Synthetic Control Hypothesis Testing

INFO/STSCI/ILRST 3900: Causal Inference

9 Nov 2023

Learning goals for today

At the end of class, you will be able to:

1. Understand example of synthetic control applied to anti-smoking legislation
2. Understand how to conduct a hypothesis test for estimates from a synthtic control analysis

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- Allows for estimating time varying trends

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- Can directly match to minimize pre-treatment fit

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- Synthetic control requires similar assumption, but for synthetic unit

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What was the effect of Proposition 99 (and the related measures) on smoking in California?

Example: Smoking in California

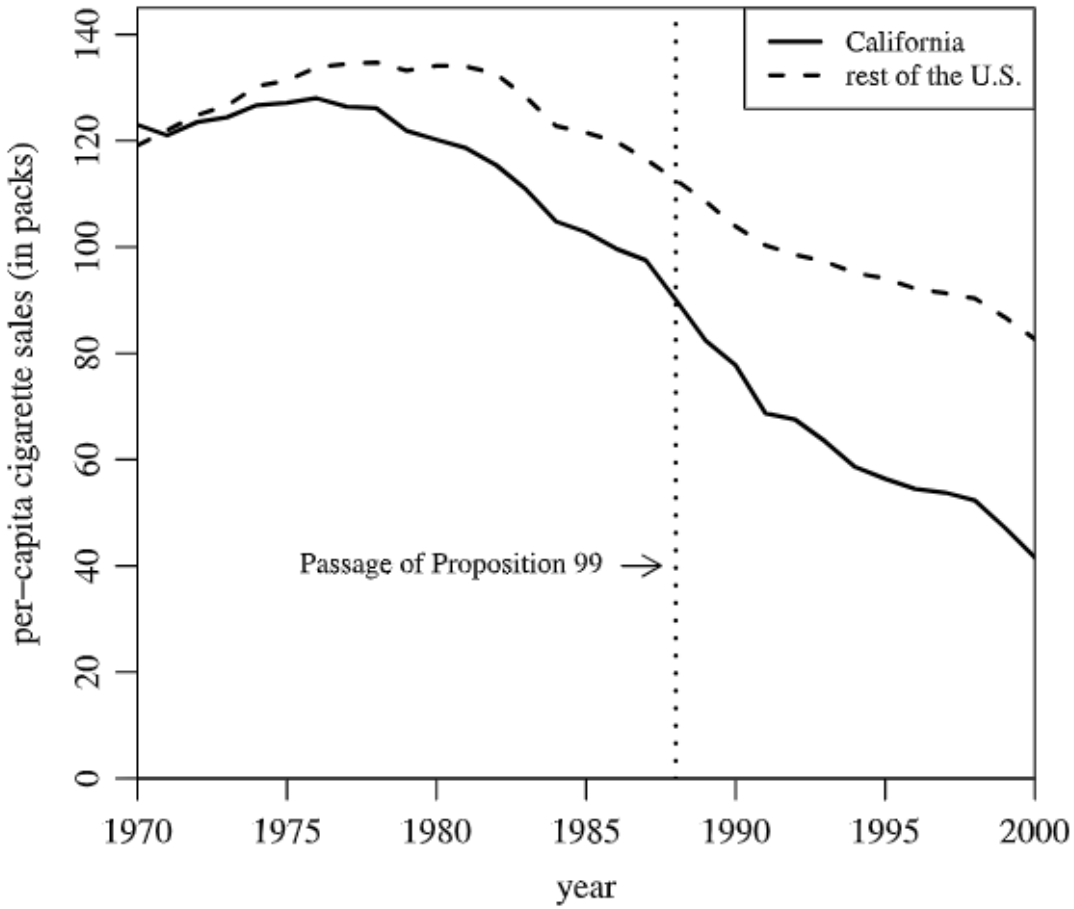

Figure 1. Trends in per-capita cigarette sales: California vs. the rest of the United States.

Example: Smoking in California

- Outcome: cigarette sales per capita
- Treatment: Prop 99, increase in cigarette tax and anti-smoking campaign
- Donor pool consists of 38 states which did not enact increase in cigarette taxes
  - If we were to use "regular" matching, would we be able to find a good match for California?
  - If we were to use diff-in-diff, should we use average of all 38 other states?

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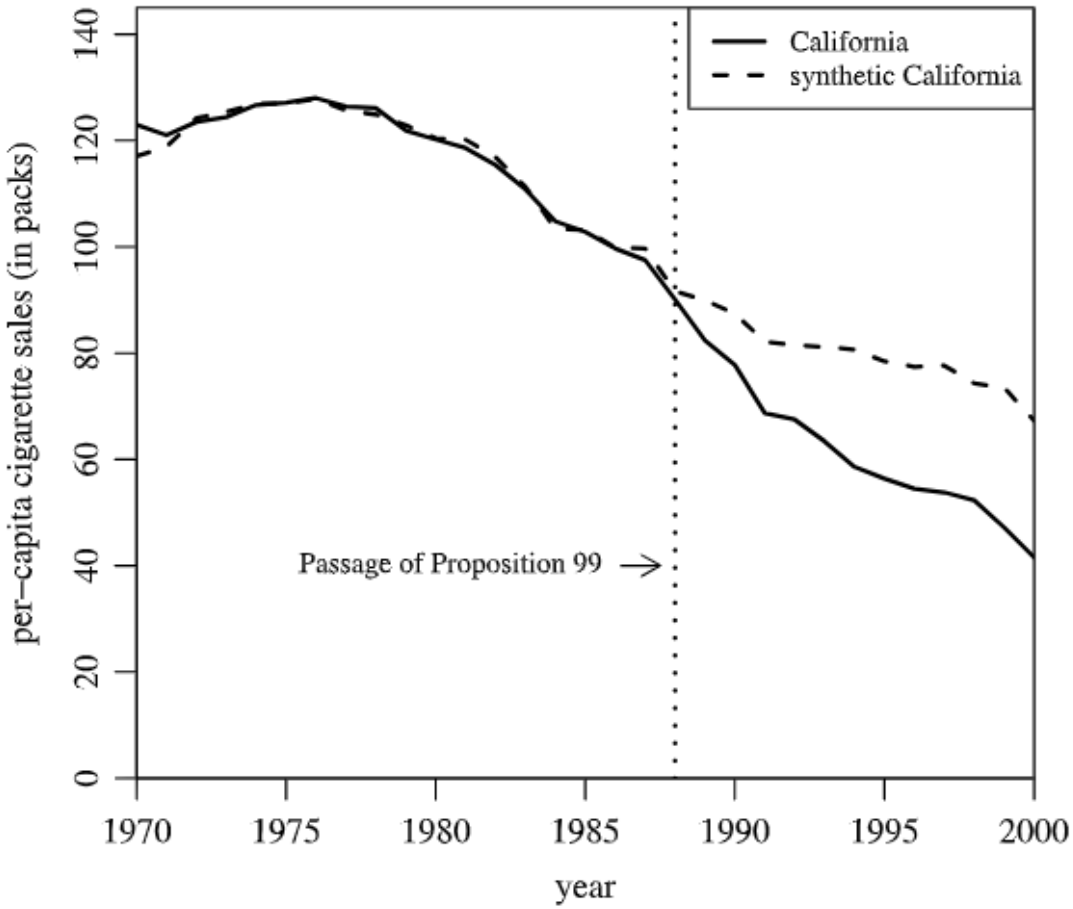
- Treatment: Prop 99, increase in cigarette tax and anti-smoking campaign
- Donor pool consists of 38 states which did not enact increase in cigarette taxes
- Weights selected by matching
  - log(GDP per capita)
  - % of population aged 15-24
  - Retail price of cigarettes
  - Beer consumption per capita
  - Cigarette sales per capita in 1975, 1980 and 1988

Example: Smoking in California

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

Example: Smoking in California



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Example: Smoking in California

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.

Example: Smoking in California

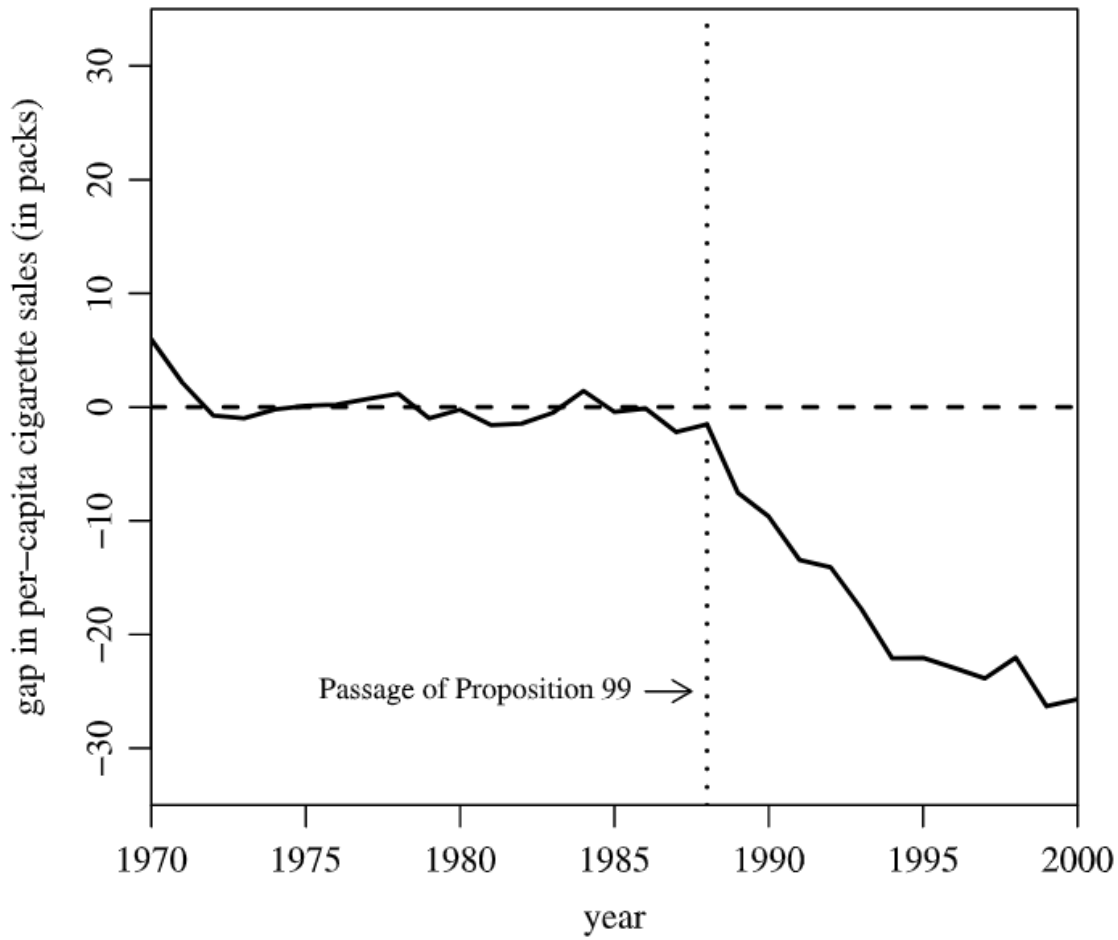

Figure 3. Per-capita cigarette sales gap between California and synthetic California.

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- In general, we expect a discrepancy between the synthetic unit and the real observations, even if the treatment had no effect
- How might we test whether the estimated effect is statistically significant?
- Placebo test:
  - Run synthetic control on other states which didn't get treatment
  - Compare difference between observed and synthetic California to the difference between observed and synthetic for untreated states

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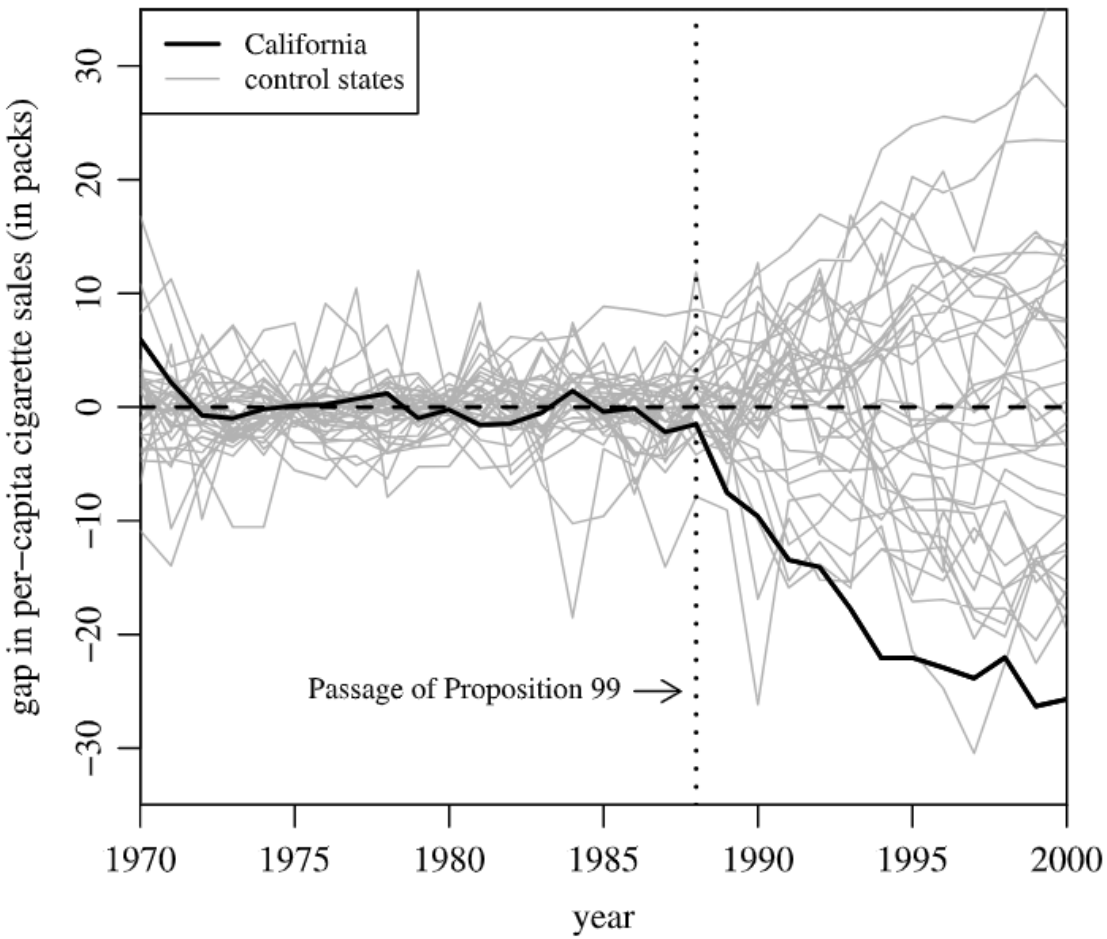

Figure 5. Per-capita cigarette sales gaps in California and placebo gaps in 34 control states (discards states with pre-Proposition 99 MSPE twenty times higher than California's).

Hypothesis testing

- Discrepancy for California:

$$\text{Ratio of Mean Squared Error} = \frac{\sum_{t \geq T_0}(Y_{t,CA} - Y_{t,synthCA})^2}{\sum_{t < T_0}(Y_{t,CA} - Y_{t,synthCA})^2}$$

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- If California is large relative to other states, indicates difference is unlikely to occur simply by chance
- P-value: is proportion of states larger than California

Exampl: Smoking in California

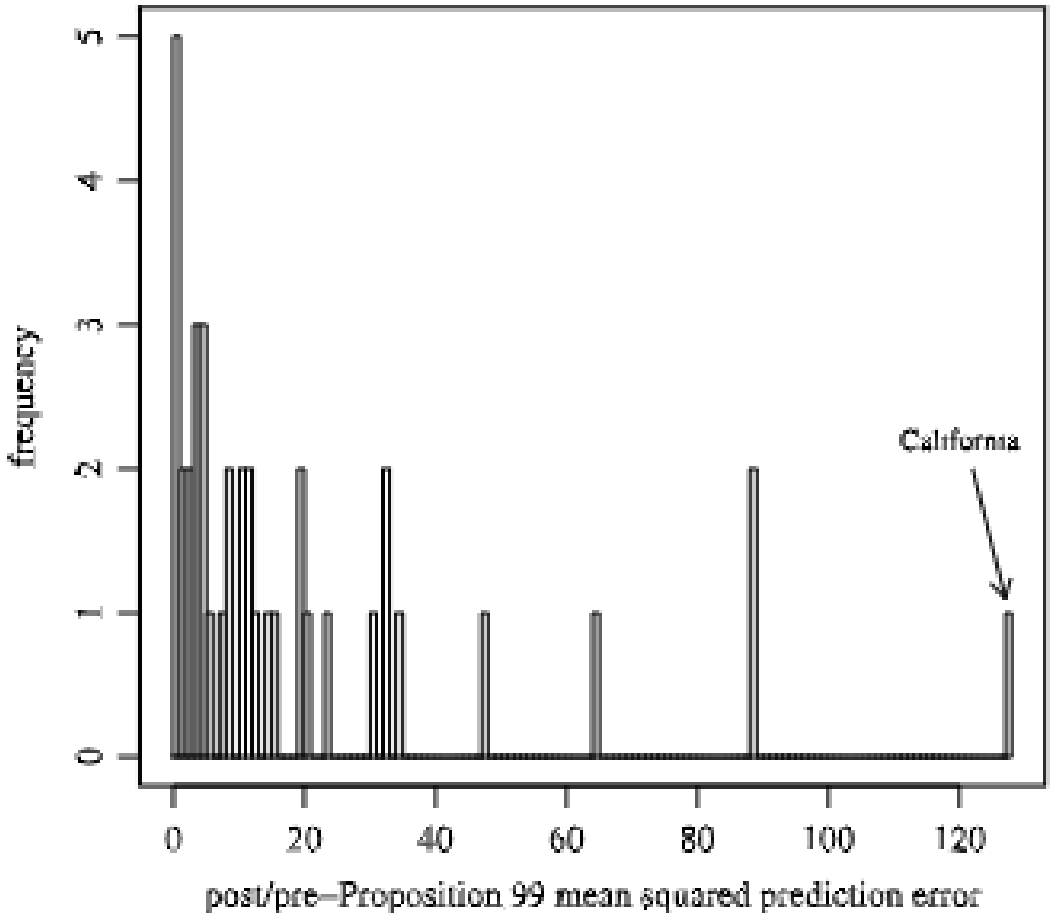

Figure 8. Ratio of post-Proposition 99 MSPE and pre-Proposition 99 MSPE: California and 38 control states.

P-value = .026

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- Synthetic unit approximates what would've happened in California without treatment
- Relies on assumption that actual observations for untreated units are what we would have also observed if California had not been treated
- If treatment in California also decreases smoking in Utah the synthetic unit we actually observe has less smoking than the synthetic unit we would've created if we were able to observe Utah without California treatment
- Gap between actual California and synthetic unit we actually construct is be smaller than gap between actual California and the synthetic unit we would've created if we were able to observe Utah without California treatment

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