Lecture 7:
Regression Discontinuity, 1 of 2

October 18, 2023

Course Administration

1. PS 3 due next week
2. If you still need approval for your replication paper, I am worried
3. Nov. 1: quantitative summary due

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4. Please come see me about your replication paper
5. You are assigned to presentations 11/29 and 12/6
6. Any other issues?

Today

Two motivating examples

1. Almond on the flu
2. Lee on incumbency

Theoretical framework

1. General framework and "precise control"
2. Potential outcomes
3. vis-a-vis experiments
4. Test for credibility
5. Generalizability

How-to steps

1. Find a credible discontinuity
2. Make a graph
3. Do a RD regression
4. Test for validity

Anderson on congestion

1. research question, endogeneity & data
2. discontinuity
3. estimation
4. validation
5. results

Two Motivating Examples

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1. Almond on the Spanish flu
2. Lee on value of incumbency

Almond Examines In-Utero Influeza Exposure

- Big research question: how does maternal health affect long-term health?
- fetal origins hypothesis says that "certain chronic health conditions can be traced to the course of fetal development" (p. 672)
- Why not look at the impact of maternal health during pregnancy on child outcomes?

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- Why not look at the impact of maternal health during pregnancy on child outcomes? better maternal health while in utero is correlated with positive unobservables for kid
- Solution: use the 1917 influenza pandemic as a "natural experiment"

Link To "Is the 1918 Influenza Pandemic Over? Long-Term Effects of *In Utero* Influenza Exposure in the Post-1940 U.S. Population"

The Discontinuity: Arrival of the Flu

- Flu struck without warning in October 1918
- Mostly gone by beginning of 1919
- Very very big
- Influences kids in utero 1918Q4 to 1919Q2
- $\rightarrow$ births in (potentially) 1919Q1 to 1919Q4
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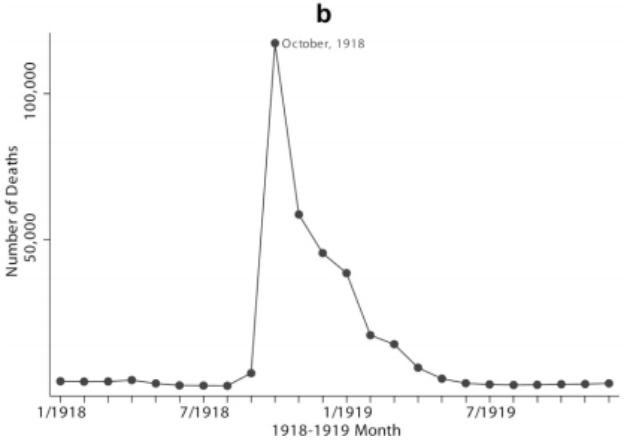

The Outcome(s): Health and Education

- Focus on births 1919Q1 to 1919Q4
- Measure "cohort departure":

$$\begin{aligned} y_i &= \beta_0 + \beta_1 1\{\text{YOB} = 1919\} \\ &+ \beta_2 \text{YOB} + \beta_3 \text{YOB}^2 + \epsilon_i \end{aligned}$$

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- We don't know whose mom got the flu!

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- How much does being an incumbent help the party in control retain the office in the next election?
- Why not look directly at relationship between incumbency and winning? incumbents should be better politicians! they won in the first place
- So instead, compare districts with "close" elections and incumbents to districts with close elections and no incumbents, so that the winner is "as good as random"

Lee (2008)

Power of Incumbency

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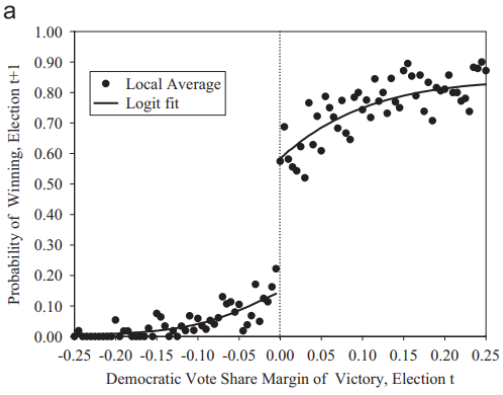


RD: Theory

The RD Theoretical Background

1. General framework
2. Understanding "precisely control"
3. In potential outcomes framework
4. RD vis-a-vis experiments
5. Tests for credibility
6. Role of covariates
7. Generalizability

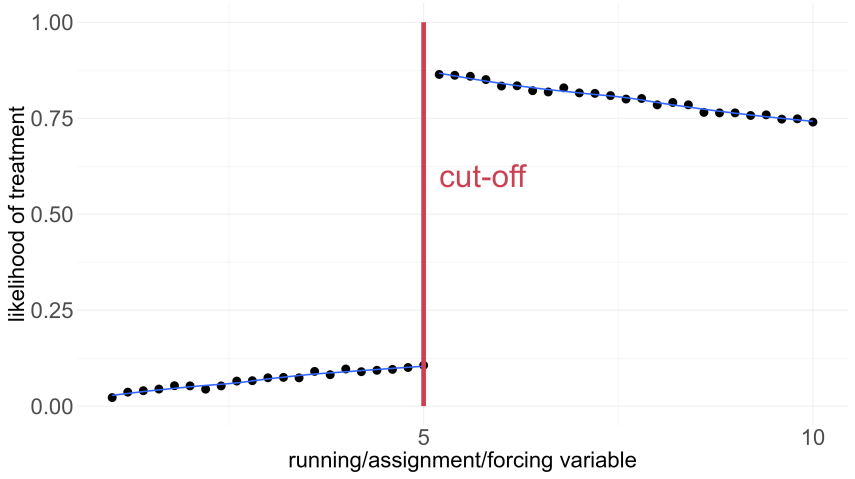
Largely based on Lee and Leemieux, 2009

The General Problem

- We are interested in $Y = \alpha + D\tau + X\beta + \epsilon$
- D is treatment
- X is the "assignment variable," because it assigns treatment; also known as the "forcing variable"
- D varies discontinuously at the treatment point
  - $D \in \{0, 1\}$
  - $D = 1$ if $X \geq c$ and $D = 0$ if $X < c$
- units should not have "precise control" over the value of X

Sharp Discontinuous Treatment at Cut-off of Assignment Variable

Fuzzy Discontinuous Treatment at Cut-off of Assignment Variable



"Precisely" is So Important It Gets Its Own Slide

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  - Medicare eligibility at age 65
  - Legal drinking and 21st birthday
- Cut-offs and outcomes where you can control behavior
  - Age at school start – in many jurisdictions the birthdate cut off is not enforced
  - Age at first Covid vaccination – age cut-off was not strictly enforced

Using the Potential Outcomes Framework

- Recall Y_{0i} is you without treatment, and Y_{1i} is you with treatment
- We are interested in $Y_{1i} - Y_{0i}$

Using the Potential Outcomes Framework

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- We are interested in $Y_{1i} - Y_{0i}$
- But in the absence of sci-fi, we don't observe this, so we settle for the population average:
  $Y_{1i} - Y_{0i}$, or $E(Y_{1i}|X) - E(Y_{0i}|X)$

Potential Outcomes and RD

With RD, we observe

- $E(Y_{0i})$ on one side of the discontinuity
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We are interested in the difference at the discontinuity, or

$$B - A = \lim_{\epsilon \uparrow 0} E(Y_i | X_i = c + \epsilon) - \lim_{\epsilon \downarrow 0} E(Y_i | X_i = c + \epsilon) = E(Y_{1i} - Y_{0i} | X = c)$$

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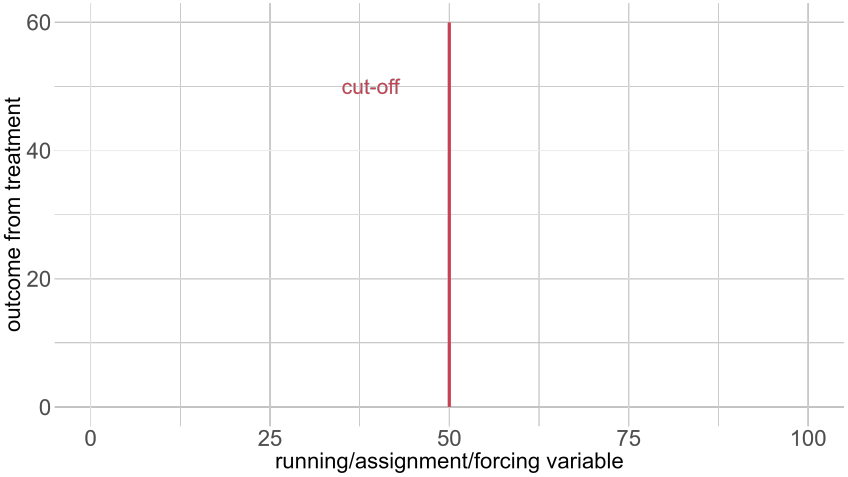
We can interpret this as the average treatment effect at the cutoff

Potential Outcomes in Figures



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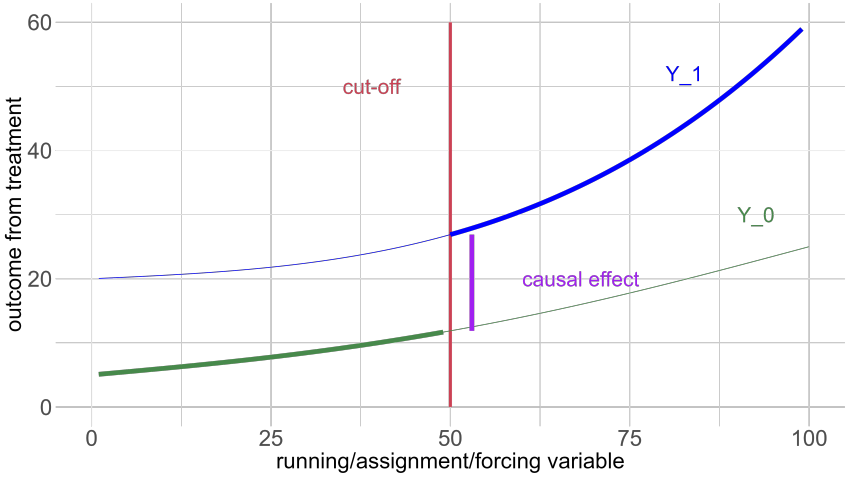

Based on Lee and Lemieux (2010)

How is a RD Like an Experiment?

- If the discontinuity is credible, the only difference between treated and control is the treatment
- The potential outcome doesn't vary by assignment variable, since the assignment variable is random at the discontinuity

Tests for Credibility

From Lee and Lemiuex, p 7-8

"All other factors determining Y must be evolving 'smoothly' with respect to X" (p. 7-8)

- pre-determined observable covariates should not jump at discontinuity
- examples of what should be smooth at discontinuity in one of the example papers?

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- pre-determined observable covariates should not jump at discontinuity
- examples of what should be smooth at discontinuity in one of the example papers?
  - Almond paper: parental income
  - Lee: characteristics of congressional districts

More Credibility

No bunching at the discontinuity: Test due to McCrary (2008)

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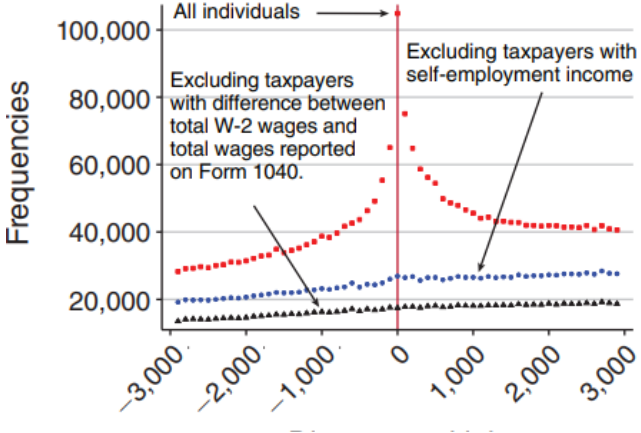
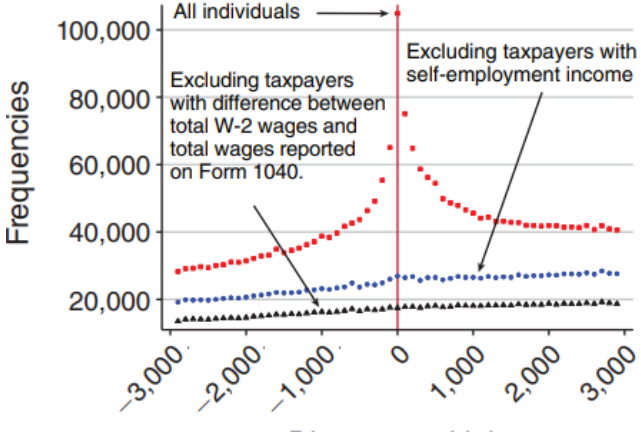
- "bunching" means more observations near the discontinuity
- If people are bunching at the discontinuity $\rightarrow$ people can precisely manipulate behavior
- What circumstances would lead to bunching at a discontinuity?
- Self-employed people and the EITC, if we want to use EITC income as an experiment

What if You Want To Use Additional Income from EITC?



What if You Want To Use Additional Income from EITC?



Bottom line: don't include self-employed people!

Covariates Are Not Strictly Necessary

- Like in an experiment, if the RD is ok, you don't need to include covariates as controls.
- But you might include them to reduce the sampling variability
- aka: lower the standard errors

Generalizability

- We worry about internal and external validity
- Do you know what these are?

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- We worry about internal and external validity
- Do you know what these are?
- This limitation of RD also holds experiments

RD: How-to

RD How-to

1. Find a credible discontinuity
2. Make a graph
3. Do a RD regression
4. Test for validity

1. Find a Credible Discontinuity

- Ask: "are individuals able to influence the assignment variables, and if so, what is the nature of this control?"
- If
  1. you can control the assignment variable
     AND
  2. there is a perceived benefit (or cost) to the treatment
- $\rightarrow$ halt!

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- Ask: "are individuals able to influence the assignment variables, and if so, what is the nature of this control?"
- If
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- $\rightarrow$ halt!
- $\rightarrow$ people on one side are systematically different than people on the other

2. Make a Graph

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What does this do for you?

1. shows the RD
2. shows the causal effect
3. tests for validity

Graph Details

- Divide the assignment variable into bins
- Make sure no bins are divided by cut-off
- Calculate average treatment, outcome and number of obs for each bin
- Graph
- Graph helps you think about the right functional form for the regression
- Lets you see other jumps – which would be concerning

What Size Bins?

- If bins are too narrow, estimates are unprecise – too noisy
- If bins are too wide, estimates may be biased – smoothing too much by the cut-off

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- If bins are too narrow, estimates are unprecise – too noisy
- If bins are too wide, estimates may be biased – smoothing too much by the cut-off
- Intuitively, bins should be narrow enough that there is no slope in the outcome variable within the bin (that's what causes bias)
- But there are other goals too, so this isn't the only priority
- There are "methods" but not clear answer

3. Do a RD regression

- In general, the form is

$$Y_i = \alpha_0 + \alpha_1 D + \alpha_2 f(X - c) + \alpha_3 D * f(X - c) + \alpha_4 Q + \epsilon$$

- What is the coefficient of interest here?

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- What is the coefficient of interest here? α_1
- Why do we include the α_3 term?

Two RD Flavors

Non-parametric

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Parametric

- assume linearity, which can also lead to bias if it's wrong
- regressions with polynominal functions of X included
  - $X + X^2 + X^3 + X^4 + \ldots$
  - uses info far from the cut-off to inform us about behavior at the cut-off

Further Considerations on Flavor

- Do not run a regression with info on both sides of the discontinuity: this constrains the slope of X to be the same
- Make sure you include an interaction between D and X
- "since the RD estimate requires data away from the cutoff, the estimate will be dependent on the chosen functional form" (p. 8)

4. Tests for Validity

- Inspect the histogram for the assignment variable
- Inspect baseline covariates versus running variable
- If things are ok, what should your graph(s) look like?

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- Inspect the histogram for the assignment variable
- Inspect baseline covariates versus running variable
- If things are ok, what should your graph(s) look like?
- No discontinuity at the discontinuity

Anderson: Research Question, Endogeneity, and Data

What is the Major Research Question?

The general and the specific research questions

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Why not just an OLS of ridership on congestion?

- Congestion should also cause ridership
- A third common factor could ridership and congestion (big event?)

Data

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- Detector – what's that?

Data

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- What's the unit of observation?

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- Detector – what's that?
- What's the unit of observation? a detector-by-hour observation

Discontinuity, Estimation and Validity

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- Discontinuity? The start date of the strike
- What is discontinuous at this date? public transit service: goes from 1 to 0
- What about the end date of the strike? Not a good discontinuity because services ramp up
- Usually papers like this show a figure with discontinuity in the treatment
- Why not here?

Estimating Equation

$$y_{i,t} = \alpha + \beta \text{strike}_{i,t} + \gamma_1 \text{date}_{i,t} + \gamma_2 \text{date}_{i,t} * \text{strike}_{i,t} + \delta X_{i,t} + \epsilon$$

- Which is the coefficient of interest?

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  - because date enters linearly
  - we care about jump at threshold, not average difference
- Could you do a diff-in-diff here?

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- What's the diff vs diff-in-diff? RD isolates to just the jump afterward

More Estimation Concerns

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- Authors write "we estimate a local linear regression. ... [which] requires a kernel function and a bandwidth."
- They use a "uniform kernel" = equal weight on all obs!
- Bandwidth of 28 days before and after $\rightarrow$ just use 28 days before and after
- What are the benefits of a "local" estimation?

Identification and Validity

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  - stock market value
  - good tv show that people rush home to watch
- What can you do to test these?

Results

What do Summary Stats Tell Us?

TABLE 3—SUMMARY STATISTICS

	Unweighted statistics		VMT-weighted statistics	
	No strike	During strike	No strike	During strike
Lanes	3.3	3.3	3.2	3.2
	(1.4)	(1.4)	(1.5)	(1.5)
Total flow	4,619	4,604	4,401	4,355
(vehicles per hour)	(2,602)	(2,531)	(2,730)	(2,674)
Average speed (mph)	53.3	49.3	52.8	48.3
	(15.9)	(17.4)	(16.6)	(17.9)
Delay relative to 55 mph	0.35	0.52	0.37	0.55
(minutes per mile)	(0.83)	(1.05)	(0.81)	(1.01)
Delay relative to 60 mph	0.39	0.57	0.41	0.61
(minutes per mile)	(0.85)	(1.07)	(0.83)	(1.04)
Delay relative to 65 mph	0.43	0.62	0.45	0.66
(minutes per mile)	(0.87)	(1.09)	(0.85)	(1.05)
Average share of time	0.101	0.115	0.110	0.125
occupied	(0.072)	(0.082)	(0.071)	(0.080)
Detectors in service	720	640	720	640
Sample size	509,946	110,844	509,946	110,844

Notes: The observation is the detector-hour. Parentheses contain standard deviations. See text for description of weights.

- What's the aim of this table? (Table 3, p. 2776)
- Or, if the estimation is working properly, what should Table 3 show?

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	(2,602)	(2,531)	(2,730)	(2,674)
Average speed (mph)	53.3	49.3	52.8	48.3
	(15.9)	(17.4)	(16.6)	(17.9)
Delay relative to 55 mph (minutes per mile)	0.35	0.52	0.37	0.55
	(0.83)	(1.05)	(0.81)	(1.01)
Delay relative to 60 mph (minutes per mile)	0.39	0.57	0.41	0.61
	(0.85)	(1.07)	(0.83)	(1.04)
Delay relative to 65 mph (minutes per mile)	0.43	0.62	0.45	0.66
	(0.87)	(1.09)	(0.85)	(1.05)
Average share of time occupied	0.101	0.115	0.110	0.125
	(0.072)	(0.082)	(0.071)	(0.080)
Detectors in service	720	640	720	640
Sample size	509,946	110,844	509,946	110,844

Notes: The observation is the detector-hour. Parentheses contain standard deviations. See text for description of weights.

- What's the aim of this table? (Table 3, p. 2776)
- Or, if the estimation is working properly, what should Table 3 show?
- All non-strike-related variables should be the same

What do Summary Stats Tell Us?

TABLE 3—SUMMARY STATISTICS

	Unweighted statistics		VMT-weighted statistics	
	No strike	During strike	No strike	During strike
Lanes	3.3	3.3	3.2	3.2
	(1.4)	(1.4)	(1.5)	(1.5)
Total flow (vehicles per hour)	4,619	4,604	4,401	4,355
	(2,602)	(2,531)	(2,730)	(2,674)
Average speed (mph)	53.3	49.3	52.8	48.3
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- How do we measure delay?

$$60/\text{speed} - 1$$

Main RD Picture

- What are the dots?

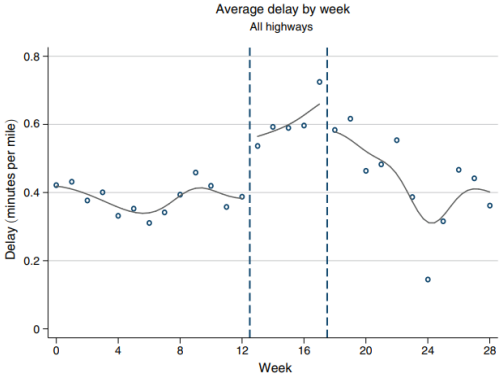
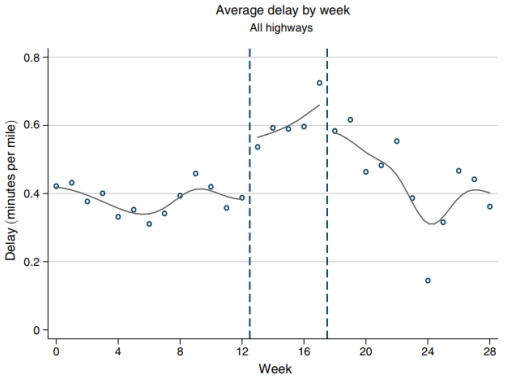


FIGURE 2. WEEKLY PEAK HOUR DELAY ON MAJOR LOS ANGELES FREEWAYS, 7/14/2003 TO 1/30/2004

Main RD Picture



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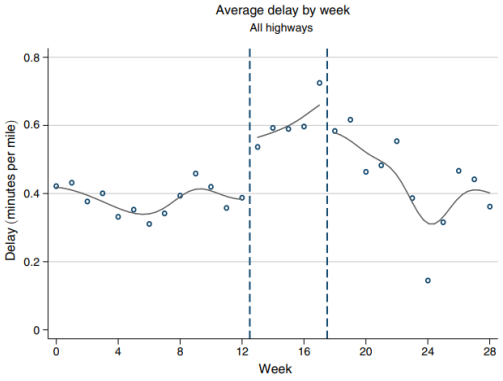

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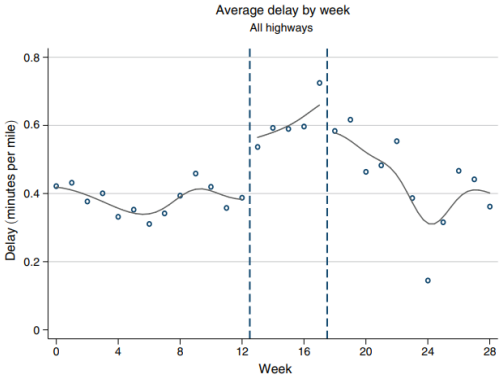

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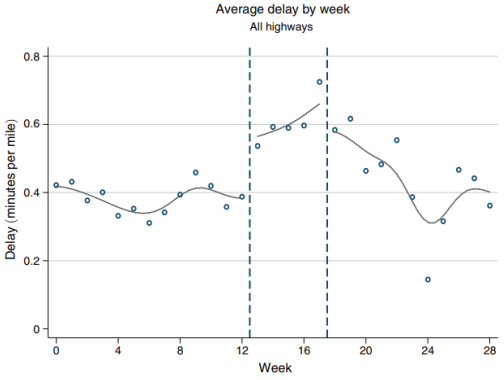

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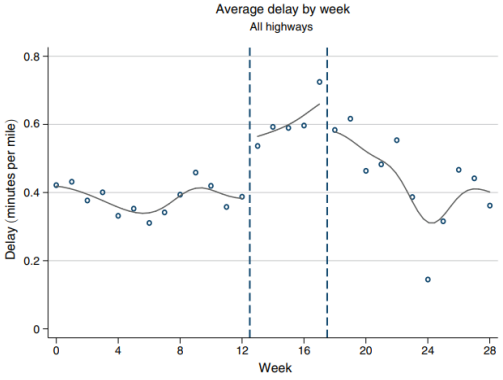

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- How do we see the main result in this figure? jump at week 13

Variation by Location

- Which is the coefficient of interest?

TABLE 4—EFFECT OF STRIKE ON DELAYS DURING ALL PEAK HOURS

Average delay (in minutes per mile)	(1)	(2)	(3)	(4)	(5)	(6)
Strike	0.194	0.332	0.218	0.190	0.357	0.125
	(0.041)	(0.076)	(0.052)	(0.051)	(0.128)	(0.042)
Date	−0.004	−0.003	−0.002	−0.003	−0.005	−0.005
	(0.002)	(0.003)	(0.002)	(0.002)	(0.004)	(0.002)
Date × strike	0.007	0.006	−0.001	0.007	0.012	0.007
	(0.002)	(0.003)	(0.002)	(0.003)	(0.007)	(0.002)
Average delay prestrike	0.409	0.369	0.264	0.357	0.600	0.434
Freeways	All					Other
Parallel transit line		101 Red line	105 Green line	110 and 710 Blue line	10 Rapid 720	
Sample size	178,549	15,854	31,058	19,152	15,357	97,128

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Variation by Location

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- How do you interpret coefficient on date? one additional day in this period is associated with a decrease in delay of 0.004 minutes per mile
- How do you interpret coefficient on date*strike? one additional day after the strike is associated with a 0.007 increase in minutes of delay per mile
- Other columns in this table limit to detectors close to different metro lines
- What is the point the author is trying to make with these extra columns?

Putting Results in Context

- Are these results more relevant for a complete shut-down of the transit system or the impact of DC's metro repair program?

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Putting Results in Context

- Are these results more relevant for a complete shut-down of the transit system or the impact of DC's metro repair program?
- The latter
- A RD can tell you about what the discontinuity does
- Not much precisely beyond that

Next Lecture

- Fuzzy RD
- RD Kink
- Read Day and Manoli, linked version
- Summary due next week if you're on the list