Lecture 10 Regression Discontinuity

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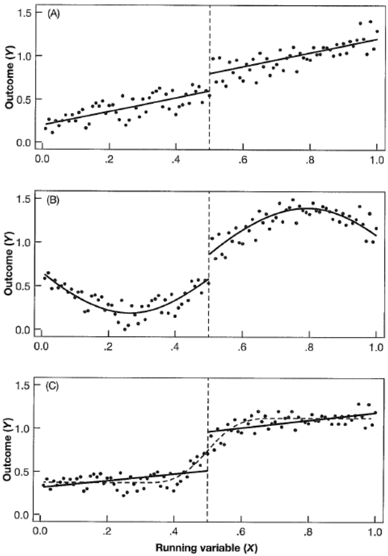
Readings

- Angrist and Pischke chapter 4
- Carpenter and Dobkin (2011), "The Minimum Legal Drinking Age", *Journal of Economic Perspectives*, Vol. 25, No. 2, pp. 133-156

How could RD go wrong?

- If the relation between the outcome variable (Y) and the running variable (X) is linear with a clear jump in $E(Y|X)$ at the cutoff, then RD should capture the causal effect of treatment — first panel
- If the relation is nonlinear, we may still see a jump at the cutoff point — second panel — or we may not see a jump — third panel
- In the third panel, if the regression is linear on the running variable, we may conclude that there is a discontinuity, when in fact there is nonlinearity.

How could RD go wrong?



How could RD go wrong?

- How can we address this issue?
  - Approach 1. Model nonlinearity directly
  - Approach 2. Focus on observations near the cutoff

Model nonlinearity

- We can model nonlinearity by including a polynomial function of the running variable. For example:

$$M_a = \alpha + \rho D_a + \gamma_1 a + \gamma_2 a^2 + \varepsilon_a$$

- Alternatively, we can allow for different coefficients on the running variable to the left and right of the cutoff. This results in a model that interacts a with D_a:

$$M_a = \alpha + \rho D_a + \gamma(a - a_0) + \delta(a - a_0)D_a + \varepsilon_a$$

  - We center the running variable by subtracting the cutoff a_0
  - ρ is still the jump in death rates at the cutoff (as can be seen by setting $a = a_0$)

Model nonlinearity

- Why could there be a change in the relation between age and mortality rates at the cutoff?
  - People younger than 21 cannot drink legally. Maybe the trend in death rates will be negative to reflect the fact that they take fewer risks as they mature.
  - Those older than 21 may have a less steep decline in mortality as they get older because they are drinking more. On the other hand, perhaps being able to drink legally discourages binge drinking.

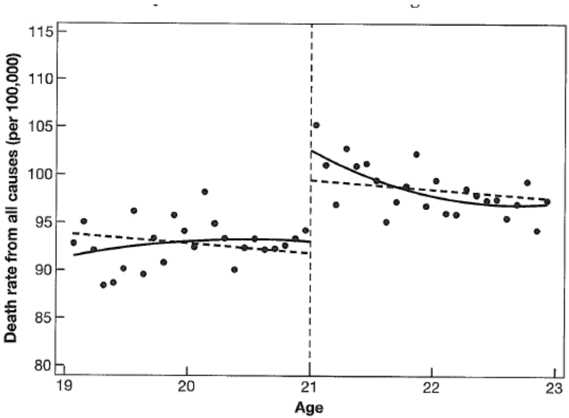
Model nonlinearity

- We can combine nonlinear trends with changes in the slope at the cutoff:

$$\begin{aligned} M_a &= \alpha + \rho D_a + \gamma_1 (a - a_0) + \gamma_2 (a - a_0)^2 + \\ & \quad \delta_1 (a - a_0) D_a + \delta_2 (a - a_0)^2 D_a + \varepsilon_a \end{aligned}$$

- In this model, both the linear and quadratic terms change as we cross the cutoff.
- The model produces the results in the figure
- The MLDA effect is now 9.5 deaths per 100,000 (compared with 7.7 in the linear model)

Model nonlinearity



Notes: This figure plots death rates from all causes against age in months. Dashed lines in the figure show fitted values from a regression of death rates on an over-21 dummy and age in months. The solid lines plot fitted values from a regression of mortality on an over-21 dummy and a quadratic in age, interacted with the over-21 dummy (the vertical dashed line indicates the minimum legal drinking age [MLDA] cutoff).

Model nonlinearity

- Which model is better, fancy or simple?
- We would like the results to not be very sensitive to the modeling choices
- The table shows the results of estimating two models:
  - Simple RD — column (1)

$$M_a = \alpha + \rho D_a + \gamma a + \varepsilon_a$$

  - Fancy RD — column (2)

$$\begin{aligned} M_a &= \alpha + \rho D_a + \gamma_1 (a - a_0) + \gamma_2 (a - a_0)^2 + \\ &\quad \delta_1 (a - a_0) D_a + \delta_2 (a - a_0)^2 D_a + \varepsilon_a \end{aligned}$$

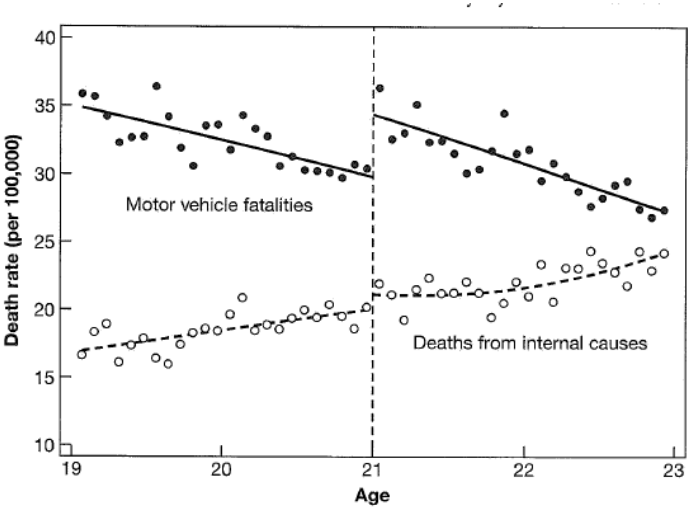
Model nonlinearity

Dependent variable	Ages 19–22 (1)	(2)	Ages 20–21 (3)	(4)
All deaths	7.66 (1.51)	9.55 (1.83)	9.75 (2.06)	9.61 (2.29)
Motor vehicle accidents	4.53 (.72)	4.66 (1.09)	4.76 (1.08)	5.89 (1.33)
Suicide	1.79 (.50)	1.81 (.78)	1.72 (.73)	1.30 (1.14)
Homicide	.10 (.45)	.20 (.50)	.16 (.59)	−.45 (.93)
Other external causes	.84 (.42)	1.80 (.56)	1.41 (.59)	1.63 (.75)
All internal causes	.39 (.54)	1.07 (.80)	1.69 (.74)	1.25 (1.01)
Alcohol-related causes	.44 (.21)	.80 (.32)	.74 (.33)	1.03 (.41)
Controls	age	age, age^2, interacted with over-21	age	age, age^2, interacted with over-21
Sample size	48	48	24	24

Model nonlinearity

- There is a significant increase in deaths from motor vehicle accidents
- There is a small but statistically significant increase in deaths from suicide and other external causes
- There is no effect on deaths from internal causes
- The estimates are not sensitive to whether we use a simple of fancy RD model
- The figure provides a visual representation of the results

Model nonlinearity



Focus on observations near the cutoff

- For points close to the cutoff, nonlinear trends are not a concern — less bias.
- We could compare death rates in a narrow window just to the left and just to the right of the cutoff:

$$M_a = \alpha + \rho D_a + \gamma a + \varepsilon_a$$

  in a sample such that $a_0 - b \leqslant a \leqslant a_0 + b$. The parameter b is the *bandwidth*.
- The drawback is that we have fewer observations, so the resulting estimates will be less precise — increased variance.
- There is a trade off between bias and variance
  - There are econometric techniques to help choose the optimal bandwidth
  - What is important is that the results are not very sensitive to different choices of the bandwidth

Focus on observations near the cutoff

- Columns (3) and (4) in the table show the results for ages 20-21 instead of 19-22. Here nonlinearity does not matter much and the simple (column (3)) and fancy (column (4)) models give similar results.

Another way RD can go wrong

- Manipulation of the running variable
  - RD assumes that there is no discontinuity in the counterfactual outcome — there would have been no discontinuity in death rates at age 21 if it had not been for the fact that those over age 21 can drink legally
  - This is violated if individuals can manipulate the running variable
- Example:
  - The UK government introduced the help to buy scheme in 2010 to help people buy their homes
  - The scheme has different components. For example, the equity loan component allows people to borrow 20% of the value of their home from the government. So, if they have a 5% deposit they only need a mortgage for 75% of the value of the home
  - The home must be newly built and with a price of up to £600,000

Another way RD can go wrong

- Suppose we would like to see if the help to buy scheme increased property transactions. We could do RD looking at property transactions of houses with a price above and below £600,000.
  - Outcome: transactions
  - Treatment: help to buy
  - Running variable: price
- The problem is that developers will have an incentive to price more homes just below the £600,000 cutoff and people will also have an incentive to look for homes below the £600,000 cutoff. There is manipulation of the running variable. Whether a home is priced above or below the cutoff is not random.
- In the MLDA example this is not an issue, because age cannot be manipulated.

One final issue with RD

- RD is a compelling method — if we know the rules that determine treatment, we can eliminate OVB. RD estimates have strong **internal validity**.
- But... RD may lack **external validity**. We focus on a specific setting and often on a narrow band around the cutoff value of the running variable. It may not be valid to extrapolate the results to other age groups and other countries.

Fuzzy RD

- In sharp RD, treatment is a dummy and is a continuous function of the running variable:

$$D_a = \begin{cases} 1 \text{ if } a \geqslant 21 \\ 0 \text{ if } a < 21 \end{cases}$$

- In fuzzy RD, it is the *probability* of treatment that is discontinuous:

$$D_a = \begin{cases} g_1(a) \text{ if } a \geqslant 21 \\ g_0(a) \text{ if } a < 21 \end{cases}$$

  The functions $g_0(a)$ and $g_1(a)$ can be anything, as long as they differ at age 21. We assume that $g_1(a) > g_0(a)$, so that being 21 or over makes drinking more likely.

- This results in a design where the discontinuity becomes an instrumental variable for treatment status instead of just switching treatment on or off.

Fuzzy RD is IV

- Imagine we look at the MLDA example as fuzzy RD: the probability of drinking increases at age 21. The second stage would be:

$$M_a = \alpha + \rho D_a + \gamma a + \varepsilon_a$$

- The first stage would be:

$$D_a = \gamma_0 + \gamma_1 a + \pi T_a + \eta_a$$

Where the dummy variable T_a indicate the point where $a \geqslant 21$:

$$T_a = \begin{cases} 1 \text{ if } a \geqslant 21 \\ 0 \text{ if } a < 21 \end{cases}$$