

Controls

EC 425/525, Set 6

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Prologue

Schedule

Last time

The conditional independence assumption: $\{Y_{0i}, Y_{1i}\} \perp\!\!\!\perp D_i | X_i$
i.e., conditional on some controls (X_i), treatment is as-good-as random.

Today

- Omitted variable bias
- Good vs. bad controls

Upcoming

- Topics: Matching estimators
- Admin: Assignment and midterm

Omitted-variable bias

Omitted-variable bias

Revisiting an old friend

Let's start where we left off: Returns to schooling.

We have two linear, population models

$$Y_i = \alpha + \rho s_i + \eta_i \quad (1)$$

$$Y_i = \alpha + \rho s_i + \mathbf{X}_i' \gamma + \nu_i \quad (2)$$

We should not interpret $\hat{\rho}$ causally in model (1) (for fear of selection bias).

For model (2), we can interpret $\hat{\rho}$ causally **if** $Y_{si} \perp\!\!\!\perp s_i | \mathbf{X}_i$ (CIA).

In other words, the CIA says that our **observable vector \mathbf{X}_i must explain all of correlation between s_i and η_i .**

Omitted-variable bias

The OVB formula

We can use the omitted-variable bias (OVB) formula to compare regression estimates from **models with different sets of control variables**.

We're concerned about selection and want to use a set of control variables to account for ability (\mathbf{A}_i)—family background, motivation, intelligence.

$$Y_i = \alpha + \beta s_i + v_i \quad (1)$$

$$Y_i = \pi + \rho s_i + \mathbf{A}_i' \gamma + e_i \quad (2)$$

What happens if we can't get data on \mathbf{A}_i and opt for (1)?

$$\frac{\text{Cov}(Y_i, s_i)}{\text{Var}(s_i)} = \rho + \gamma' \delta_{As}$$

where δ_{As} are coefficients from regressing \mathbf{A}_i on s_i .

Omitted-variable bias

Interpretation

Our two regressions

$$Y_i = \alpha + \beta s_i + v_i \quad (1)$$

$$Y_i = \pi + \rho s_i + \mathbf{A}_i' \gamma + e_i \quad (2)$$

will yield the same estimates for the returns to schooling

$$\frac{\text{Cov}(Y_i, s_i)}{\text{Var}(s_i)} = \rho + \gamma' \delta_{As}$$

if **(a)** schooling is uncorrelated with ability ($\delta_{As} = 0$) or **(b)** ability is uncorrelated with earnings, conditional on schooling ($\gamma = 0$).

Omitted-variable bias

Example

Table 3.2.1, The returns to schooling

| | 1 | 2 | 3 | 4 |
|------------------|---------|----------|-----------|----------|
| Schooling | 0.132 | 0.131 | 0.114 | 0.087 |
| | (0.007) | (0.007) | (0.007) | (0.009) |
| Controls | None | Age Dum. | 2 + Add'l | 3 + AFQT |

Here we have four specifications of controls for a regression of log wages on years of schooling (from the NLSY).

Omitted-variable bias

Example

Table 3.2.1, The returns to schooling

| | 1 | 2 | 3 | 4 |
|------------------|---------|----------|-----------|----------|
| Schooling | 0.132 | 0.131 | 0.114 | 0.087 |
| | (0.007) | (0.007) | (0.007) | (0.009) |
| Controls | None | Age Dum. | 2 + Add'l | 3 + AFQT |

Column 1 (no control variables) suggests a 13.2% increase in wages for an additional year of schooling.

Omitted-variable bias

Example

Table 3.2.1, The returns to schooling

| | 1 | 2 | 3 | 4 |
|------------------|---------|----------|-----------|----------|
| Schooling | 0.132 | 0.131 | 0.114 | 0.087 |
| | (0.007) | (0.007) | (0.007) | (0.009) |
| Controls | None | Age Dum. | 2 + Add'l | 3 + AFQT |

Column 2 (age dummies) suggests a 13.1% increase in wages for an additional year of schooling.

Omitted-variable bias

Example

Table 3.2.1, The returns to schooling

| | 1 | 2 | 3 | 4 |
|------------------|---------|----------|-----------|----------|
| Schooling | 0.132 | 0.131 | 0.114 | 0.087 |
| | (0.007) | (0.007) | (0.007) | (0.009) |
| Controls | None | Age Dum. | 2 + Add'l | 3 + AFQT |

Column 3 (column 2 controls plus parents' ed. and self demographics) suggests a 11.4% increase in wages for an additional year of schooling.

Omitted-variable bias

Example

Table 3.2.1, The returns to schooling

| | 1 | 2 | 3 | 4 |
|------------------|---------|----------|-----------|----------|
| Schooling | 0.132 | 0.131 | 0.114 | 0.087 |
| | (0.007) | (0.007) | (0.007) | (0.009) |
| Controls | None | Age Dum. | 2 + Add'l | 3 + AFQT |

Column 4 (column 3 controls plus AFQT[†] score) suggests a 8.7% increase in wages for an additional year of schooling.

[†] AFQT is Armed Forces Qualification Test.

Omitted-variable bias

Example

Table 3.2.1, The returns to schooling

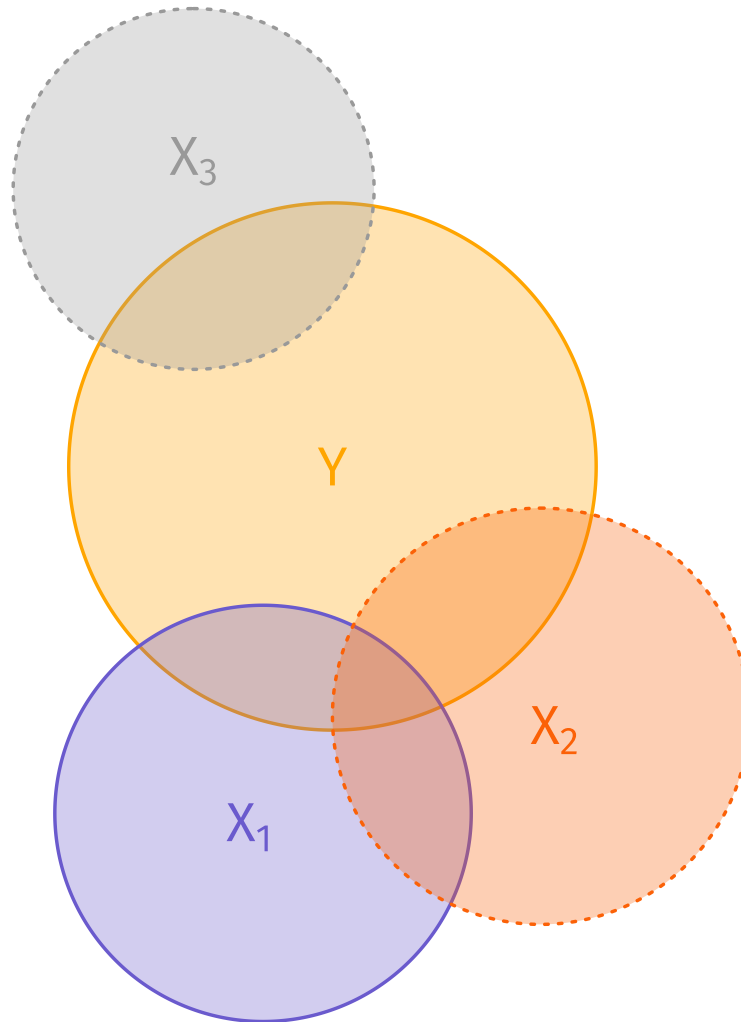
| | 1 | 2 | 3 | 4 |
|------------------|------------------|------------------|------------------|------------------|
| Schooling | 0.132 (0.007) | 0.131 (0.007) | 0.114 (0.007) | 0.087 (0.009) |
| Controls | None | Age Dum. | 2 + Add'l | 3 + AFQT |

As we ratchet up controls, the estimated returns to schooling drop by 4.5 percentage points (34% drop in the coefficient) from **Column 1** to **Column 4**.

$$\frac{\text{Cov}(Y_i, s_i)}{\text{Var}(s_i)} = \rho + \gamma' \delta_{As}$$

If we think **ability positively affects wages**, then it looks like we also have **positive selection into schooling**.

Omitted: X_2 and X_3



Omitted-variable bias

Note

This OVB formula **does not** require either of the models to be causal.

The formula compares the regression coefficient in a **short model** to the regression coefficient on the same variable in a **long model**.[†]

[†] Here, **long model** refers to a model with more controls than the **short model**.

Omitted-variable bias

The OVB formula and the CIA[†]

In addition to helping us think through and sign OVB, the formula

$$\frac{\text{Cov}(Y_i, s_i)}{\text{Var}(s_i)} = \rho + \gamma' \delta_{As}$$

drives home the point that we're leaning *very* hard on the conditional independence assumption to be able to interpret our coefficients as causal.

Q When is the CIA plausible?

A Two potential answers

1. Randomized experiments
2. Programs with arbitrary cutoffs/lotteries

[†] The title for my first spy novel.

Control variables play an enormous role in our quest for causality (the CIA).

Q Are "more controls" always better (or at least never worse)?

A No. There are such things as...

Bad controls

Bad controls

Defined

Q What's a *bad* control—when can a control make a bad situation worse?

A *Bad controls* are variables that are (also) affected by treatment.

Q Okay, so why is it bad to control using a variable affected by treatment?

Hint It's a flavor of selection bias.

Let's consider an example...

Bad controls

Example

Suppose we want to know the **effect of college graduation on wages**.

1. There are only two types of jobs: blue collar and white collar.
2. White-collar jobs, on average, pay more than blue-collar jobs.
3. Graduating college increases the likelihood of a white-collar job.

Q Should we control for occupation type when considering the effect of college graduation on wages? (Will occupation be an omitted variable?)

A No. Imagine college degrees are randomly assigned. When we condition on occupation, we compare degree-earners who chose blue-collar jobs to non-degree-earners who chose blue-collar jobs. Our assumption of random degrees says **nothing** about random job selection.

Bad controls

Formal-ish derivation

More formally, let

- W_i be a dummy for whether i has a white-collar job
- Y_i denote i 's earnings
- C_i refer to i 's **randomly assigned** college-graduation status

$$Y_i = C_i Y_{1i} + (1 - C_i) Y_{0i}$$
$$W_i = C_i W_{1i} + (1 - C_i) W_{0i}$$

Because we've assumed C_i is randomly assigned, differences in means yield causal estimates, *i.e.*,

$$E[Y_i \mid C_i = 1] - E[Y_i \mid C_i = 0] = E[Y_{1i} - Y_{0i}]$$
$$E[W_i \mid C_i = 1] - E[W_i \mid C_i = 0] = E[W_{1i} - W_{0i}]$$

Bad controls

Formal-ish derivation, continued

Let's see what happens when we throw in some controls—*e.g.*, focusing on the the wage-effect of college graduation for white-collar jobs.

$$\begin{aligned} & E[Y_i \mid W_i = 1, C_i = 1] - E[Y_i \mid W_i = 1, C_i = 0] \\ &= E[Y_{1i} \mid W_{1i} = 1, C_i = 1] - E[Y_{0i} \mid W_{0i} = 1, C_i = 0] \\ &= E[Y_{1i} \mid W_{1i} = 1] - E[Y_{0i} \mid W_{0i} = 1] \\ &= E[Y_{1i} \mid W_{1i} = 1] - E[Y_{0i} \mid W_{1i} = 1] \\ &\quad + E[Y_{0i} \mid W_{1i} = 1] - E[Y_{0i} \mid W_{0i} = 1] \\ &= \underbrace{E[Y_{1i} - Y_{0i} \mid W_{1i} = 1]}_{\text{Causal effect on white-collar workers}} + \underbrace{E[Y_{0i} \mid W_{1i} = 1] - E[Y_{0i} \mid W_{0i} = 1]}_{\text{Selection bias}} \end{aligned}$$

Bad controls

Formal-ish derivation, continued

By introducing a bad control, we introduced selection bias into a setting that did not have selection bias without controls.

Specifically, the selection bias term

$$E[Y_{0i} \mid W_{1i} = 1] - E[Y_{0i} \mid W_{0i} = 1]$$

describes how college graduation changes the composition of the pool of white-class workers.

Note Even if the causal effect is zero, this selection bias need not be zero.

Bad controls

A trickier example

A timely/trickier example: Wage gaps (*e.g.*, female-male or black-white).

Q Should we control for occupation when we consider wage gaps?

- What are we trying to capture?
- If we're concerned about discrimination, it seems likely that discrimination also affects occupational choice and hiring outcomes.
- Some motivate occupation controls with groups' differential preferences.

What's the answer?

Bad controls

Proxy variables

Angrist and Pischke bring up an interesting scenario that intersects omitted-variable bias and bad controls.

- We want to estimate the returns to education.
- Ability is omitted.
- We have a proxy for ability—a test taken after schooling finishes.

We're a bit stuck.

1. If we omit the test altogether, we've got omitted-variable bias.
2. If we include our proxy, we've got a back control.

With some math/luck, we can bound the true effect with these estimates.

Bad controls

Example

Returning to our OVB-motivated example, we control for occupation.

| Table 3.2.1, The returns to schooling | | | | | |
|---------------------------------------|---------|----------|-----------|----------|----------------|
| | 1 | 2 | 3 | 4 | 5 |
| Schooling | 0.132 | 0.131 | 0.114 | 0.087 | 0.066 |
| | (0.007) | (0.007) | (0.007) | (0.009) | (0.010) |
| Controls | None | Age Dum. | 2 + Add'l | 3 + AFQT | 4 + Occupation |

Schooling likely affects occupation; how do we interpret the new results?

Bad controls

Conclusion

Timing matters.

The right controls can help tremendously, but bad controls hurt.

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