

# Part 8: Program Evaluation (f): Synthetic Control Methods

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Applied Econometrics

# Motivation: Recap

Difference in Difference approaches have some drawbacks:

- We need to really believe **parallel trends**
  - Is  $\Delta PA$  really a good counterfactual for  $\Delta NJ$ ?
  - Obvious question: why not pick  $\Delta DE$  or  $\Delta NY$ ?
  - Measured effect shouldn't change if our assumption is valid (but it probably will!)
- With multiple treated individuals we can use 2WFE estimator

$$y_{it} = \beta X_{it} + \delta_i \cdot T_{it} + \gamma_i + \gamma_t + u_{it}$$

- It assumes **additivity** of FE  $\gamma_i + \gamma_t$  are independent!
- States have different baseline levels  $\gamma_i$  but evolution over time is common  $\gamma_t$ .
- Turns out it doesn't really generalize the diff-in-diff with  $I > 2$  (Imai and Kim 2020).

## Motivation: Recap

Matching Estimators had drawbacks too:

- We need to believe in as if random-assignment conditional on  $X$
- CIA:  $\{Y_i(1), Y_i(0)\} \perp T_i | X_i$ .

But we could use pretty flexible methods in constructing our matched controls:

- We could try to match on multiple dimensions of  $X$ .
- $k$ -NN, kernels, etc.

What if we could use ideas from **matching** to better satisfy something like our **parallel trends** assumptions?

Example: Abadie, Diamond,  
Hainmueller (2010)

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# The Question

In 1988 California passes anti-smoking Prop 99

- increased excise tax by 25 cents per pack,
- earmarked the tax revenues to health and anti-smoking education budgets and funded anti-smoking ads
- led to indoor smoking bans in restaurants and bars city by city

What was the effect on per capita cigarette sales?

- Already a bunch of pre-existing trends.
- What is a good control for California?

Use state-level data from 1970-2000.

# The Idea

Use a convex combination of other states to construct a **synthetic counterfactual California**.

- We observe  $Y_{it}, X_{it}, T_{it}$ .
- Assume only  $i = 1$  and  $t > T_0$  are **treated**.
- Construct a **donor pool** of potential controls subscripted by  $j$ .
- Choose some **weights**  $w_j$  for each entity (state) in donor pool. How?
  - Same  $\mathbf{X}_1 = \sum_j w_j \mathbf{X}_j$  as treated observations (like matching).
  - Same  $(Y_{1,1}, \dots, Y_{1,T_0}) = \sum_j w_j \cdot (Y_{j,1}, \dots, Y_{j,T_0})$  (like parallel trends).
  - Weights sum to one  $\sum_j w_j = 1$  and maybe are non-negative (or not!)
- Idea is to match all of the  $X$ 's and all of the  $Y_{it}$ 's in the **pre-period**

Table 1. Cigarette sales predictor means

Variables	California		Average of 38 control states
	Real	Synthetic	
Ln(GDP per capita)	10.08	9.86	9.86
Percent aged 15–24	17.40	17.40	17.29
Retail price	89.42	89.41	87.27
Beer consumption per capita	24.28	24.20	23.75
Cigarette sales per capita 1988	90.10	91.62	114.20
Cigarette sales per capita 1980	120.20	120.43	136.58
Cigarette sales per capita 1975	127.10	126.99	132.81

NOTE: All variables except lagged cigarette sales are averaged for the 1980–1988 period (beer consumption is averaged 1984–1988). GDP per capita is measured in 1997 dollars, retail prices are measured in cents, beer consumption is measured in gallons, and cigarette sales are measured in packs.

# Donor Weights

Table 2. State weights in the synthetic California

State	Weight	State	Weight
Alabama	0	Montana	0.199
Alaska	–	Nebraska	0
Arizona	–	Nevada	0.234
Arkansas	0	New Hampshire	0
Colorado	0.164	New Jersey	–
Connecticut	0.069	New Mexico	0
Delaware	0	New York	–
District of Columbia	–	North Carolina	0
Florida	–	North Dakota	0
Georgia	0	Ohio	0
Hawaii	–	Oklahoma	0
Idaho	0	Oregon	–
Illinois	0	Pennsylvania	0
Indiana	0	Rhode Island	0
Iowa	0	South Carolina	0
Kansas	0	South Dakota	0
Kentucky	0	Tennessee	0
Louisiana	0	Texas	0
Maine	0	Utah	0.334
Maryland	–	Vermont	0
Massachusetts	–	Virginia	0
Michigan	–	Washington	–
Minnesota	0	West Virginia	0
Mississippi	0	Wisconsin	0
Missouri	0	Wyoming	0



# Trend Check and Treatment Effects

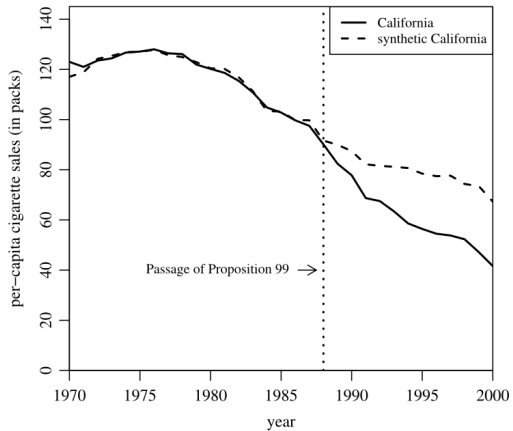
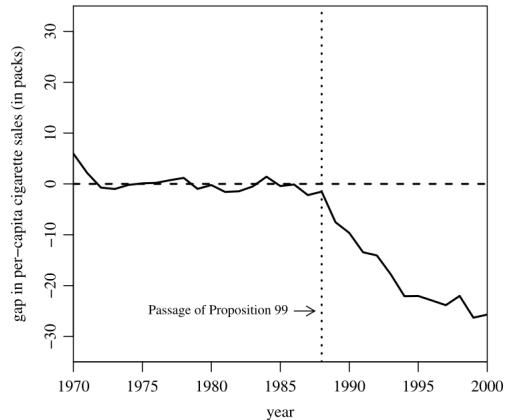


Figure 2. Trends in per-capita cigarette sales: California vs. synthetic California.



## But still some issues

- How sensitive are weights estimates to different covariates?
  - “state-level measures of unemployment, income inequality, poverty, welfare transfers, crime rates, drug related arrest rates, cigarette taxes, population density, and numerous variables to capture the demographic, racial, and social structure of states”.
- Can we run a **placebo check**? Do we detect effects where we know there is a null effect?
  - Put California in the donor pool.
  - Pick a state from the donor pool at pretend that receives the treatment after  $T_0$
  - Choose  $w_j$  following the synthetic control procedure.
  - Compute the treatment effects in the same way.
  - Repeat for all states in donor pool.
  - Compare **mean-square prediction error** (MSPE) for  $(Y_{1,1}, \dots, Y_{1,T_0})$
  - This doubles as **inference**.

# Placebo Test

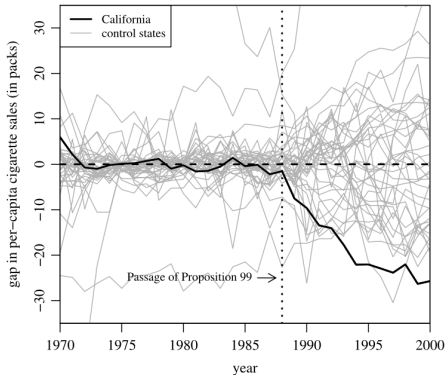


Figure 4. Per-capita cigarette sales gaps in California and placebo gaps in all 38 control states.

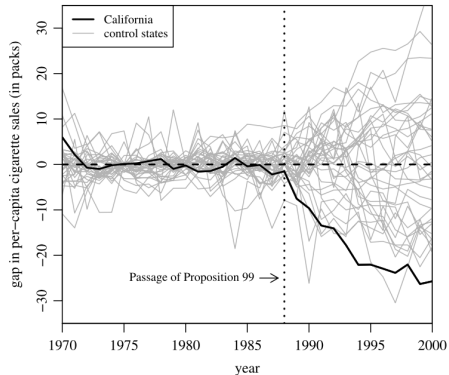


Figure 5. Per-capita cigarette sales gaps in California and placebo gaps in 34 control states (discards states with pre-Proposition 99 MSPE twenty times higher than California's).

# More Placebo Tests: How unusual is the CA result?

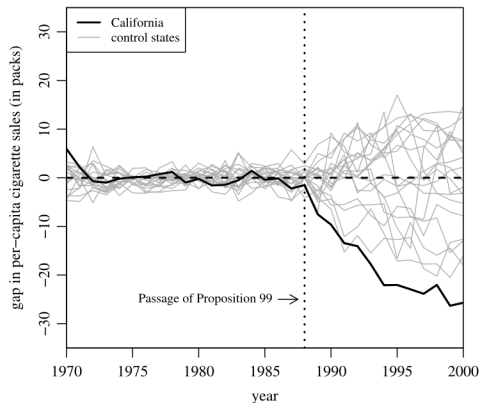


Figure 7. Per-capita cigarette sales gaps in California and placebo gaps in 19 control states (discards states with pre-Proposition 99 MSPE two times higher than California's).

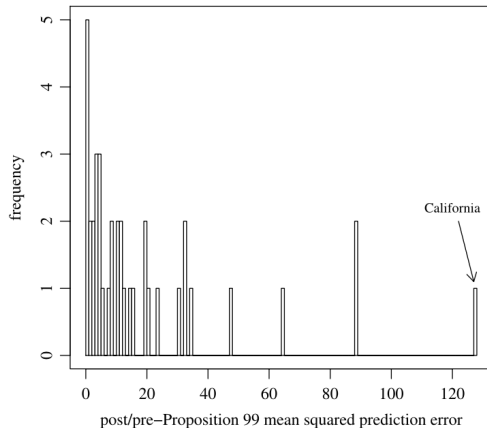


Figure 8. Ratio of post-Proposition 99 MSPE and pre-Proposition 99 MSPE: California and 38 control states.

Thanks

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