Difference in Difference Models

Bill Evans

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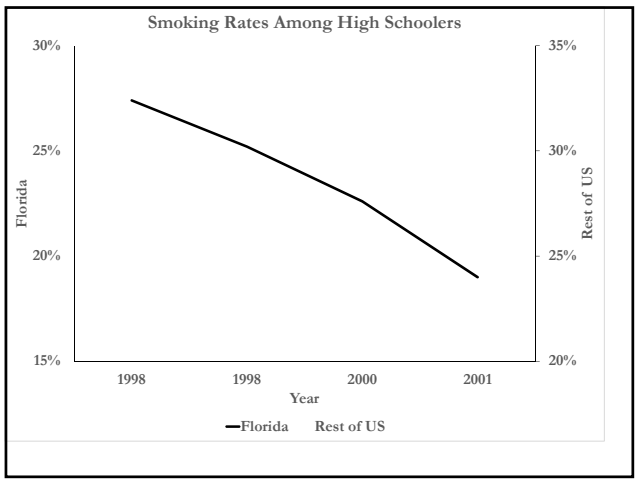
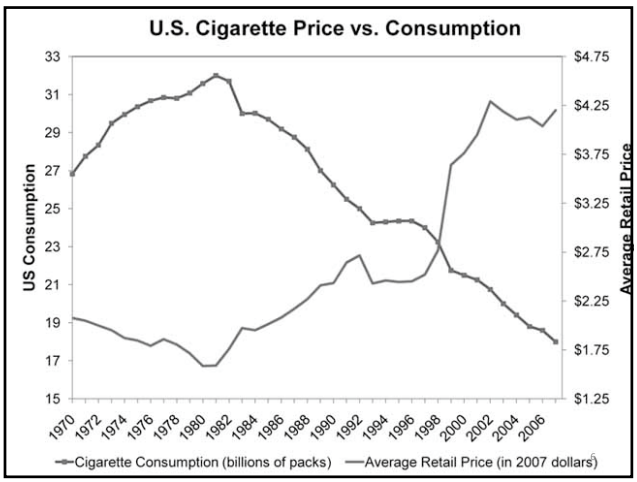
Florida

- 8/25/1997, State of Florida settles out of court in their suits against tobacco manufacturers
- Awarded $13 billion over 25 years
- Use $200m to run anti-smoking campaign aimed at kids
- Florida Tobacco Pilot Program (FTPP)
- Precursor to the national 'truth' campaign

- Florida's edgy "Truth" advertising campaign continues to have a significant impact in reducing teen smoking, a team of researchers concluded from a new study that examines the impact of the state's anti-tobacco advertising.

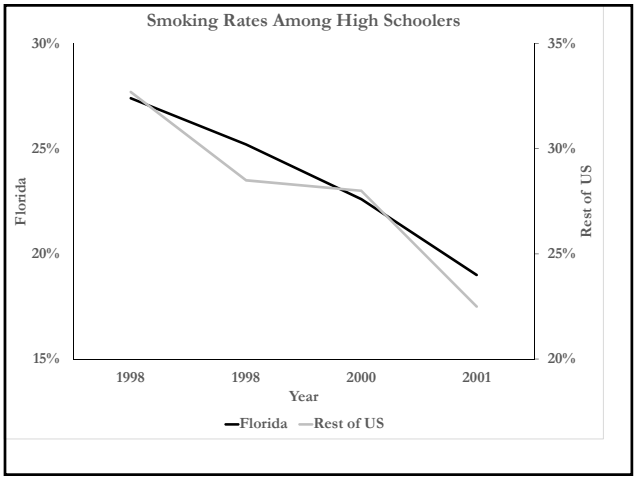
- in 1998, when surveillance began for tobacco use among Florida youth, 27.4 percent of high school students were current cigarette smokers. by 2000, this rates had declined to 22.6 among high school students.
- Note: 4.8 percentage point decline or a 17.5% reduction in teen smoking





Nationwide

- Teen smoking rates fell from 36.5 to 31.4%
- A 5.1 percentage point decline or roughly 14%
- Rates in Florida fell by 4.8 percentage points – rates nationwide fell by a similar amount



Random assignment clinical trial

- New drug that lowers cholesterol
- Recruit N people with high cholesterol
  - ½ in treatment (receive active ingredient)
  - ½ in control (placebo)
- Measure cholesterol levels
  - Before the start of treatment
  - Then again after a specified time

	Before Treatment	3 months later	Difference
Group 1 (Treatment)	Y_{t1}	Y_{t2}	$\Delta Y_t = Y_{t2} - Y_{t1}$
Group 2 (Control)	Y_{c1}	Y_{c2}	$\Delta Y_c = Y_{c2} - Y_{c1}$
Difference			$\Delta\Delta Y$ $\Delta Y_t - \Delta Y_c$

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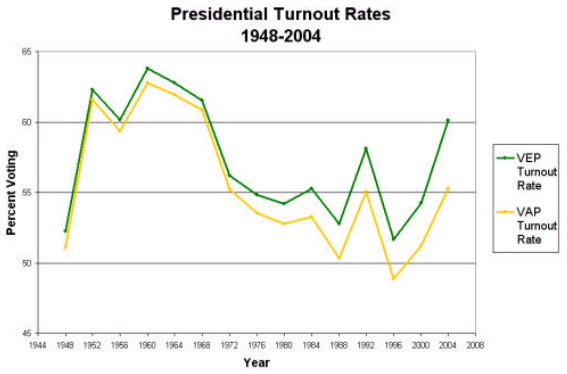
Difference in difference models

- Maybe the most popular "identification strategy" in applied statistical work in economucs
- Attempts to mimic random assignment with treatment and "comparison" sample

Simple problem set up

- One group is 'treated' with an intervention
- Have pre & post treatment data for the group receiving intervention
- Can examine time-series changes but,
- Unsure how much of the change is due to secular changes



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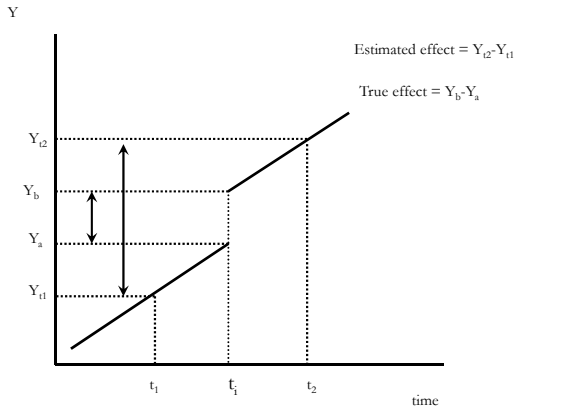
Example

- 1993 Federal government passes Motor Voter
  - Register to vote when you get drivers license
  - Designed to decrease the cost of voting
- Some states had state Motor Voter Law prior to 1993
- Suppose you compare outcomes in states before/after 1993 (1992 vs 1996 elections)

- States with new law saw an increase in voter registration of 8.4% points
  - 1992: 76.1%
  - 1996: 84.5%
- Question: how much of the increase was the law and how much was it secular trends?
- Cannot say without controlling for factors that impact these trends

- If the outcome of interest is trending over time, before/after comparisons will provide a biased estimate of the law
- Look at this graphically



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- Intervention occurs at time period t_1
- True effect of law
  - $Y_b - Y_a$
- Only have data at t_1 and t_2
  - If using time series, estimate of the effectiveness of the law is $Y_{t1} - Y_{t2}$
- Solution?

Difference in difference models

- Pool cross-sectional and time series data
- Use time series of "untreated" group to establish "trends"
- What would have occurred in the treatment states in the absence of the intervention?

Difference in Difference

	Before Change	After Change	Difference
Group 1 (Treat)	Y_{t1}	Y_{t2}	ΔY_t $= Y_{t2}-Y_{t1}$
Group 2 (Control)	Y_{c1}	Y_{c2}	ΔY_c $=Y_{c2}-Y_{c1}$
Difference			$\Delta\Delta Y$ $\Delta Y_t - \Delta Y_c$

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Motor Voter Example

- Data in two years
  - 1992 Presidential (before MV)
  - 1996 Presidential (after)
- Two groups of states
  - Treated group (states that got MV through federal law in 1993)
  - Control group (states that had MV laws already)

Difference in Difference

	Before MV	After MV	Difference
Group 1 (Treat)	0.761	0.845	0.084
Group 2 (Control)	0.834	0.867	0.033
Difference			0.050

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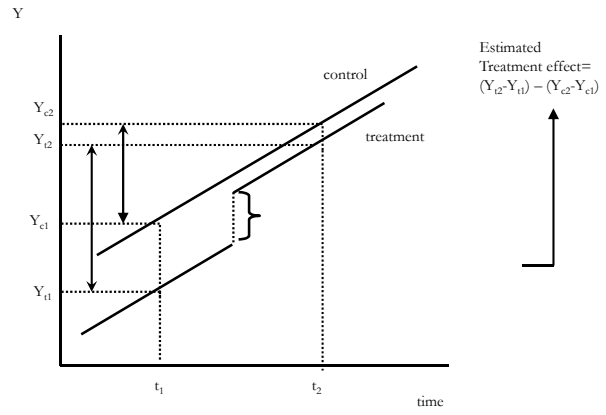

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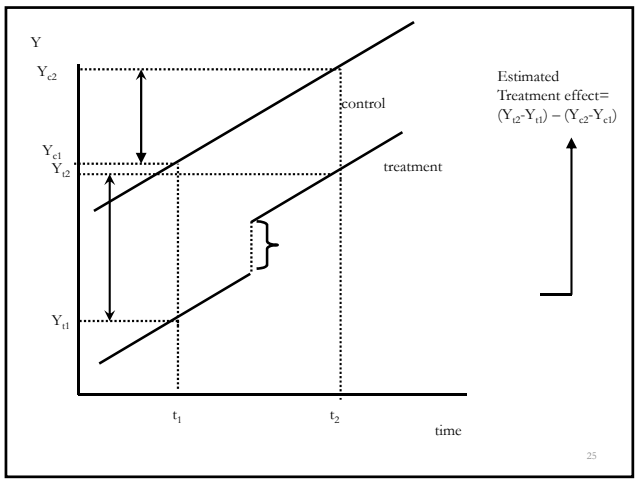
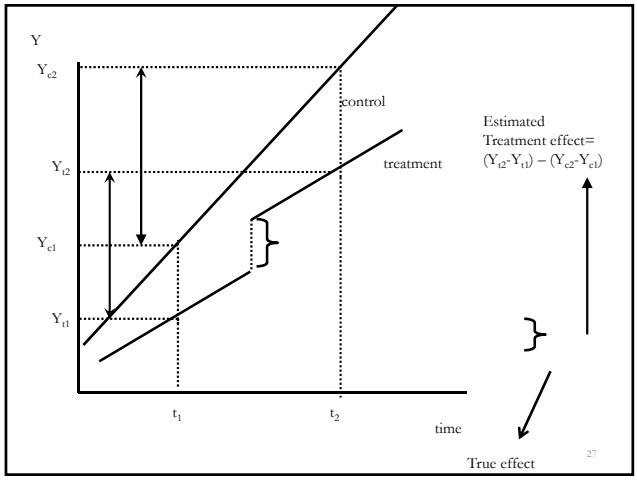
Key Assumption

- Control group identifies the time path of outcomes that would have happened in the absence of the treatment
- In this example, Y falls by $Y_{c2}-Y_{c1}$ even without the intervention
- Note that underlying 'levels' of outcomes are not important (return to this in the regression equation)



- In contrast, what is key is that the time trends in the absence of the intervention are the same in both groups
- If the intervention occurs in an area with a different trend, will under/over state the treatment effect
- In this example, suppose intervention occurs in area with faster falling Y



Basic Econometric Model

- Data varies by
  - state (i)
  - time (t)
  - Outcome is Y_{it}
- Only two periods
- Intervention will occur in a group of observations (e.g. states, firms, etc.)

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- Three key variables
  - T_{it} =1 if obs i belongs in the state that will eventually be treated
  - A_{it} =1 in the periods when treatment occurs
  - $T_{it}A_{it}$ -- interaction term, treatment states after the intervention
- $Y_{it} = \beta_0 + T_{it}\beta_1 + A_{it}\beta_2 + T_{it}A_{it}\beta_3 + \varepsilon_{it}$

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$$Y_{it} = \beta_0 + T_{it}\beta_1 + A_{it}\beta_2 + T_{it}A_{it}\beta_3 + \varepsilon_{it}$$

	Before Change	After Change	Difference
Group 1 (Treat)			
Group 2 (Control)			
Difference			

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Meyer et al.

- Workers' compensation
  - State run insurance program
  - Compensate workers for medical expenses and lost work due to on the job accident
- Premiums
  - Paid by firms
  - Function of previous claims and wages paid
- Benefits -- % of income w/ cap

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- Typical benefits schedule
  - Min(pY,C)
  - P=percent replacement
  - Y = earnings
  - C = cap
  - e.g., 65% of earnings up to $400/week

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- Concern: Moral hazard. Benefits will discourage return to work
- Empirical question: duration/benefits gradient
- Previous estimates
- $Y_i = \beta_0 + X_i\beta_1 + R_i\beta_2 + \varepsilon_i$
  - Y (duration)
  - R (replacement rate)
  - X (represents some other controls)
- Expect $\beta_2 > 0$ (Higher replacement, longer duration)

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- Problem: Does realization of ε_i convey any information about R?
  - Workers with longer duration tend to be higher income workers
  - They also have lower replacement rates (earnings put them above the weekly cap)
- $Cov(R_i, \varepsilon_i)<0$
- Is β_2 over or under estimated?

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Solution

- Quasi experiment in KY and MI
- Increased the earnings cap
  - Increased benefit for high-wage workers
    - (Treatment)
  - Did nothing to those already below original cap (comparison)
- Compare change in duration of spell before and after change for these two groups

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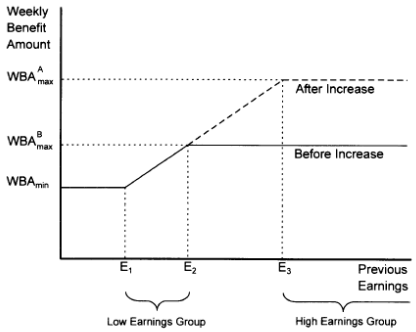

FIGURE 1. TEMPORARY TOTAL BENEFIT SCHEDULE BEFORE AND AFTER AN INCREASE IN THE MAXIMUM WEEKLY BENEFIT

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Data from Meyer et al.

- Data set kentucky.dta
- Key variables
  - durat (duration)
  - highearn (a high earning worker (treatment))
  - afchnge (after the law change)

```
. * generate log duration
. gen ldurat=ln(durat)
.
. * sort the data by highearn and afchnge
. sort highearn afchnge
.
. * gets means of ldurat for
. * 2x2 table
. by highearn afchnge: sum ldurat
```

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```
-------------------------------------------------------------------------------
-> highearn = 0, afchnge = 0

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      ldurat |      1652    1.123241    1.227601  -1.386294   5.204007

-------------------------------------------------------------------------------
-> highearn = 0, afchnge = 1

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      ldurat |      1464    1.137382    1.273859  -1.386294   5.204007

-------------------------------------------------------------------------------
-> highearn = 1, afchnge = 0

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      ldurat |      1128     1.35583    1.254325  -1.386294   5.204007

-------------------------------------------------------------------------------
-> highearn = 1, afchnge = 1

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      ldurat |      1103    1.599077    1.302141  -1.386294   5.204007
```

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Difference in Difference
Mean average ln(duration)

	Before change	After change	Difference
High earn (Treat)	1.356	1.599	0.243
Low earn (Control)	1.123	1.137	0.014
Difference	0.233	0.462	0.229

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Model

- Y_{it} = duration of spell on WC
- A_{it} = period after benefits hike
- H_{it} = treated or high earnings group (Income>E_3)
- $Y_{it} = \beta_0 + H_{it}\beta_1 + A_{it}\beta_2 + A_{it}H_{it}\beta_3 + \varepsilon_{it}$
- Diff-in-diff estimate is β_3

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```
. * get the treatment effect
. gen treat=highearn*afchnge

. * run difference in difference regression
. reg ldurat highearn afchnge treat

      Source |       SS       df       MS              Number of obs =    5347
-------------+------------------------------           F(  3,  5343) =   39.58
       Model |  188.983823     3  62.9946077           Prob > F      =  0.0000
    Residual |  8503.76169  5343   1.5915706           R-squared     =  0.0217
-------------+------------------------------           Adj R-squared =  0.0212
       Total |  8692.74552  5346  1.62602797           Root MSE      =  1.2616

------------------------------------------------------------------------------
      ldurat |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   highearn |   .2325891   .0487277     4.77   0.000     .1370629    .3281152
   afchnge |   .0141418   .0452831     0.31   0.755    -.0746316    .1029151
      treat |   .2291051   .0700319     3.27   0.001      .091814    .3663963
      _cons |   1.123241   .031039    36.19   0.000     1.062391     1.18409
------------------------------------------------------------------------------
```

Very low R2

Interpret coefficients

Compare results to 2 x 2 table – exactly the same

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More general model (allow for covariates)

- $Y_{it} = \beta_0 + H_{it}\beta_1 + A_{it}\beta_2 + A_{it}H_{it}\beta_3 + X_{1it}\alpha_1 + X_{2it}\alpha_2 + X_{3it}\alpha_3 + \ldots. X_{kit}\alpha_k + \varepsilon_{it}$

Results controlling for other covariates

TABLE 6—REGRESSION EQUATIONS FOR NATURAL LOGARITHM OF DURATION, HIGH- AND LOW-EARNINGS GROUPS POOLED, AND HIGH-EARNINGS GROUP SEPARATELY

	Specific			
	High- and low-earnings groups pooled			
	Kentucky		Michigan	
Explanatory variable	(i)	(ii)	(iii)	(iv)
After-increase indicator variable	0.016 (0.045)	−0.004 (0.038)	0.082 (0.084)	0.003 (0.073)
High-earnings-group indicator variable	−1.522 (1.099)	−0.594 (0.930)	5.577 (4.811)	3.607 (4.162)
After-increase × high-earnings-group indicator variable	0.215 (0.069)	0.162 (0.059)	0.157 (0.153)	0.203 (0.132)

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Replicate results in Table 6, column (i)

```
. reg ldurat highearn afchnge treat male married lage lprewage high_x_lpre _I*

      Source |       SS       df       MS              Number of obs =    5347
-------------+------------------------------           F( 17,  5329) =   16.09
       Model |  424.366738    17  24.9627493            Prob > F      =  0.0000
    Residual |  8268.37878  5329  1.55158168            R-squared     =  0.0488
-------------+------------------------------           Adj R-squared =  0.0458
       Total |  8692.74552  5346  1.62602797            Root MSE      =  1.2456

------------------------------------------------------------------------------
      ldurat |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    highearn |  -1.522196   1.099035    -1.39   0.166    -3.676755    .6323633
     afchnge |   .0155081   .0447622     0.35   0.729     -.072244    .1032603
       treat |   .2146878   .0693106     3.10   0.002     .0788106     .350565
        male |  -.0722981    .046195    -1.57   0.118    -.1628593    .0182631
     married |   .0509362   .0409132     1.24   0.213    -.0292704    .1311427
        lage |   .2522586   .0522575     4.83   0.000     .1498124    .3547047
   lprewage |   .2582666   .1038422     2.49   0.013     .0546934    .4618397
high_x_lpre |   .2318765    .187021     1.24   0.215    -.1347612    .5985142
_Iindustry_2 |   .2488065   .0593033     4.20   0.000     .1325477    .3650652
_Iindustry_3 |   .1725146   .0416086     4.15   0.000     .0909448    .2540844
  _Iinjury_2 |    .780188    .155637     5.01   0.000     .4750758      1.0853
```

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Questions to ask?

- What parameter is identified by the quasi-experiment? Is this an economically meaningful parameter?
- What assumptions must be true in order for the model to provide and unbiased estimate of β_3?
- Do the authors provide any evidence supporting these assumptions?

Card and Krueger

Minimum wage laws

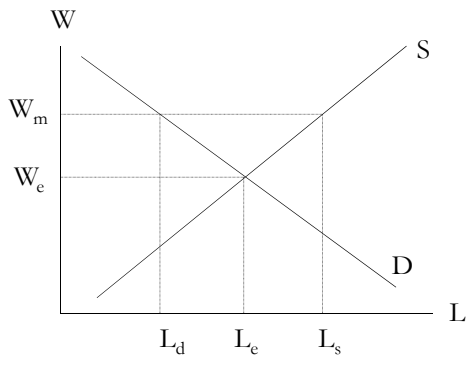
- Minimum wage laws imposed by state, local and Federal governments
- "covered" sector includes most jobs
- States/locals can raise but not lower Federal minimum wage

Federal Minimum Wages

- 01/01/1981 $3.35
- 04/01/1990 $3.80
- 04/01/1991 $4.25
- 10/01/1996 $4.75
- 09/01/1997 $5.15
- 07/24/2007 $5.85
- 07/24/2008 $6.55
- 07/24/2009 $7.25

Some State Minimum Wage Laws

- WA $8.55
- OR $8.40
- CT/DC $8.25
- VT $8.04
- IL/MA/CA $8.00



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Textbook model of Minimum Wage

- Original conditions: W_e, L_e
- Minimum wage imposed, $W_m > W_e$
- Labor supply: higher wage encourages more work – labor supply increases to L_s
- Labor demand: higher wage is a shift along the demand curve to L_d
- New unemployment rate: $L_s - L_d$
- Job loss from minimum wage: $L_e - L_d$

Research Question?

- What happens to labor demand when minimum wage laws increased?
- Economic significance: test of theory of demand
- Policy significance: key question faced by lawmakers every time there is a proposed change in the minimum wage law.

NJ Minimum Wage Hike

- Federal MW stuck at $3.35 for most of the 90s
- Because of inflation, real value of MW fell considerably
- Nov 1989 law raised MW in 2 steps
  - To $3.80 on 4/1/90
  - To $4.25 on 4/1/91
- NJ law
  - Passed in early 1990
  - Went into effect April 1, 1992
  - Raised minimum wage from $4.25 - $5.05/hr, 18% increase

- In 1992, NJ slipped into a recession
- In March of 1992, State legislature voted to phase it in over two years,
  - Governor vetoed
  - Vote margin not large enough to override veto
- Law went into effect as planned

Questions

- Why is NJ a good setting to test the impact of minimum wage on employment?
- Why is the fast food industry a good industry to examine?

Why fast food industry?

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Research methodology

- Examine employment before and after law goes into effect in NJ fast food restaurants
- Compare this change to changes in employment for employers not impacted by law
  - Fast food restaurants in PA
  - "Control group"

- Telephone interview of fast food restaurants before law goes into effect
- Ask store manager for basic information
  - Employees (full and part time)
  - Wages
  - Price of a basic meal
- Re-survey the same stores in November

Table 1: Sample Frame

	NJ Stores		PA Stores	
	Contacted	Interview	Contacted	Interview
Wave 1	364	331	109	79
Wave 2	331	321	79	78

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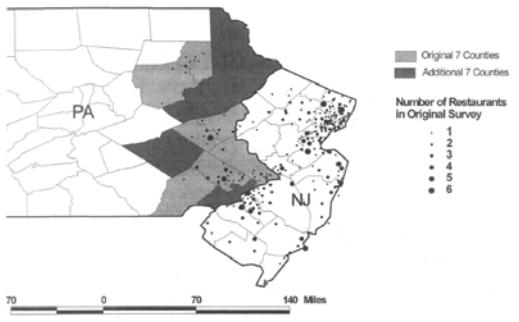

FIGURE 1. AREAS OF NEW JERSEY AND PENNSYLVANIA COVERED BY ORIGINAL SURVEY AND BLS DATA

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Notes about sample

- Restaurants from 4 chains --BK, KFC, Roy's, Wendy's – no McDonalds
- Key outcome, Full time equivalents
  - FTE
  - FTE = Full time + .5* halftime

TABLE 2—MEANS OF KEY VARIABLES

Variable	Stores in: NJ	PA	t^a
1. *Distribution of Store Types (percentages):*			
a. Burger King	41.1	44.3	−0.5
b. KFC	20.5	15.2	1.2
c. Roy Rogers	24.8	21.5	0.6
d. Wendy's	13.6	19.0	−1.1
e. Company-owned	34.1	35.4	−0.2

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2. *Means in Wave 1:*			
a. FTE employment	20.4 (0.51)	23.3 (1.35)	−2.0
b. Percentage full-time employees	32.8 (1.3)	35.0 (2.7)	−0.7
c. Starting wage	4.61 (0.02)	4.63 (0.04)	−0.4
d. Wage = $4.25 (percentage)	30.5 (2.5)	32.9 (5.3)	−0.4
e. Price of full meal	3.35 (0.04)	3.04 (0.07)	4.0
f. Hours open (weekday)	14.4 (0.2)	14.5 (0.3)	−0.3
g. Recruiting bonus	23.6 (2.3)	29.1 (5.1)	−1.0

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Table 2 – Means at Wave 1

Outcome	NJ	PA	t-stat on difference
%BK	41.1	44.3	-0.5
% Roys	24.8	21.5	0.6
FTE	20.4	23.3	-2.0
% full time	32.8	35.0	-0.7
Starting wage	4.61	4.63	-0.4
Hours open	14.4	14.5	-0.3

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TABLE 3—AVERAGE EMPLOYMENT PER STORE BEFORE AND AFTER THE RISE IN NEW JERSEY MINIMUM WAGE

Variable	Stores by state: PA (i)	NJ (ii)	Difference, NJ − PA (iii)	Stores in New Jersey[a]: Wage = $4.25 (iv)	Wage = $4.26–$4.99 (v)	Wage ≥ $5.00 (vi)	Differences within NJ[b]: Low–high (vii)	Midrange–high (viii)
1. FTE employment before, all available observations	23.33 (1.35)	20.44 (0.51)	−2.89 (1.44)	19.56 (0.77)	20.08 (0.84)	22.25 (1.14)	−2.69 (1.37)	−2.17 (1.41)
2. FTE employment after, all available observations	21.17 (0.94)	21.03 (0.52)	−0.14 (1.07)	20.88 (1.01)	20.96 (0.76)	20.21 (1.03)	0.67 (1.44)	0.75 (1.27)
3. Change in mean FTE employment	−2.16 (1.25)	0.59 (0.54)	2.76 (1.36)	1.32 (0.95)	0.87 (0.84)	−2.04 (1.14)	3.36 (1.48)	2.91 (1.41)
4. Change in mean FTE employment, balanced sample of stores[c]	−2.28 (1.25)	0.47 (0.48)	2.75 (1.34)	1.21 (0.82)	0.71 (0.69)	−2.16 (1.01)	3.36 (1.30)	2.87 (1.22)
5. Change in mean FTE employment, setting FTE at temporarily closed stores to 0[d]	−2.28 (1.25)	0.23 (0.49)	2.51 (1.35)	0.90 (0.87)	0.49 (0.69)	−2.39 (1.02)	3.29 (1.34)	2.88 (1.23)

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Variable	Stores by state: PA (i)	NJ (ii)	Difference, NJ − PA (iii)
1. FTE employment before, all available observations	23.33 (1.35)	20.44 (0.51)	−2.89 (1.44)
2. FTE employment after, all available observations	21.17 (0.94)	21.03 (0.52)	−0.14 (1.07)
3. Change in mean FTE employment	−2.16 (1.25)	0.59 (0.54)	2.76 (1.36)
4. Change in mean FTE employment, balanced sample of stores[c]	−2.28 (1.25)	0.47 (0.48)	2.75 (1.34)
5. Change in mean FTE employment, setting FTE at temporarily closed stores to 0[d]	−2.28 (1.25)	0.23 (0.49)	2.51 (1.35)

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Table 3 – row 4

Change in full time equivalent employment Mean and (standard error of mean)		
$PA(\overline{x}_1)$	$NJ(\overline{x}_2)$	$Diff(\overline{x}_2 - \overline{x}_1)$
-2.28	0.47	2.75
(1.25)	(0.48)	(1.34)

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Why did employment increase

- Maybe PA is a poor control – notice that employment in NJ increased, but in PA it fell. Most of the effect is generated by an increase in the employment in PA
  - What would we like to know tp help prove PA is a good control?
- Fast food is a monopsony?
  - Nah – fast food restaurants are all different

Alternative control groups

- Maybe PA is a bad control – are there other control groups available?
- High wage stores in NJ
  - Stores currently paying above the new MW
  - Will not be impacted by the new law – it is not binding

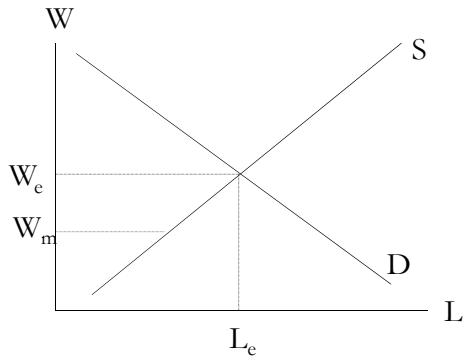

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TABLE 3—AVERAGE EMPLOYMENT PER STORE BEFORE AND AFTER THE RISE IN NEW JERSEY MINIMUM WAGE

Variable	Stores by state: PA (i)	Stores by state: NJ (ii)	Stores by state: Difference, NJ − PA (iii)	Stores in New Jersey[a]: Wage = $4.25 (iv)	Stores in New Jersey[a]: Wage = $4.26–$4.99 (v)	Stores in New Jersey[a]: Wage ≥ $5.00 (vi)	Differences within NJ[b]: Low-high (vii)	Differences within NJ[b]: Midrange–high (viii)
1. FTE employment before, all available observations	23.33 (1.35)	20.44 (0.51)	−2.89 (1.44)	19.56 (0.77)	20.08 (0.84)	22.25 (1.14)	−2.69 (1.37)	−2.17 (1.41)
2. FTE employment after, all available observations	21.17 (0.94)	21.03 (0.52)	−0.14 (1.07)	20.88 (1.01)	20.96 (0.76)	20.21 (1.03)	0.67 (1.44)	0.75 (1.27)
3. Change in mean FTE employment	−2.16 (1.25)	0.59 (0.54)	2.76 (1.36)	1.32 (0.95)	0.87 (0.84)	−2.04 (1.14)	3.36 (1.48)	2.91 (1.41)
4. Change in mean FTE employment, balanced sample of stores[c]	−2.28 (1.25)	0.47 (0.48)	2.75 (1.34)	1.21 (0.82)	0.71 (0.69)	−2.16 (1.01)	3.36 (1.30)	2.87 (1.22)
5. Change in mean FTE employment, setting FTE at temporarily closed stores to 0[d]	−2.28 (1.25)	0.23 (0.49)	2.51 (1.35)	0.90 (0.87)	0.49 (0.69)	−2.39 (1.02)	3.29 (1.34)	2.88 (1.23)

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Table 3 – row 4

Change in full time equivalent employment Mean and (standard error of mean)		
High Wage stores in NJ (1)	Low Wage stores in NJ (2)	Diff [Δ= (2)-(1)]
-2.16	1.21	3.36
(1.01)	(0.82)	(1.30)

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- Reduced turnover?
  - High turnover of jobs in fast food – 400% in a year
  - Most due to quits
  - Higher wage reduces quits, decreases number of "open" jobs

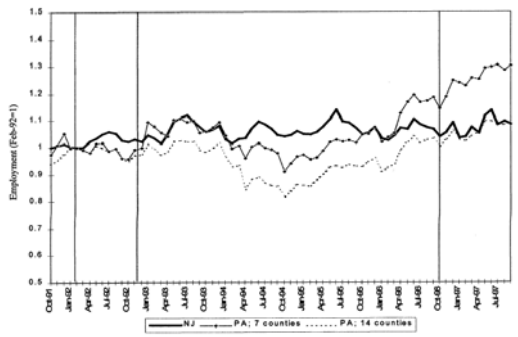

FIGURE 2. EMPLOYMENT IN NEW JERSEY AND PENNSYLVANIA FAST-FOOD RESTAURANTS, OCTOBER 1991 TO SEPTEMBER 1997

Note: Vertical lines indicate dates of original Card-Krueger survey and the October 1996 federal minimum-wage increase.
Source: Authors' calculations based on BLS ES-202 data.

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