

Instrumental Variables (IV)

1) The Takeaway

- Instrumental variables are a general identification strategy that can be used to deal with selection on unobservable confounders (omitted variable bias), simultaneity and endogeneity, and measurement error
- We use two-stages, where the 1st stage estimates the impact of the instrument on treatment assignment, and the second stage estimates the impact of the treatment on the outcome of interest

2) Pros

- When you have a good IV, IV is as good as random
- Deal with selection on unobservable confounders

3) Cons

- There are up to 5 assumptions that need to hold in order for IV to be unbiased and it is very, very hard to find an IV that satisfies all 5 assumptions
- We have larger standard errors with IV
- We can only identify the local average treatment effects (LATE) for compliers

4) The IV Estimator

- With Homogenous Treatment Effects: $\delta_{IV} = \frac{C(Y,Z)}{C(D,Z)}$
- With Heterogenous Treatment Effects: $\delta_{IV,LATE} = \frac{EffectofZonY}{EffectofZonD} = \frac{E[Y_i(D_i^1,1) - Y_i(D_i^0,0)]}{E[D_i^1 - D_i^0]} = E[(Y_i^1 - Y_i^0) | D_i^1 - D_i^0 = 1]$ is the impact of the treatment for the complier population
- Two-Stage Least Squares Estimator: $\hat{\delta}_{IV} = \frac{C(Z,Y)}{C(Z,D)} = \frac{C(\hat{D},Y)}{V(\hat{D})}$

5) Assumptions and Testable Assumptions

- Exclusive Restriction Assumption (Homogenous and Heterogenous Treatment Effects)
 - The instrument works only through the treatment on our outcome of interest
 - If the instrument is correlated with an observed or unobserved factor then the estimator will be biased
 - $C(Z, X) = 0$, $C(Z, U) = 0$, and $C(Z, \varepsilon) = 0$
 - This assumption is only testable on observable covariates and untestable on unobserved covariates
 - For heterogenous treatment effects: $Y_i(D_i, Z_i)$ is a function of D_i only
- Non-zero 1st stage assumption (Homogenous and Heterogenous Treatment Effects)
 - The instrument must be correlated with the treatment $C(Z, D) \neq 0$
 - For heterogeneous treatment effect: $E[D_i^1 - D_i^0] \neq 0$
 - This assumption is testable
- Independence assumption (Heterogenous Treatment Effects)
 - This assumption states that potential outcomes AND **potential treatment status** is independent of the instrument

- ii. $\{Y_i(D_i^1, 1), Y_i(D_i^0, 0), D_i^1, D_i^0\} \perp Z_i$
 - iii. $E[D_i|Z_i = 1] - E[D_i|Z_i = 0] = E[D_i^1|Z_i = 1] - E[D_i^0|Z_i = 0] = E[D_i^1 - D_i^0]$
 - iv. For example, a draft lottery is independent of potential outcomes and potential treatment status. Is correlated with the actual treatment, but not the potential treatment status?
 - d. Stable Unit Treatment Value Assumption (SUTVA) (Heterogenous Treatment Effects)
 - i. No spillover effects
 - ii. For example, if Child A wins a lottery into a charter school and Child B gets to enroll due to Child A winning, then that is a spillover/externality
 - e. Monotonicity Assumption (Heterogenous Treatment Effects)
 - i. This assumption requires that the instrument to operate in the same direction on all individuals
 - ii. For example, if a judge is not consistent and gives severe and leniency in inconsistent ways, then the monotonicity assumption would be violated
 - iii. From the switching equation, $D_i = \pi_0 + \pi_1 Z_i + \phi_i$, π_1 is the causal effect of the instrument on the treatment and $\pi_{1i} \geq 0 \forall i$ or $\pi_{1i} \leq 0 \forall i$
- 6) Potential Treatment Status
- a. Compliers are the focus of the LATE: $D_i^1 - D_i^0 = 1$
 - b. See Discussion #5 on ELMS
- 7) Popular Instrumental Variables
- a. Lotteries
 - i. A draft lottery for military service, charter schools, or Medicaid expansion
 - ii. Pro: These are a powerful instrument for treatment assignment
 - iii. Con: They may suffer from nonrandom attrition or noncompliance
 - iv. Intent to Treat (ITT) will be smaller than the LATE, since not everyone who is awarded treatment takes up treatment
 - b. Judge Fixed Effects
 - i. Using a randomized wheel of judges to assign cases to different judges
 - ii. 3 Concepts with Judge Fixed Effects
 - 1. There is a narrow window that all justice-involved individuals must go through
 - 2. Randomized assignment to judges
 - 3. There is discretion among the judges
 - c. Bartik Instruments
 - i. See Discussion #5 on ELMS