NY Fed Econometrics Reading Group: Synthetic Controls

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Motivation

- Use synthetic controls when no single untreated unit provides a good comparison for unit affected by treatment or event
- It is possible to show causality
- Fairly straightforward when done correctly
- Can be applied to a wide range of settings

Main Idea

- Construct a synthetic treatment unit from a group of comparison units
- Compare the synthetic treatment outcome and actual treatment outcome

Primary Issues:

- How to select comparison units?
- Robustness? Biases?

Related Literature

Focus on Abadie, Diamond, Hainmueller (2015) - Comparative Politics (West Germany Reunification)

Other related literature:

- Abadie and Gardeazabal (2003) - Basque Terrorism
- Abadie, Diamond, Hanmueller (2010) - Tobacco Control Program

Can we name other studies?

Presentation Roadmap

Setup

Let there be $J+1$ units, indexed by j

- $j = 1$ is the treatment (unit in question)
- $j = 2, 3, ..., J+1$ comparison units ("donor pool")

Let there be time periods $t = 1, 2, ..., T$

- T_0 is pre-intervention periods ($t = 1, 2, ..., T_0$)
- T_1 is post-intervention periods ($t = T_1, ..., T$)

Weights

Goal: Take weighted average of units in donor pool [$(J \times 1)$ vector]: $W = (w_2, ..., w_{J+1})'$

- $0 \leq w_j \leq 1$ for $j = 2, ..., J+1$ and $\sum_{j=2}^{J+1} w_j = 1$

Selecting Weights: Introduce X_1 pre-intervention characteristics of treated unit [$(k \times 1)$ vector] and X_0 pre-intervention characteristics of donor pool [$(k \times J)$ matrix].

- Select W^* that minimizes the size difference between pre-intervention characteristics of treated unit and synthetic control: $X_1 - X_0 W$
- Let there be m characteristic variables. Minimize $\sum_{m=1}^{k} v_m (X_{1m} - X_{0m} W)^2$ where v_m is a weight that reflects the relative importance that we assign to the m-th variable

Outcome Variables

Let Y_{jt} be the outcome of unit j at time t.

- Y_1 is $(T_1 \times 1)$ vector of post-intervention values of treated
- Y_0 is $(T_1 \times J)$ matrix of post-intervention values of donor group

Goal: Comparison of post-intervention between synthetic control and actual outcome $(Y_1 - Y_0 W^*)$

- In terms of units: $Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt}$

Problems to Address

- Unit choice (e.g. city-level, county-level, "region"-level, country-level, etc.)
- Stable Unit Treatment Value Assumption (SUTVA)
- Inference?

Inference

- Falsification exercises - check to see whether synthetic controls estimated effects of similar or even greater magnitudes in cases where the intervention did not take place
  - In-time placebos - are there large estimates in periods before treatment timing?
  - In-space placebos - are there large estimates in units not exposed in donor pool?

Limitations

- Selecting the donor pool - how to do this properly?
  - Does the shock also apply to units in the donor pool?
  - Are the units in the donor pool similar enough?
  - Is the donor pool too large such that there is overfitting?
- Require a long pre-intervention period to make more believable
  - Goes back to in-time and in-space placebos

Presentation Roadmap

Western German Reunification

Question: The economic costs of 1990 German Reunification. What are the economic costs of Western Germany, without focusing on the convergence of East and West German economies? What is the magnitude of this effect?

How to go about answering this question? Use Synthetic Controls!

Data and Set-up

- Country-level Panel Data: 1960-2003
  - Treatment Unit: West Germany
  - Treatment Timing: 1990
  - Donor Pool: 16 OECD member countries
- Outcome Variable: real per capita GDP (PPP adjusted to 2002 USD)
  - Other Pre-reunification characteristics: per capita GDP, inflation rate, industry share of value added, investment rate, schooling, and measure of trade openness
  - Robust

Synthetic Control

- Training Period: 1971-1980; Validation period: 1981-1990
- Cross-validation technique: Select v_m to minimize RMSPE over validation period (minimize out-of-sample prediction error)
  - Choose $W = W^*$ s.t. minimize $\sum_{m=1}^{k} v_m(X_{1m} - X_{0m}W)^2$
  - This will determine what the most important predictors are.
  - Top 3 importance: GDP per capita (0.44), investment rate (0.25), trade openness (0.13)

Weight Selection - Countries

Country	Synthetic Control Weight	Regression Weight	Country	Synthetic Control Weight	Regression Weight
Australia	0	0.12	Netherlands	0.09	0.14
Austria	0.42	0.26	New Zealand	0	0.12
Belgium	0	0	Norway	0	0.04
Denmark	0	0.08	Portugal	0	−0.08
France	0	0.04	Spain	0	−0.01
Greece	0	−0.09	Switzerland	0.11	0.05
Italy	0	−0.05	United Kingdom	0	0.06
Japan	0.16	0.19	United States	0.22	0.13

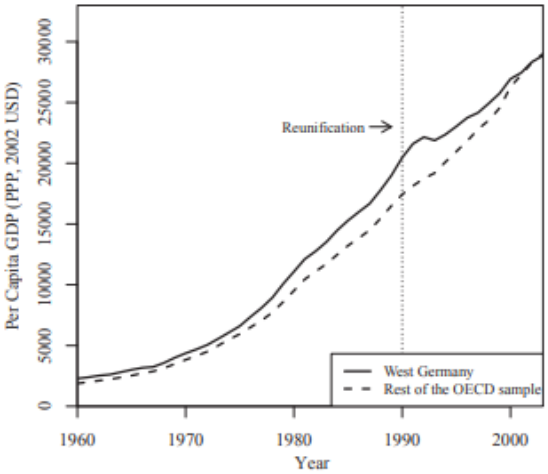
Notes: The synthetic weight is the country weight assigned by the synthetic control method. The regression weight is the weight assigned by linear regression. See text for details.

Growth Predictors

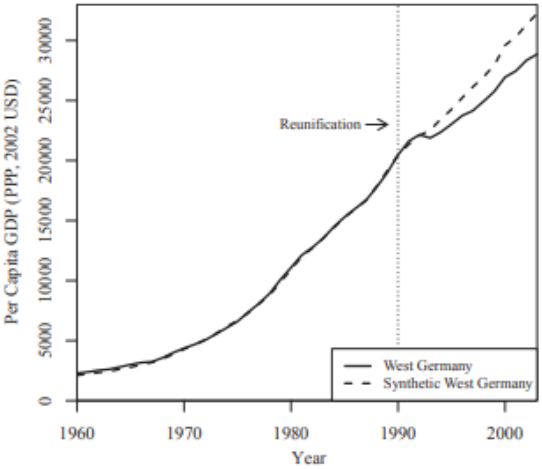
	West Germany	Synthetic West Germany	OECD Sample
GDP per capita	15808.9	15802.2	8021.1
Trade openness	56.8	56.9	31.9
Inflation rate	2.6	3.5	7.4
Industry share	34.5	34.4	34.2
Schooling	55.5	55.2	44.1
Investment rate	27.0	27.0	25.9

Notes: GDP per capita, inflation rate, trade openness, and industry share are averaged for the 1981–90 period. Investment rate and schooling are averaged for the 1980–85 period. The last column reports a population-weighted average for the 16 OECD countries in the donor pool.

Synthetic Control - OECD Donor Pool vs Western Germany



Synthetic Control - Results



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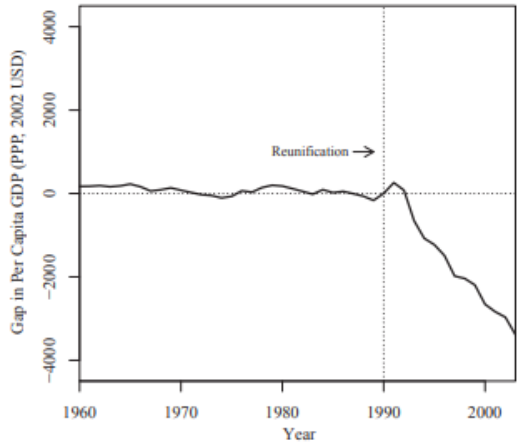
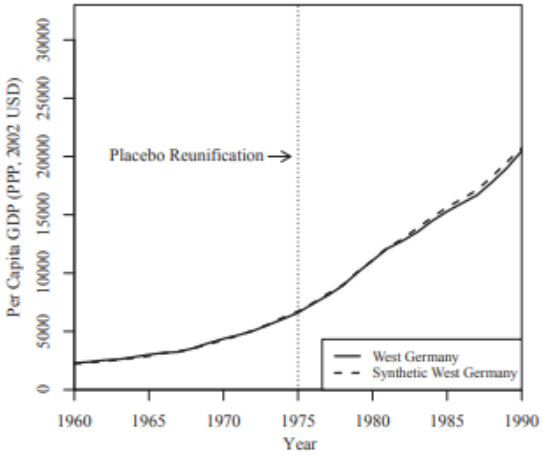


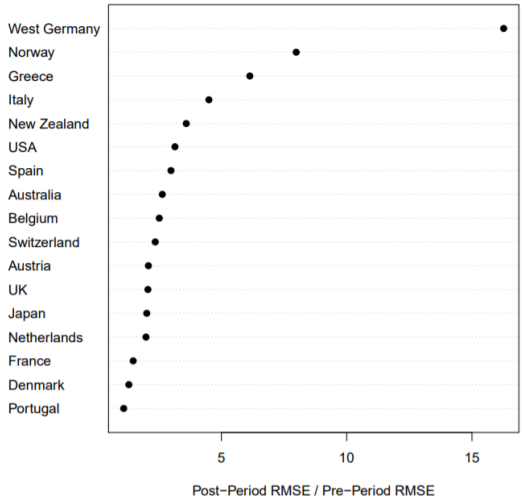
Placebo Studies

- Placebo Reunification (1975) - "in-time" placebo
- Compare RMSPE ratio between West Germany and all countries in donor pool - "in-space" placebo
  - Leave-one-out distribution - remove one country with positive weight

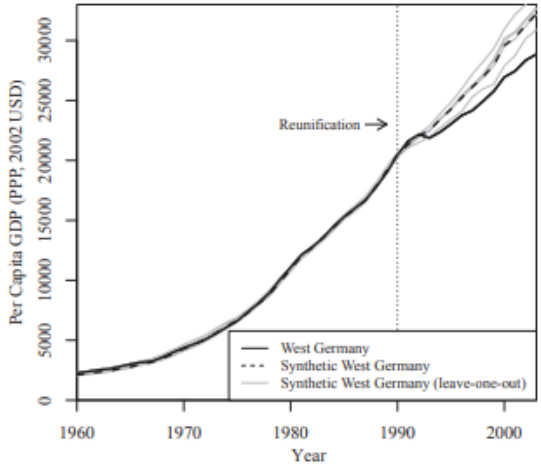
Placebo Studies - In time



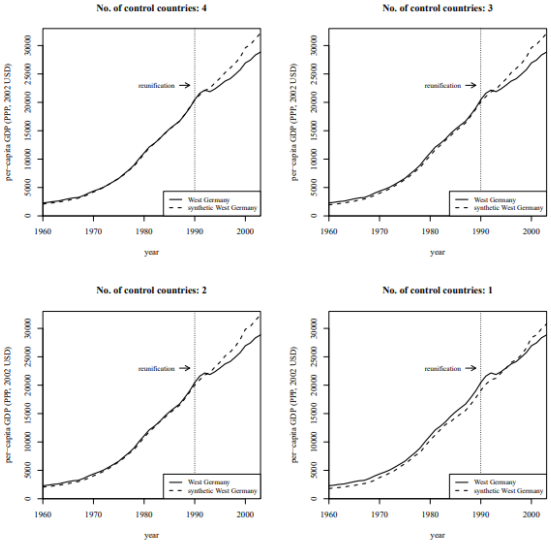
Placebo Studies - RMSE ratios



Placebo Studies - In space



Over-fitting tests



Presentation Roadmap

Conclusion

- Use synthetic controls when there is no suitable match between treated and untreated units
- Placebo tests to validate synthetic control
  - "In-time"
  - "In-space"
- Donor pool choice matters!
  - Unit size
  - Donor pool comparable to Treatment Unit
- Time periods matters!

Do I Have to Calculate Everything by Hand?

NO! Use `synth` package (Stata, MATLAB, R)!

Find these packages on Jens Hainmueller's website

Discussion Points

- Diff-in-diff vs. Synthetic Controls: Which is better?
  - How comparable are the control and treated groups?
  - Smaller unit size may lend itself to Diff-in-Diff
  - Use synthetic controls when there is no good counterfactual group
- Using Synthetic Controls: how to ensure validity?
  - Construct many synthetic controls such that you get "error" terms as to not cherrypick
  - Comparability of units: easier for more granular units (e.g. counties), harder for larger units (e.g. countries)