Econometrics for Causal Inference
URP Part 2: Difference-in-Difference

Sungkyunkwan University
- Machine Learning and Econometrics -

December 31, 2024

Last Time...

▶ Econometrics and Causal Inference

▶ What is Causal Inference

▶ Counterfactual

▶ Difference-in-Difference

Potential Problems in DiD

Card and Kruger (1994)

▶ Treatment: minimum wage increase in October 1996

▶ Treatment Group: PA

▶ Control Group: NJ

▶ $(E[Y|s = PA, t = 1] - E[Y|s = NJ, t = 1])$
$-(E[Y|s = PA, t = 0] - E[Y|s = NJ, t = 0])$
$= (23.33 - 20.44) - (21.17 - 21.03) = 2.76$

▶ $Y = \alpha PA + \beta T + \tau PA \times T + \epsilon$
$\hat{\tau} = 2.76$

Card and Kruger (1994)

▶ Conditions for proper DiD

1. Well-defined control group (good counterfactual)
2. Treatment effect must occur after treatment

▶ If both state had different trends before treatment...

$\longrightarrow$ research design in this paper failed.
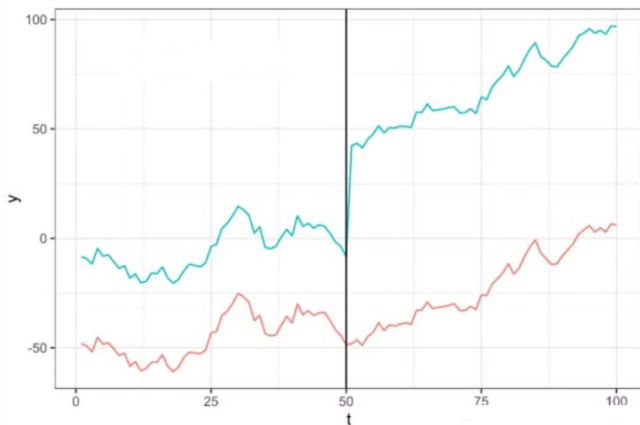
No Parallel Trend

Figure: Difference-in-Difference

No Parallel Trend

- i: treatment group / i: control group
- $t = 1$: after treatment / $t = 0$: before treatment

$$\tau^{\hat{D}D} = (Y_{i,t=1}(1) - Y_{j,t=1}(0)) - (Y_{i,t=0}(0) - Y_{j,t=0}(0))$$

$$= (Y_{i,t=1}(1) - Y_{i,t=0}(0)) - Y_{j,t=1}(0) - Y_{j,t=0}(0))$$

$$+ (Y_{i,t=1}(0) - (Y_{i,t=1}(0))$$

$$= (Y_{i,t=1}(1) - Y_{i,t=1}(0)) + [(Y_{i,t=1}(0) - Y_{i,t=0}(0)) - (Y_{j,t=1}(0) - Y_{j,t=0}(0))]$$

$$\approx E[Y_{i,t=1}(1) - Y_{i,t=1}(0)] + E[Y_{i,t=1}(0) - Y_{i,t=0}(0)]$$

$$- E[Y_{j,t=1}(0) - Y_{j,t=0}(0)]$$

$$= \tau + CounterfactualTrend - UntreatedTrend$$

- Parallel Trend: Counterfactual Trend = Untreated Trend

No Parallel Trend

Figure: Violate Parallel Trend Assumption
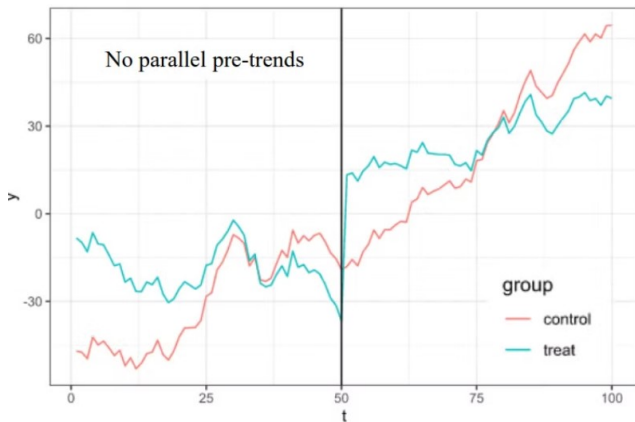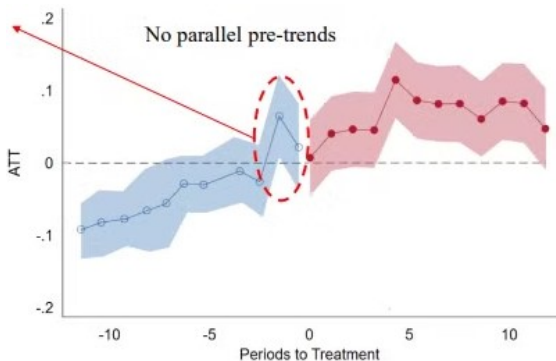
Anticipation Effect

Figure: Anticipation Effect

Check and Solve

Adding Covariates

- ▶ Control for important variables

- ▶ Build Ceteris Paribus as close as possible

DiD Event Study

- ▶ Check parallel trend

- ▶ Analyze dynamic effect

Adding Covariates

$$Y_{it} = \alpha + \tau\, Treat_i \times Post_i + \beta\, Treat_i + \delta\, Post_t + \gamma X_{it} + \epsilon_{it}$$

$$E[Y_1(0) - Y_0(0)|Post = 1] \neq E[Y_1(0) - Y_0(0)|Post = 0]$$

▶ But it can be....

$$E[Y_1(0) - Y_0(0)|Post = 1, X] = E[Y_1(0) - Y_0(0)|Post = 0, X]$$

DiD Event Study

$$Y_{it} = \alpha + \sum_{\tau=0}^{m} \delta_{-\tau} D_{i,t-\tau} + \sum_{\tau=1}^{q} \delta_{+\tau} D_{s,t+\tau} + X_{it}'\beta + \epsilon_{it}$$
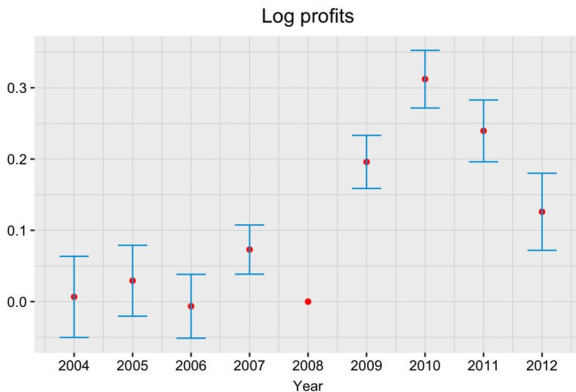

FIGURE 4

Event-study coefficients $\{\beta_s\}$ for log profits, estimated using the event-study specification in (19).

Why DiD Event Study

▶ Check parallel trend (Rambachan, 2023)

▶ Dynamic treatment effect

Benzarti and Carloni (2019)

The Effect of Value-added Taxes

- ▶ Treatment: 2009 VAT Reform

    - ▶ Before: a standard rate of 19.6% applied to sit-down meals and a reduced rate of 5.5% for take-away meals
    - ▶ After: decrease in the price of meals consumed in sit-down restaurants and equalization between the VAT rate between sit-down meals and take-away meals

- ▶ Treatment group: sit-down restaurants

$$logY_{idt} = \eta \cdot 1\{i \in T\} \times After + \lambda_t + \omega_i + \epsilon_{idt}$$

- ▶ Dynamic Effects

$$logY_{idt} = \sum_{\nu=-k}^{q} \eta_\nu \cdot 1\{i \in T\} \times 1\{t = \nu\} + \lambda_t + \omega_i + \epsilon_{idt}$$
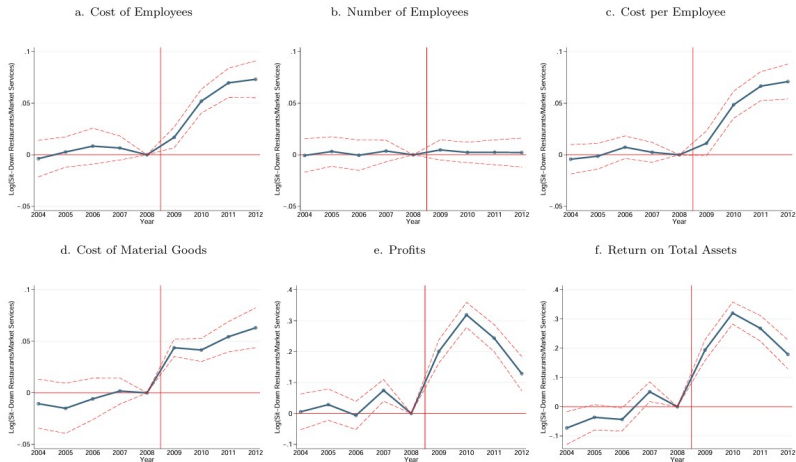
Benzarti and Carloni (2019)
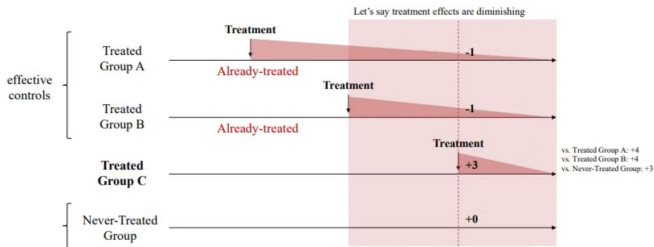
Dynamic Effects

Figure 2. : Dynamic Effects of the VAT Cut: Sit-Down Restaurants vs. Market Services

Figure: Event Study DiD

Staggered DiD

Continuous Treatment Effect

▶ Binary treatment: treatment or not
▶ Continuous treatment: treatment level
  ▶ Example: receive regular income from government in proportion to income level.

Kim and Sim (2024)

▶ The impact of regulations on firm size on firm growth

▶ Treatment: regulations on firm size

▶ Treatment Effect: firm growth (employment, revenue)

▶ Legal amendment in 2015
  ▶ The criteria for Small-and-Mid-Sized firm have changed
  ▶ "treatment group" is made

Homework

Billboards really work?

▶ Data: experiment result for billboard (hypothetical)

▶ Treatment on July

▶ Work
  ▶ Make regression model using variables in data
  ▶ Conduct DiD analysis
  ▶ Check parallel trend
  ▶ Report and plot the result
  ▶ 1-2 pages report and code