THE WORLD BANK

IMPACT EVALUATION

# Technical Track
# Session IV
# Instrumental Variables

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# An example to start off with…

- Say we wish to evaluate a voluntary job training program
  - Any unemployed person is elegible
  - Some people choose to register ("Treatments")
  - Other people choose not to register ("Comparisons")

- Some simple (but not-so-good) ways to evaluate the program:
  - Compare before and after situation in the treatment group
  - Compare  situation of treatments and comparisons after the intervention
  - Compare situation of treatments and comparisons before and after

# Voluntary job training program

Say we decide to compare outcomes for those who participate to the outcomes of those who do not participate:

a simple model to do this:

$$y = \alpha + \beta_1 D + \beta_2 x + \varepsilon$$

Where $D$ = 1 if person participates in training

$D$ = 0 if person does not participate in training

$x$ = control variables ( exogenous & observable)

Why is this not working properly? 2 problems:

- ▹ Variables that we omit (for various reasons) but that are important
- ▹ Decision to participate in training is endogenous

# Problem #1: Omitted Variables

Even in a well-thought model, we'll miss

▹ "forgotten" characteristics: we didn't know they mattered

▹ characteristics that are too complicated to measure

*Examples*:

▹ Varying talent and levels of motivation

▹ Different levels of information

▹ Varying opportunity cost of participation

▹ Varying level of access to services

The full "correct" model is: $y = \alpha + \gamma_1 D + \gamma_2 x + \gamma_3 M + \eta$

The model we use: $y = \alpha + \beta_1 D + \beta_2 x + \varepsilon$

# Problem #2: Endogenous Decision to Participate

- Participation is a decision variable? ➔ endogenous!
- (I.e. it depends on the participants themselves)

$$y = \alpha + \beta_1 D + \beta_2 x + \varepsilon$$
$$D = \pi + \pi_2 M + \xi$$

$$=> y = \alpha + \beta_1(\pi + \pi_2 M + \xi) + \beta_2 x + \varepsilon$$
$$=> y = \alpha + \beta_1 \pi + \beta_2 x + \beta_1 \pi_2 M + \beta_1 \xi + \varepsilon$$

- So: in the two cases: we're missing the M term, which we need to estimate the correct model, but which we cannot measure properly.

- The "correct model is: $y = \alpha + \gamma_1 D + \gamma_2 x + \gamma_3 M + \eta$
- Simplified model: $y = \alpha + \beta_1 D + \beta_2 x + \varepsilon$

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- Say we estimate the treatment effect $\gamma_1$ with $\beta_{1,OLS}$
- If $M$ is correlated with $D$, and we don't include $M$ in the simplified model, then the estimator of the parameter on $D$ will pick up part of the effect of $M$. This will happen to the extent that $M$ and $D$ are correlated.
- Thus: our OLS estimator $\beta_{1,OLS}$ of the treatment effect $\gamma_1$ captures the effect of other characteristics ($M$) in addition to the treatment effect.
- This means that there is a difference between $E(\beta_{1,OLS})$ and $\gamma_1$

  → the expected value of the OLS estimator $\beta_1$ isn't $\gamma_1$, the real treatment effect

  → $\beta_{1,OLS}$ is a biased estimator of the treatment effect $\gamma_1$.

- The "correct model is: $y = \alpha + \gamma_1 T + \gamma_2 x + \gamma_3 D + \eta$
- Simplified model: $y = \alpha + \beta_1 T + \beta_2 x + \varepsilon$

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- This means that there is a difference between $E(\beta_{1,OLS})$ and $\gamma_1$
  → the expected value of the OLS estimator $\beta_1$ isn't $\gamma_1$, the real treatment effect
  → $\beta_{1,OLS}$ is a biased estimator of the treatment effect $\gamma_1$.

- Why did this happen?
  - One of the basic conditions for OLS to be BLUE was violated:

- In other words $E(\beta_{1,OLS}) \neq \gamma_1$ (biased estimator)
- Even worse…..$plim(\beta_{1,OLS}) \neq \gamma_1$ (inconsistent estimator)

# What can we do to solve this problem?

$$y = \alpha + \gamma_1 D + \gamma_2 x + \gamma_3 M + \eta$$

$$y = \alpha + \beta_1 D + \beta_2 x + \varepsilon$$

- Try to clean the correlation between $D$ and $\varepsilon$:
- Isolate the variation in $D$ that is not correlated with $\varepsilon$ through the omitted variable $M$
- We can do this using an instrumental variable (*IV*)

# Basic idea behind IV

$$y = \alpha + \gamma_1 D + \gamma_2 x + \gamma_3 M + \eta$$

$$y = \alpha + \beta_1 D + \beta_2 x + \varepsilon$$

- The basic problem is that *corr (D,M)* ≠ *0*
- Find a variable *Z* that satisfies two conditions:
  1. Correlated with *D*: *corr (Z , D)* ≠ *0*

     ---- *Z* and *D* are correlated, or *Z* predicts part of *D*
  2. *Z* is not correlated with *ε*: *corr (Z , ε) = 0*

     ----By itself, *Z* has no influence on *y*. The only way it can influence *y* is because it influences *D*. All of the effect of *Z* on *y* passes through *D*.
- Examples of *Z* in the case of voluntary job training program?

# Two-stage least squares (2SLS)

Remember the original model with endogenous $D$:

$$y = \alpha + \beta_1 D + \beta_2 x + \varepsilon$$

Step 1: Regress the endogenous variable D on the instrumental variable(s) Z and other exogenous variables

$$D = \delta_0 + \delta_1 x + \theta_1 Z + \tau$$

▹ Calculate the predicted value of $D$ for each observation: $\hat{D}$

▹ Since $Z$ and $x$ are not correlated with $\varepsilon$ , neither will be $\hat{D}$.

▹ You will need one instrumental variable for each potentially endogenous regressor

# Two-stage least squares (2SLS)

Step 2: Regress $y$ on the predicted variable $\hat{D}$ and the other exogenous variables

$$y = \alpha + \beta_1 \hat{D} + \beta_2 x + \varepsilon$$

- ▹ Note: the standard errors of the second stage OLS need to be corrected because $\hat{D}$ is not a fixed regressor.
- ▹ In practice: use STATA ivreg command, which does the two steps . at once and reports correct standard errors.
- ▹ Intuition: by using $Z$ for $D$, we cleaned $D$ of its correlation with $\varepsilon$.
- ▹ It can be shown that (under certain conditions) $IV$ yields a consistent estimator of $\gamma_1$(large sample theory)

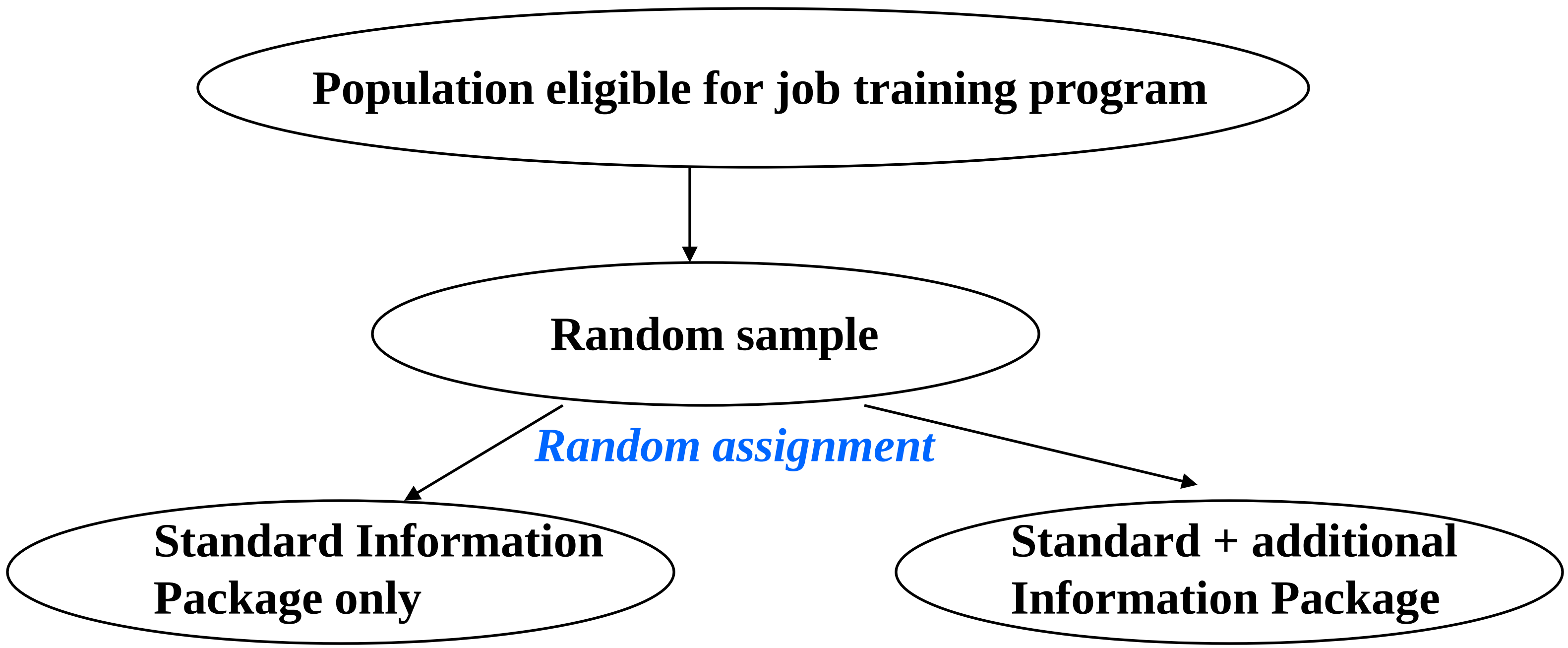
# Uses of instrumental variables

- Simultaneity: X and Y cause each other
  - instrument X
- Omitted Variables: X is picking up the effect of other variables which are omitted
  - instrument X with a variable that is not correlated with the omitted variable(s)
- Measurement Error: X is not measured precisely
  - instrument X

# Where do we find instrumental variables?

- Searching for one – hard!
- Creating one with information
  - If everyone is eligible to participate in treatment
  - But some have more information than others
    - Who has more information will be more likely to participate
  - Provision of "additional information" on a random basis

# Example 1: voluntary job training program




**Monthly income 1 year later = 700**

**Monthly income one year later= 850**

**30 percent takeup**

**90 percent takeup**

**Question: what is the impact of the job training program?**

| Standard Information Package only | Standard + additional Information Package |
|---|---|
| Monthly income 1 year later = 700 | Monthly income one year later= 850 |
| 30 percent takeup | 90 percent takeup |

**Question: what is the impact of the job training program?**

- **Difference between the "well informed" and "not well informed" group**

  **…………………………………**

- **Corrected for the differential take-up rate**

  **…………………………………**

- **Practically: Impact = ……………………………**

# Link back to the estimation formula

- Stage 1:
  - Regress the participation on training on a dummy for whether person received additional information package (linear model)
  - Compute predicted value of participation

- Stage 2:
  - Regress wages on the predicted value of participation

# Example 2: School autonomy in Nepal

- Goal is to evaluate
  - A. Autonomous school management by communities
  - B. School report cards
- Data
  - You can include 1000 schools in the evaluation
  - Each community freely chooses to participate or not.
  - School report cards done by NGOs
  - Each comunity has exactly one school.
- Task: design the implementation of the program so it can be evaluated – propose method of evaluation.

# School autonomy in Nepal

| | | Intervention B: School report card intervention by NGO | | |
|---|---|---|---|---|
| | | Yes | No | *Total* |
| Instrumental Variable for Intervention A: NGO visits community to inform on procedures for transfer of the school to community management | Yes | 300 | 300 | *600* |
| | No | 200 | 200 | *400* |
| | *Total* | *500* | *500* | *1000* |

# Reminder and a word of caution….

- *corr* $(Z,\varepsilon) = 0$
  - if *corr* $(Z, \varepsilon) \neq 0$ "Bad instrument" ¡Problem!
  - ¡Finding a good instrument is hard!
  - ¡Use both theory and common sense to find one!
  - We can think of designs that yield good instruments.

- *corr* $(Z,D) \neq 0$
  - "Weak instruments": the correlation between *Z* and *D* needs to be sufficiently strong.
  - If not, the bias stays large even for large sample sizes.