Instrumental Variables I: Theory

Lecture 9 - Introduction to Causal Inference

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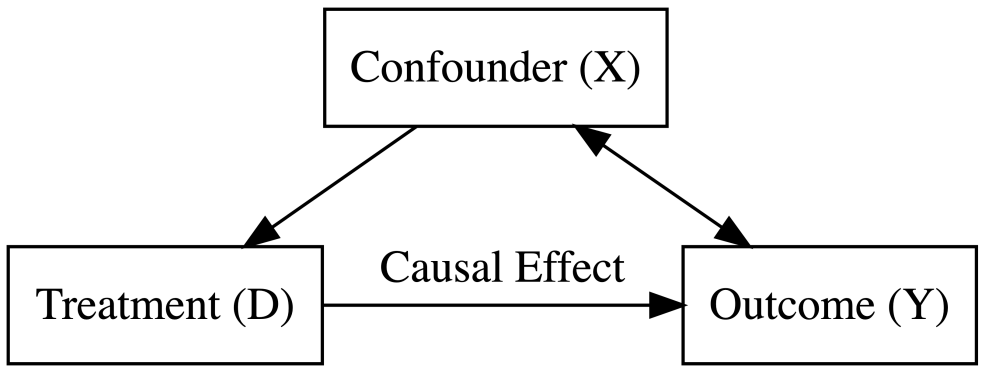
Our Issue

Issue: We want to find the effect of treatment D on outcome Y, but there is a confounder.

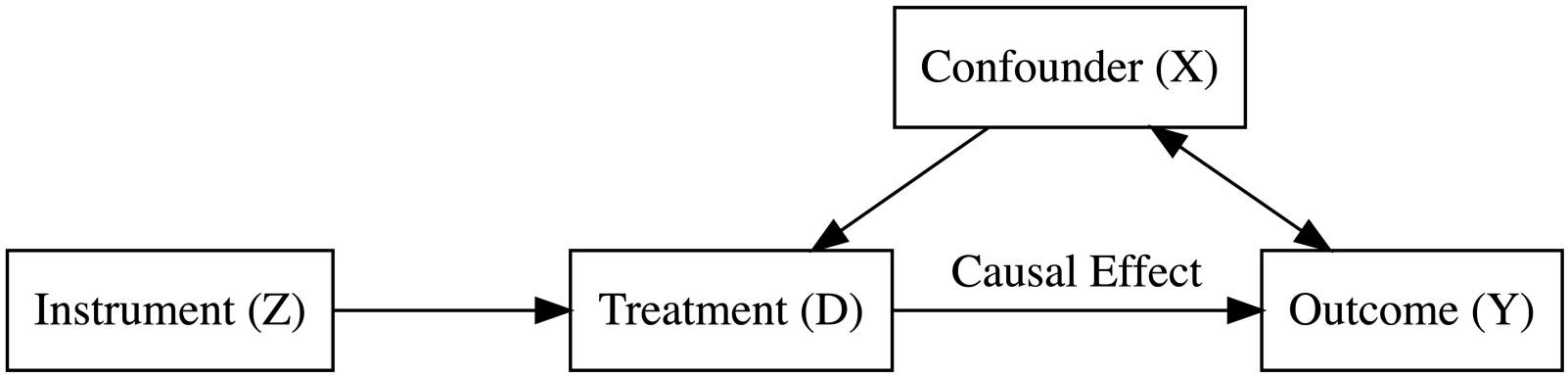


Let us say a random experiment is not possible (we do not control who gets or does not get the scholarship).

- How can we get the treatment D to be exogenous to get the causal effect?

Instrumental Variable

What if we have an extra variable Z:

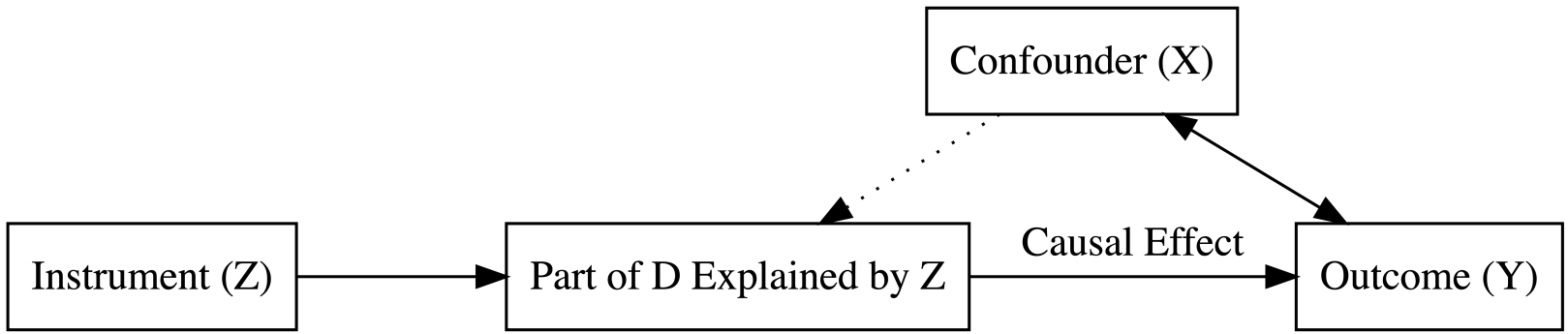


This **instrumental variable** Z has a few characteristics:

1. Z is correlated with the treatment D.
2. Z is uncorrelated with any confounder X.
3. Z has no direct effect on the outcome Y (only through D).
4. Z is **exogenous** to Y (no confounders between Z and Y).

Inducing Exogeneity in Treatment

Instead of using our original treatment variable D, let us instead only use the **part of D caused by Z**. Let us call this $\hat{D}$.



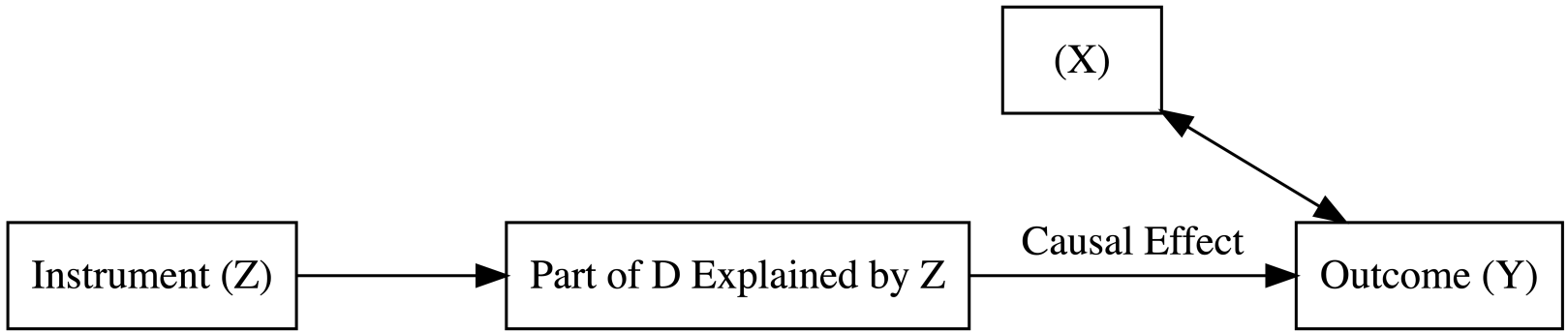
The confounder X does not cause $\hat{D}$. Why?

- Because $\hat{D}$ is the part of D explained by Z.
- Since Z is uncorrelated with X, then $\hat{D}$ is not caused by X.

Thus, X is no longer a confounder - since it doesn't affect selection in $\hat{D}$.

Instrumental Variables Estimator

By using an instrument Z and $\hat{D}$, X is no longer a confounder between $\hat{D}$ and Y. Thus, $\hat{D}$ is exogenous (if Z is exogenous).



Since $\hat{D}$ is exogenous and there are no more confounders between $\hat{D}$ and Y, we can calculate the causal effect of $\hat{D}$ on Y.

- This is the Local Average Treatment Effect of $\hat{D}$ on Y.
- Note: This might not be the same as the effect of D on Y (we are using $\hat{D}$, not D).

Local Average Treatment Effect

The calculated treatment effect of $\hat{D}$ on Y is called the local average treatment effect.

- Substantively, it is the causal effect of D on Y for the part of D explained by Z
- This is also called the causal effect for **compliers**. Compliers are the units whose treatment D that "comply" (are influenced/caused) by the exogenous Z.

As noted before, this might not be equal to the total average treatment effect (ATE) between D and Y.

- This has caused debates over the usefulness of the LATE of $\hat{D}$ on Y. Some believe LATE is not that useful, while others believe it is better than nothing.

Requirements of a Valid Instrument

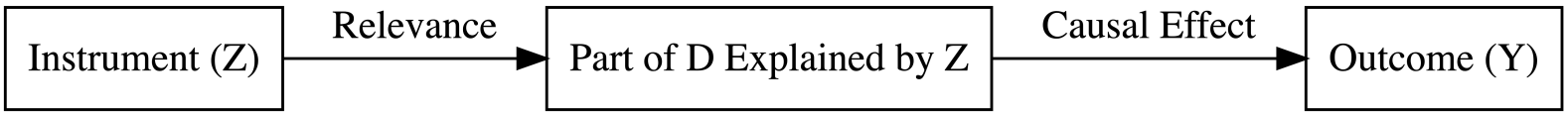
For instrumental variables to work, we must have an instrument that meets 3 assumptions:

- **Relevance**: Z must be correlated with D.
- **Exogeneity**: Z must be exogenous/randomly assigned in respect to both D and Y. That means no confounders between Z and Y, and Z and D.
- **Exclusions**: Z must not have a direct causal effect on Y (It should have an indirect one through D, but no direct causal effect).

The next few slides covers each in more detail.

Relevance Assumption

The relevance assumption is that Z must be correlated with D.



This makes sense - if Z is not correlated with D, then no part of D can be explained by Z.

We can test relevance by running a regression of D on Z:

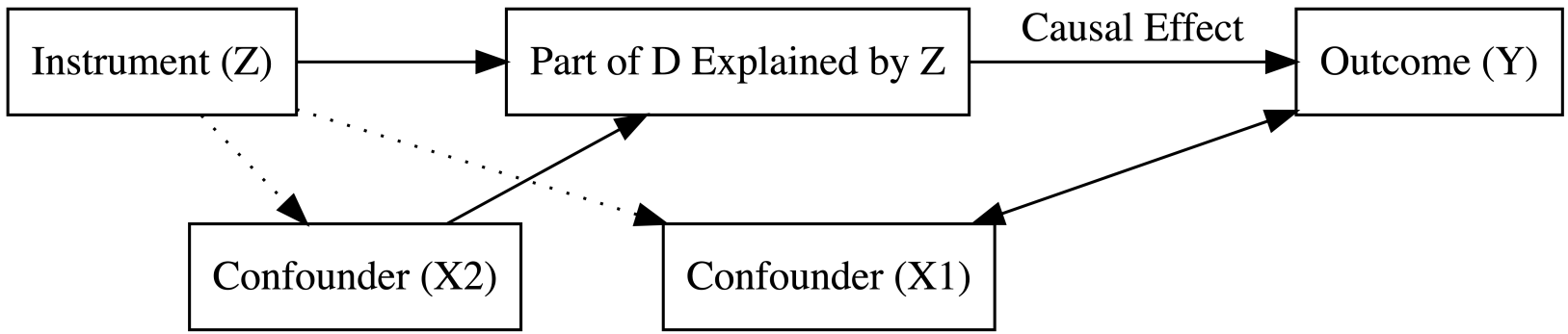
$$D_i = \delta + Z_i\beta + \varepsilon_i$$

- If β is significant, relevance is met.

Note: in the next lecture, we will discuss more issues with a weakly correlated Z and D.

Exogeneity Assumption

Z must be exogenous/randomly assigned in respect to both D and Y. The dotted lines below shows violations to exogeneity:



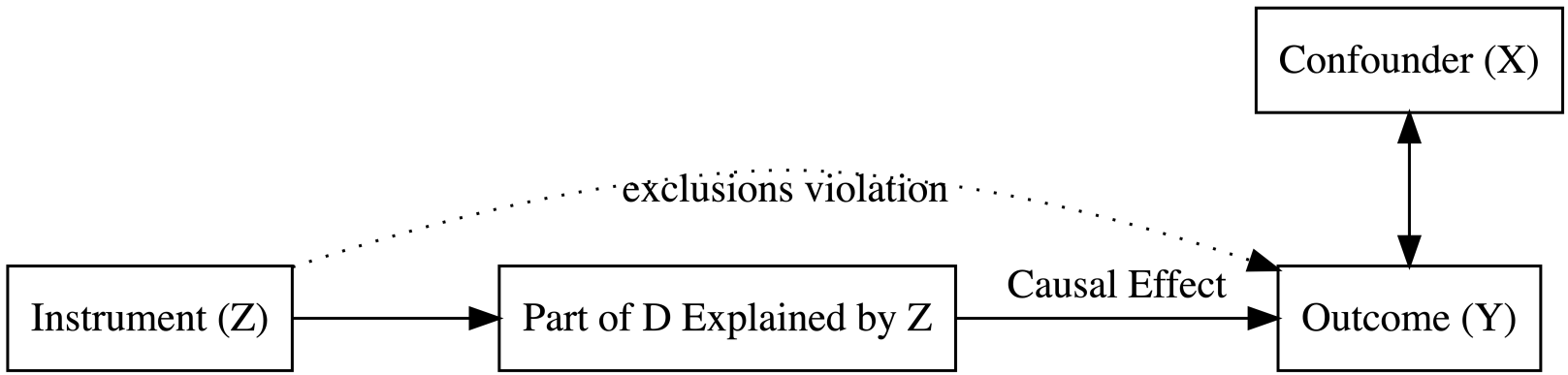
We can solve exogeniety violations by **controlling**/**accounting** for the confounders.

- We will cover this in the next lecture during estimation.

There is no real way to test exogeneity violations. The recommendation is to draw a diagram like this based on your understanding of the research topic.

Exclusions Restriction

The exclusions restriction states Z must not have a direct effect on Y. It can only have an indirect effect through D.



Why? Well if Z has an independent effect on Y outside of D, then Z is a confounder between $\hat{D}$ and Y, and $\hat{D}$ will no longer be exogeneous.

There is no way to test the exclusions restriction. You can only justify it through your own understanding of the research topic in question.

Finding Valid Instruments

It is difficult finding an instrument that plausibly satisfies relevance, exogeneity, and exclusions.

- In the econometrics literature, a lot of attention is put on trying to find an instrument that doesn't violate exclusions.
- However, **Exogeneity** is actually probably the more difficult assumption to meet - it is hard to find a Z that is truly randomly assigned in terms of both D and Y.
- Common instruments are often random by nature: Lotteries, rainfall, natural disasters, random selection of beneficiaries for policy pilots, etc.

The most reliable way to find instruments is with non-compliance or examiner designs, that we will cover in a later lecture.