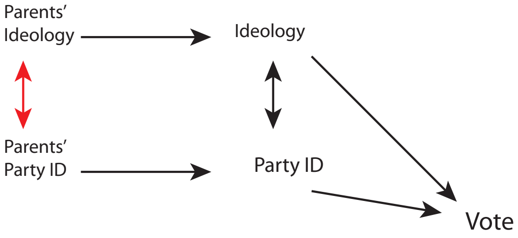


What about parents?

Party ID and Ideology tend to be set in childhood & early adulthood

Any missing arrows?

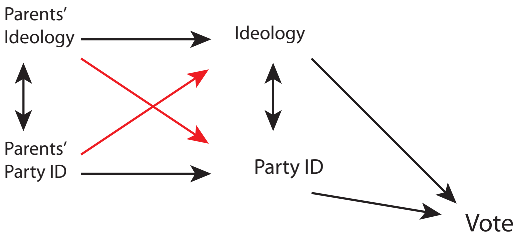
A complex causal model



If Party ID and ideology mutually cause each other for subjects, they should mutually cause for parents

Any other missing arrows?

A complex causal model



Perhaps parents' Party ID causes subject ideology? (Thoughts?)

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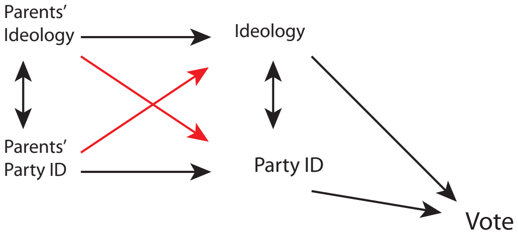
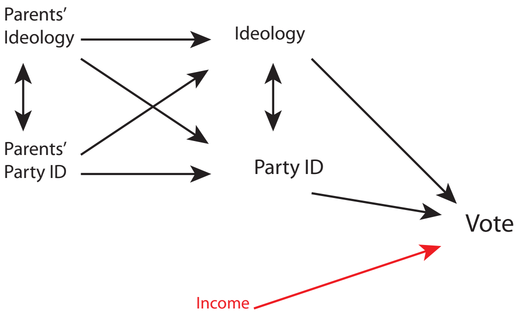


What's correlated in this model?

Uncorrelated?

If our main interest is modeling Vote, what are we still missing?

A complex causal model

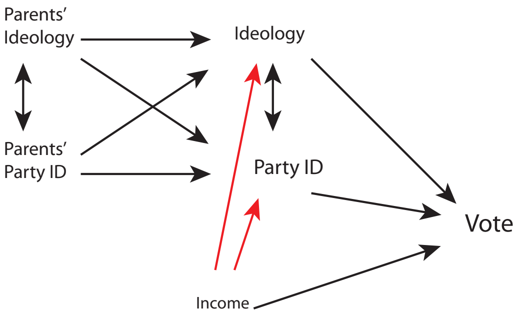


We could add the subject's income

Do we need more arrows?

That is, does Income cause anything else besides vote choice?

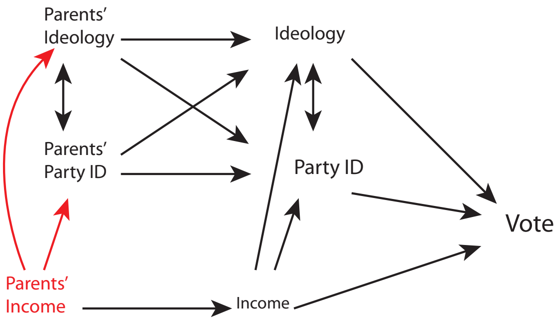
A complex causal model



Income probably shapes Ideology & Party ID directly

Does Income suggest any other missing variables?

A complex causal model

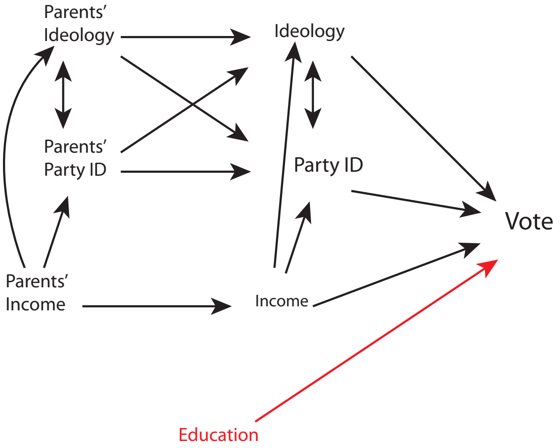


Parents' Income a likely cause of subject's income

Parents' Income should shape Parents' Ideol. & Party ID

Other missing variables?

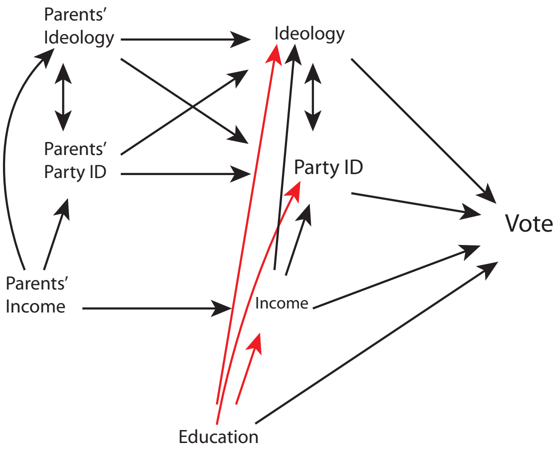
A complex causal model



How about subject's Education? (Is this a simple relationship?)

Are we missing any arrows?

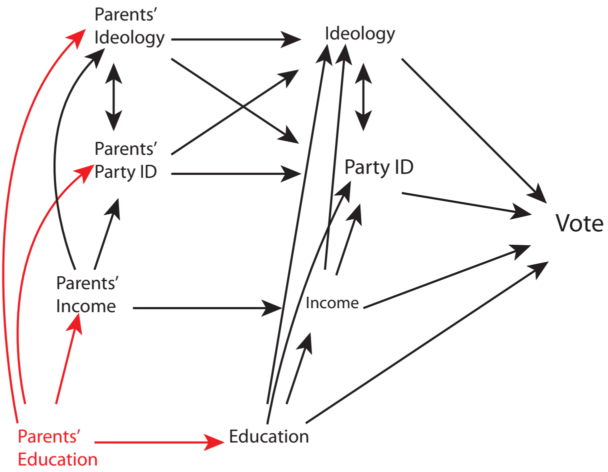
A complex causal model



Lots: Education should influence income, ideology, and Party ID

You can probably guess the last variable in our diagram

A complex causal model

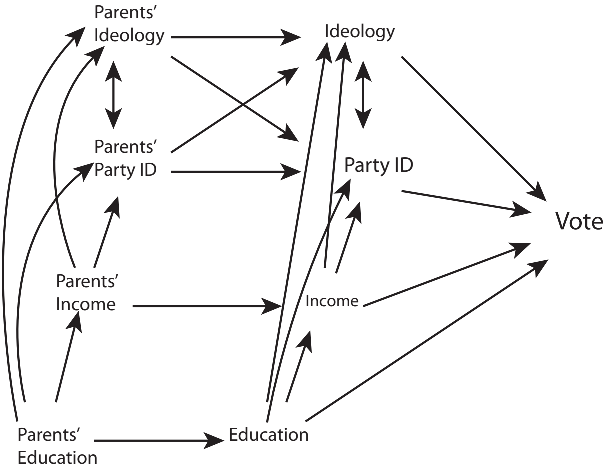


Once again, we include the parents' character-istics

What happens if we omit?

Misattribute effects of parental education!

A complex causal model



What's causally related in this diagram?

What is (and isn't) correlated?

How do we test causal theories?

To tease out the difference between correlation & causation, we'll need some notation:

Definitions

Y_i	dependent variable observed for case i
X_i	treatment variable, as assigned for case i
Z_i	a confounding variable for case i; it may or may not be observed
$\mathrm{E}(A\|B = b)$	expected value of A when $B = b$

Correlation redux

Finding whether two variables are correlated is easy

Simple formula for correlation (we'll discuss at much greater length when we get to quantitative methods):

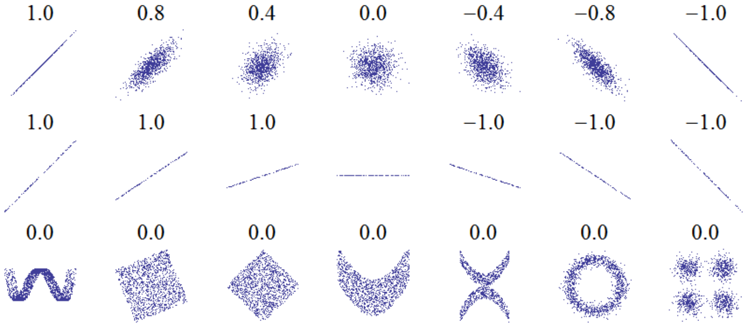
$$\mathrm{corr}(X, Y) = \frac{\mathrm{E}\left((X - \mathrm{E}(X))\,(Y - \mathrm{E}(Y))\right)}{\sqrt{\mathrm{var}(X)}\sqrt{\mathrm{var}(Y)}}$$

where

$$\mathrm{var}(X) = \mathrm{E}\left((X - \mathrm{E}(X))^2\right)$$

Finding whether two variables are causally related is hard

Correlation examples



Fundamental problem of causal inference

$$\text{Average causal effect of } X_i \text{ on } Y_i = \mathrm{E}(Y_i|X_i = 1) - \mathrm{E}(Y_i|X_i = 0)$$

In words, the effect of X_i is the difference between Y_i when X_i is present and Y_i when X_i is absent

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But we only ever observe one of these!

The other is *counterfactual*, and can only be estimated

Why are we taking expectations?
Because there is random noise around each case
We're interested in the *average* causal effect, which removes the random noise

Fundamental problem of causal inference

Would the economy be better or worse had Obama and the Democratic Congress not implemented last year's stimulus package?

If we could rerun time like a tape (er, DVD? Blu-Ray? Video file?),
we could change X_i for the same unit and see the change in Y_i

That is, we could remove the stimulus package,
and track unemployment over the last year

Lacking a time machine, and the power to change history, FPC is unsolvable

Coping with Causality

Can we make some assumptions that would help us tackle FPC?

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- Selection process is related to size of outcome variable
- Points to importance of controls for selection process in observational studies

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Unit homogeneity is at least partly *testable* with enough data

How do we satisfy conditional independence?

Controlled experiment Randomly assign observations to two groups, then (artificially) expose the first group to the treatment. Completely solves.

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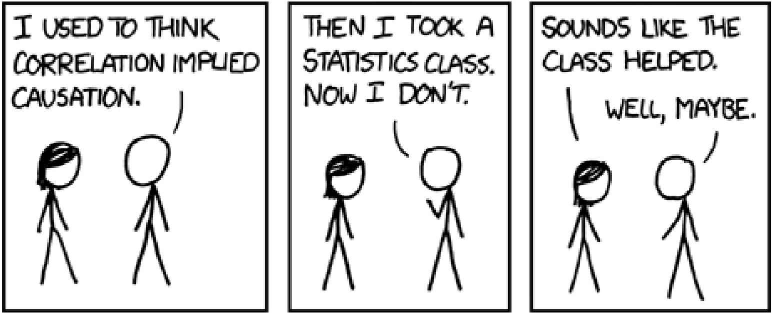
May solve, but never certain. Similar vulnerabilities as Matching.

Can we imagine applying these methods to the effectiveness of Keynesian stimulus?



http://xkcd.com/552/