

Research Design

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Health Services Research

- Many questions in health services research aim to establish causality
 - Does the adoption of electronic medical records reduce health care costs or improve quality of care?
 - Did the transition to Patient Aligned Care Teams (PACT) improve quality of care and health outcomes?
 - What effect will the Affordable Care Act (ACA) have on the demand for VHA services?
- Ideally studied through randomized controlled trials
- When can regression analysis of observational data answer these questions?

Poll: Familiarity with Regressions

- How would you describe your familiarity with regression analysis?
 - Regression is my middle name.
 - I've run a few regressions and get the gist of how they work.
 - I took a statistics class many years ago.
 - What is a regression?
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Objectives

- Provide a conceptual framework for research design
 - Review the linear regression model
 - Define exogeneity and endogeneity
 - Discuss three forms of endogeneity
 - Omitted variable bias
 - Sample selection
 - Simultaneous causality
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Research Question

- Start with a research question:
 - What is the effect of X on Y ?
- For example:
 - What effect does education have on health?

Linear Regression Model

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + e_i$$

- Y : outcome variable of interest
- X_1 : explanatory variable of interest
- X_2 : control variable
- e : error term
 - e is the difference between the observed and predicted values of Y
 - e contains all other factors besides X_1 and X_2 that determine the value of Y
- β_1 : the change in Y associated with a unit change in X_1 , holding constant X_2
 - $\hat{\beta}_1$ is our estimate of β_1
- Model specifies all meaningful determinants of Y

Linear Regression Model (2)

- In our example:

$$health_i = \beta_0 + \beta_1 education_i + e_i$$

- *health*: dependent variable
 - *education*: independent variable
 - *e*: error term
 - *e* contains all other factors besides education that determine health
 - β_1 : the change in health associated with an increase in education
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- When does $\hat{\beta}_1$ estimate the *causal* effect of education on health?

Exogeneity

- Assumption: $E(e_i|X_i) = 0$
 - Conditional mean of e_i given X_i is zero
 - Conditional mean independence
 - X is “exogenous”
 - Knowing X_i does not help us predict e_i
 - e_i is the difference between the observed and predicted values of Y_i
 - e_i contains other factors besides X_i that determine the value of Y_i
 - Information other than X_i does not tell us anything more about Y_i
 - Implies that X_i and e_i **cannot** be correlated
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Exogeneity (2)

- In the context of a randomized controlled trial:

$$outcome_i = \beta_0 + \beta_1 treatment_i + e_i$$

- e_i can include things like age, gender, pre-existing conditions, income, education, etc.
- Because treatment is randomly assigned, *treatment* and e are independent
 - This implies *treatment* is exogenous
- In observational studies, *treatment* is not randomly assigned
 - The best we can hope for is that *treatment* is *as if* randomly assigned

Exogeneity (3)

- In our example:

$$health_i = \beta_0 + \beta_1 education_i + e_i$$

- In order for $\hat{\beta}_1$ to estimate the causal effect of education on health, *education* must be exogenous
 - All factors other than education do not tell us anything more about health
- In the context of a randomized controlled trial, *education* is exogenous
 - Is the same true in the context of observational studies?

Endogeneity

- Violation of the exogeneity assumption
 - X is endogenous
 - Always true when X_i is correlated with e_i
- $\hat{\beta}_1$ is biased
 - $\hat{\beta}_1$ is unbiased if the expected value of $\hat{\beta}_1$ is equal to the true value of β_1
- $\hat{\beta}_1$ will not estimate a causal effect of X on Y
 - $\hat{\beta}_1$ is a measure of the correlation between X and Y
 - Correlation does not imply causation

Forms of Endogeneity

- Omitted variable bias
- Sample selection
- Simultaneous causality

Omitted Variable Bias

- Arises when:
 - A variable omitted from the regression model is a determinant of the dependent variable, Y
 - The omitted variable is correlated with the regressor, X
 - Leads $\hat{\beta}_1$ to be biased
 - $\hat{\beta}_1$ also captures the correlation between the omitted variable and the dependent variable
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Omitted Variable Bias (2)

- Regression model: $Y_i = \beta_0 + \beta_1 X_i + e_i$
- Say another factor, W_i , determines Y_i
 - W_i is included in the error term, e_i
- If X_i and W_i are correlated
 - X_i and e_i are correlated
- X_i is endogenous
 - $\hat{\beta}_1$ is biased
 - $\hat{\beta}_1$ also captures the correlation between W_i and Y_i

Omitted Variable Bias: Example

- In our example:

$$health_i = \beta_0 + \beta_1 education_i + e_i$$

- Two questions:
 - Besides education, do any other factors determine health?
 - Are those factors correlated with education?
- Consider two factors: income and social networks

Omitted Variable Bias: Example (2)

- Income
 - Individuals with higher incomes may be more able to afford goods and services that promote good health
 - Individuals with higher levels of education tend to have higher incomes
- Social networks
 - Individuals with greater social networks may be more able to obtain better health care
 - Individuals with higher levels of education are more likely to have social networks that facilitate access to better health care

Omitted Variable Bias: Solutions

- Multiple linear regression
 - Include all relevant factors in the regression model so that we have conditional mean independence
 - Often not possible to include all omitted variables in the regression
 - Randomized controlled trial
 - Natural experiment
 - More on this in the Natural Experiments and Difference-in-Differences lecture on April 8
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Omitted Variable Bias: Solutions (2)

- Utilize panel data (same observational unit observed at different points in time)
 - Fixed effects regression: control for unobserved omitted variables that do not change over time
 - For more information: Stock and Watson, Chapter 10
- Instrumental variables regression
 - Utilize an instrumental variable that is correlated with the independent variable of interest but is uncorrelated with the omitted variables
 - More on this in the Instrumental Variables Regression lecture on April 22

Sample Selection

- Arises when:
 - A selection process influences the availability of data
 - The selection process is related to the dependent variable, Y , beyond depending on X
 - Leads $\hat{\beta}_1$ to be biased
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Sample Selection (2)

- Form of omitted variable bias
 - The selection process is captured by the error term
 - Induces correlation between the regressor, X , and the error term, e

Sample Selection: Examples

- Want to evaluate the effect of a new tobacco cessation program (offered to all patients) on quitting
 - $quit_i = \beta_0 + \beta_1 treatment_i + e_i$
 - Problem: Individuals who participate in the program may be more likely to quit to begin with
- Want to evaluate the effect of a new primary care model (rolled out for some patients at a facility) on patient satisfaction
 - $satisfaction_i = \beta_0 + \beta_1 model_i + e_i$
 - Problem: Patients who don't like the new program stop coming to the facility and receive their care elsewhere

Sample Selection: Solutions

- Randomized controlled trial
- Natural experiment
 - More on this in the Natural Experiments and Difference-in-Differences lecture on April 8
- Sample selection and treatment effect models
 - For more information:
 - Greene, 2000 Chapter 20
 - Wooldridge, 2010, Chapter 17
- Instrumental variables regression
 - More on this in the Instrumental Variables Regression lecture on April 22

Simultaneous Causality

- Arises when:
 - There is a causal link from X to Y
 - There is also a causal link from Y to X
 - Also called simultaneous equations bias
 - Leads $\hat{\beta}_1$ to be biased
 - Reverse causality leads $\hat{\beta}_1$ to pick up both effects
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Simultaneous Causality: Example

- We want to estimate the effect of primary care visits on health

$$health_i = \beta_0 + \beta_1 pcvisits_i + e_i$$

- If a person's health also affects the likelihood of making a primary care visit:

$$pcvisits_i = \gamma_0 + \gamma_1 health_i + \varepsilon_i$$

- Both equations are necessary to understand the relationship between primary care visits and health

Simultaneous Causality: Example (2)

- We now have two simultaneous equations:

$$health_i = \beta_0 + \beta_1 pcvisits_i + e_i \quad (1)$$

$$pcvisits_i = \gamma_0 + \gamma_1 health_i + \varepsilon_i \quad (2)$$

- Suppose a positive error e_i leads to a higher value of $health_i$ (better health)

$$health_i = \beta_0 + \beta_1 pcvisits_i + e_i \quad (1)$$


- If $\gamma_1 < 0$, then a higher value of $health_i$ leads to a lower value of $pcvisits_i$

$$pcvisits_i = \gamma_0 + \overset{<0}{\gamma_1} health_i + \varepsilon_i \quad (2)$$


- Therefore, a positive error e_i leads to a lower value of $pcvisits_i$
 - $e_i \uparrow \rightarrow pcvisits_i \downarrow$
 - $pcvisits_i$ and e_i are correlated
 - $\hat{\beta}_1$ is biased

Simultaneous Causality: Solutions

- Randomized controlled trial where the reverse causality channel is eliminated
 - Natural experiment
 - More on this in the Natural Experiments and Difference-in-Differences lecture on April 8
 - Instrumental variables regression
 - Utilize an instrumental variable that is correlated with X but is uncorrelated with the error term (does not otherwise determine Y)
 - More on this in the Instrumental Variables Regression lecture on April 22
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Summary

- Good research design requires an understanding of how the dependent variable is determined
- Need to ask: is the explanatory variable of interest exogenous?
 - Are there omitted variables?
 - Is there sample selection?
 - Is there simultaneous causality?
- Exogeneity is necessary for the estimation of a causal treatment effect
- Understanding sources of endogeneity can:
 - Help us understand what our regression estimates actually estimate and the limitations of our analyses
 - Can point us to appropriate methods to use to answer our research question

Resources

- Stock and Watson, Introduction to Econometrics, 3rd edition (2011)
- Green, Econometric Analysis, 7th edition (2012)
- Wooldridge, Econometric Analysis of Cross Section and Panel Data, 2nd edition (2010)