Synthetic Control Method with Pre-Trends: the Case of Augusto Pinochet's Chile*

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Abstract

This paper studies the sensitivity of the synthetic control method estimates to the existence of "pre-trends," i.e. situations when the synthetic control is unable to replicate the trend of the outcome variable of the treated unit in the pre-intervention period. Using Pinochet's Chile as an example, we show that the paths of the synthetic control and treated unit diverge before the "intervention" begins. We further confirm this by backdating the intervention. As a result, the synthetic control method estimates for Chile are highly sensitive to the choice of the donor pool and the pre-treatment period. Our results indicate that in settings where pre-trends may be present, the synthetic control method should be used with caution.

*All remaining errors are ours.

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1 Introduction

"Parallel trends" is a common assumption in the literature on differences-in-differences (hereafter DiD) designs, and researchers using DiD often test for "pre-trends" (Roth (2022); Roth and Sant'Anna (2023)). When this assumption is violated, one of the available remedies is to use the synthetic control method (Kreif et al. (2016); Ryan et al. (2019)). However, while it may be more robust to the existence of pre-trends than some of the DiD estimators, the synthetic control method (hereafter SCM) is not totally immune. Abadie (2021, p. 414-415) remarks:

"**The absence of estimated effects prior to the intervention** provides credibility of the synthetic control estimator, as it demonstrates that the synthetic control is able to **reproduce the trajectory of the outcome variable for the treated unit** before the intervention occurs." (emphasis ours)

Abadie (2021) recommends backdating the intervention as a robustness check to ensure that there are no anticipation effects and that the SCM is indeed able to accurately match the treated unit before the intervention occurs.

In this paper, we re-examine the role that Augusto Pinochet, who ruled Chile from 1973 to 1989, and his policies played in the so-called "Miracle of Chile," the rapid growth of Chile's economy that started around mid-1980s. We show that the backdating exercise recommended by Abadie (2021) uncovers pre-existing differences between the treated and synthetic control units. We call these differences "pre-trends," to highlight that they represent the diverging trajectories of the treated and synthetic control units before the intervention.

Several existing papers study Chile's economy during and after Pinochet's rule using the SCM. Escalante (2022) considers the period of 1960-1988 using the World Bank data. He studies the impact of Pinochet's rule on Chile's economy in 1973-

1988 and finds that Chile's economy underperformed relative to the counterfactual, meaning that Pinochet's rule had a negative impact on economic growth. In turn, Uhr et al. (2017) examine the effects of re-democratization using the period of 1976-2014, also utilizing the World Bank data, considering only countries with complete data for this period. They find that after the democratization of 1989, Chile's economy significantly outperformed the synthetic control unit, meaning that democratization resulted in faster economic growth. Overall, taken together these results imply that Pinochet's rule was detrimental for Chile's economy.

We revisit the results of these papers and highlight some issues associated with the use of the SCM in this context. More specifically, we show that the results in both papers may be susceptible to the existence of pre-trends, where the divergence between the actual and counterfactual units starts before the "intervention" takes place. In order to better illustrate this, we conduct two backdating tests and apply the SCM to Chile's economy in 1970 and 1986. In both cases, we find that the resulting effects are comparable in magnitude to the effects found for 1973 and 1989, respectively. We also show that different inference methods may yield very different results.

We then expand the pool of control countries and shorten the pre-treatment period, which may allow us to find a better match for Chile and alleviate the problem of pre-trends. Doing this may potentially result in overfitting, because the number of possible controls in the donor pool is large and the number of pre-treatment observations is small. Nevertheless, we show that the results differ substantially from the ones in existing studies, especially for 1973.

Our contribution is twofold. First, we contribute to the econometrics literature by highlighting possible issues associated with the use of the SCM. We show that in some cases, the SCM may fail to capture important aspects of the data and as a results

is highly sensitive to the choices made by the researcher, such as the composition of the donor pool and the length of the pre-treatment period. Therefore, we emphasize the importance of conducting robustness checks, such as backdating, when using the SCM. Second, we contribute to the empirical literature on the role Pinochet's rule played in Chile's economic growth by showing that the existing results on Pinochet's influence on Chile's economy may be affected by pre-trends and should be viewed with caution.

The rest of the paper is organized as follows. Section 2 describes the data and methodology we use in this paper. Section 3 presents our results. Section 4 concludes.

2 Methodology and Data

In our analysis, we use the World Bank data on real GDP per capita.[1] For the first part of our analysis, we restrict the donor pool to the 23 countries used in Escalante (2022).[2] We then use 43 countries to try to match the "Occidental World" pool in Uhr et al. (2017), and then expand our donor pool to all 87 countries for which the GDP and inflation data are available for all years between 1960 and 2010.

Let $y_{j,t}$, $j = 1, ..., J$, $t = 1, ..., T$, be the outcome variable, such as the natural logarithm of GDP per capita, in country j in period t ($t = 1$ corresponds to the first year in the sample while $t = T$ corresponds to the last year). We use natural logarithms instead of GDP per capita because the SCM tends to work better with this transformation (Korolev (2021)). We order the countries so that $j = 1$ corresponds to Chile, the treated unit. Depending on the "intervention" we are interested in (the

[1] Available at https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.PCAP.KD&country=.

[2] These countries are Argentina, Australia, Bolivia, Brazil, Canada, China, Colombia, Congo DR, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, Philippines, Portugal, South Africa, Spain, United States, and Uruguay. The data for Venezuela is unavailable.

beginning or the end of Pinochet's rule), the treatment takes place in 1973 or in 1989. The counterfactual for periods $t > T_0$, after the intervention takes place, is given by

$$\hat{y}^0_{1,t} = Y^{'}_{-1,t}\hat{\beta}_{sc},$$

where $Y_{-1,t} = (y_{2,t}, ..., y_{J+1,t})'$ and the synthetic control weights $\hat{\beta}_{sc}$ solve:

$$\min_{\beta} \sum_{t=1}^{T_0} v_t(y_{1,t} - Y^{'}_{-1,t}\beta)^2 \qquad \text{subject to } \sum_{j=2}^{J+1} \beta_j = 1, \beta_j \geq 0, j = 2, ..., J+1,$$

where v_t are the importance weights that are normally chosen by the estimation procedure automatically.

From the statistical point of view, imposing restrictions on the estimates may alleviate the problem of overfitting: achieving a nearly perfect pre-treatment fit when the number of controls is large and the number of periods is small. From the economic point of view, these restrictions make the resulting estimate easier to interpret: the synthetic control unit can be interpreted as a weighted average of the units in the donor pool.

We should note that the way we implement the SCM is somewhat different from the way it is used in Escalante (2022) and Uhr et al. (2017). Instead of matching Chile with other countries based on the *average* GDP per capita over a time period along with the average values of a number of other predictors, we match Chile with other countries based on the *entire* time series of the log GDP per capita in the pre-treatment period. This is in line with the more recent literature on the SCM and its modifications, such as Ben-Michael et al. (2021) and Arkhangelsky et al. (2021).

One potential drawback of the SCM is that it rules out a parallel shift in trends (see, e.g., Doudchenko and Imbens (2016)). In other words, if the treated country and

all countries in the donor pool have parallel trends but different levels of the outcome variable, then the SCM may fail to find a good match. In order to solve this issue, in some of our specifications we demean the outcome variable in the pre-treatment period for each unit, which we call demeaned SCM. We implement the standard and the demeaned versions of the SCM using the **augsynth** package in R by Ben-Michael et al. (2021).

3 Results

First, we attempt to replicate the results of Escalante (2022) and Uhr et al. (2017) for 1973 and 1989, respectively. Panel A of Figure 1 shows the counterfactuals from the SCM along with Chile's actual GDP per capita. Panel B shows the SCM point estimates (the difference between the actual and counterfactual values) along with the measures of uncertainty about the estimates obtained using different methods. The top section of Panel B uses the placebo tests, as in Escalante (2022) and Uhr et al. (2017). The middle section shows the 95% confidence intervals constructed using the conformal inference procedure developed by Chernozhukov et al. (2021) and implemented in the **augsynth** package by Ben-Michael et al. (2021). The bottom section uses the so-called jackknife+ method introduced in Barber et al. (2021) and available in the **augsynth** package.

The traditional placebo-based test suggests that the effects may be significant, but it is informal. The conformal inference confidence intervals are very wide, and none of the effects are significant. The jackknife+ procedure makes more restrictive assumptions than the conformal inference procedure, but results in much narrower confidence intervals. This highlights the fact that care should be taken when choosing the inference method, because the conclusions about statistical significance may

strongly depend on the method chosen.

Now we turn to a more substantial issue. First, we note that the left part of Panel A of Figure 1 matches Figure 1 in Escalante (2022) very closely. The right part of Panel A of Figure 1 is quite similar to Figure 1 in Uhr et al. (2017), but in our case the synthetic unit follows Chile's actual pre-treatment log GDP per capita more closely than in Uhr et al. (2017), and the pre-trends are less pronounced. This may be due to the fact that we match Chile with other countries based on the *entire* time series of log GDP per capita from 1976 to 1988. Another difference between our paper and the existing studies is that we use logarithms rather than levels. Overall, these results suggest that Pinochet might have mad a negative effect on Chile's economy, statistical significance aside: the counterfactual (Chile without Pinochet) is ahead of the actual unit after 1973; while after 1989, the counterfactual (Chile with Pinochet still in power) is behind the actual unit.

However, there is a problem with these results. In both cases, there are pre-trends, i.e. the divergence between the actual and counterfactual unit starts before the "intervention" takes place. These pre-trends are especially pronounced for 1973. To further highlight this issue, we run two backdating tests: we apply the SCM to the same data, but pretend that the interventions take place in 1970 and 1986 instead of 1973 and 1989, respectively. The results are shown in Figure 2. When we backdate the intervention to 1970, Chile's actual GDP per capita starts to fall behind the counterfactual one as early as 1972. When we backdate the intervention to 1986, Chile's actual GDP per capita overtakes the counterfactual one in 1988. These differences are statistically insignificant if we use the conformal inference method, but they are significant if we use jackknife+. Quantitatively, these effects are comparable in magnitude to the effects in the first few years after the interventions in Figure 1.

In fact, 1970 may not really be a true "placebo," because Salvador Allende,

Pinochet's predecessor as president of Chile, came to power in November 1970. He began implementing a program called "the Chilean way to socialism" (Solimano (2012, p. 20)), and his policies included nationalization of large banks and industrial companies, as well as foreign-owned copper mines. Eventually, Allende's policies resulted in an economic downturn accompanied by high inflation that exceeded 100% in 1972 and 1973. Our results agree with these facts and suggest that Chile's economy began to underperform after Allende came to power. Because his rule only laster three years, the SCM, as used in Figure 1, may fail to capture the consequences of his rule (hence the divergence between the actual and counterfactual units), and some of the effects attributed to Pinochet's rule may be a result of the non-parallel pre-trends.

The same, albeit to a lesser extent, may also be true in 1989. Chile's economy experienced a dramatic recession in 1982-1983, when GDP fell by 14%. In response, Chile's government decided to abandon the fixed exchange rate for peso in June 1982, and it also implemented a variety of policies aimed at dealing with the crisis, such as financial aid to the private sector, reintroduction of some of the protective tariffs, and more stringent regulation of the financial system (Solimano (2012, p. 30), Ffrench-Davis (2002 [2010], Ch. 1, p. 16-17)). It may be the case that because of these policies, or for other reasons, Chile's economy accelerated in the late 1980s, before Pinochet's rule ended. Then some of the positive effects attributed to the end of Pinochet's rule and Chile's transition to democracy may be a result of non-parallel pre-trends.

Next, we illustrate what happens when we attempt to eliminate the pre-trends. For 1989, we keep the same 43 countries in the donor pool as in our previous specification, that roughly matches the "Occidental World" pool in Uhr et al. (2017), but shorten the pre-treatment period from 1976-1988 to 1982-1988. For 1973, we expand the donor pool to include all 87 countries with complete data on GDP per capita and

inflation between 1960 and 2010 in the World Bank database, and we shorten the pre-treatment period to 1968-1972 instead of 1960-1972. We also use the demeaned SCM instead of its standard version. Figure 3 presents the results.

For both 1973 and 1989, this new modified approach virtually eliminates the pre-trends, especially for 1973. The resulting effects in Figure 3 are much smaller than in Figure 1. The new counterfactual for 1973 is well below the old counterfactual. In fact, it follows Chile's actual log GDP per capita very closely until around 1980 and then falls behind. The new counterfactual for 1989 is below Chile's actual log GDP per capita, but well above the old counterfactual. In contrast to the results in the existing literature, these results indicate that Pinochet's rule did not necessarily have a negative effect on Chile's economy in the 1970s and 1980s, and that the effect of the democratization of 1989, although still positive, is smaller than previously estimated.

We shall emphasize that because of a very short pre-treatment period that we use and a very large number of countries in the donor pool, especially for 1973, our results may also be somewhat problematic. However, our main goal is not to conclusively estimate Pinochet's influence on Chile's economy, but instead to show the existence of pre-trends, highlight possible issues with the use of the SCM, and demonstrate the sensitivity of the resulting estimates to the choices made by the researcher.

Panel B of Figure 3 shows the 95% confidence intervals. The intervals obtained using conformal inference are still very wide, and none of the effects are significant. In contrast, the intervals obtained using jackknife+ are extremely narrow. Given the large number of countries in the donor pool and the small number of pre-treatment periods, these confidence intervals look overly optimistic in the sense that they likely underestimate the statistical uncertainty about the estimates.

In Figure 4 we re-do the analysis for 1973, but further expand the donor pool from 87 countries to 92 countries for which a complete real GDP per capita series is

available (but not necessarily inflation). The results differ significantly from those on the left side of Figure 3, further illustrating how sensitive the SCM can be when the number of donors is large.

Finally, Table 1 compares the SCM weights for 1973 in old and new specifications. Our donor pool is not exactly the same as in Escalante (2022) and Uhr et al. (2017), but the composition of our synthetic control unit is fairly similar to theirs. For 1973, the largest weights are assigned to Panama, Uruguay, Peru, and Bolivia; and for 1989, to Paraguay, Uruguay, and Honduras. In our modified specification, the largest weights for 1973 are assigned to Niger, Nigeria, Kenya, and the Bahamas (when there are 87 countries in the donor pool), or to Malawi and Bangladesh (when there are 92 countries in the donor pool); and for 1989, to Uruguay, St. Vincent and the Grenadines, and Puerto Rico.

4 Conclusion

In this paper, use Pinochet's Chile as a setting to study possible issues associated with the use of the SCM. We show that both for 1973 and 1989, the divergence between the actual and synthetic control units that starts before the treatment takes place. We further highlight this issue by using the backdating tests: applying the SCM to Chile in 1970 and 1986. Therefore, a key condition stated in Abadie (2021), the ability of the SCM to match the trajectory of the treated unit before the intervention, is violated.

We then modify the estimation strategy and use a shorter pre-treatment period along with, for 1973 only, a larger donor pool. By doing this, we eliminate or at least substantially alleviate the problem of pre-trends, and the resulting estimated effects of Pinochet's rule are much smaller than in the existing literature. At the same time,

our estimates may potentially be prone to overfitting, because we only use a few time periods along with a large number of donor countries.

We also show that inference about the SCM estimates is highly sensitive to the method choice. The traditional choice in the literature is to use the placebo tests, but those are pretty informal. The conformal inference procedure developed by Chernozhukov et al. (2021) seems to result in very wide confidence intervals in the case of Chile. In contrast, the jackknife+ method introduced in Barber et al. (2021) may yield unrealistically narrow confidence intervals. Developing an inference method that would be less conservative than conformal inference but more robust than jackknife+ may be an important area for future research.

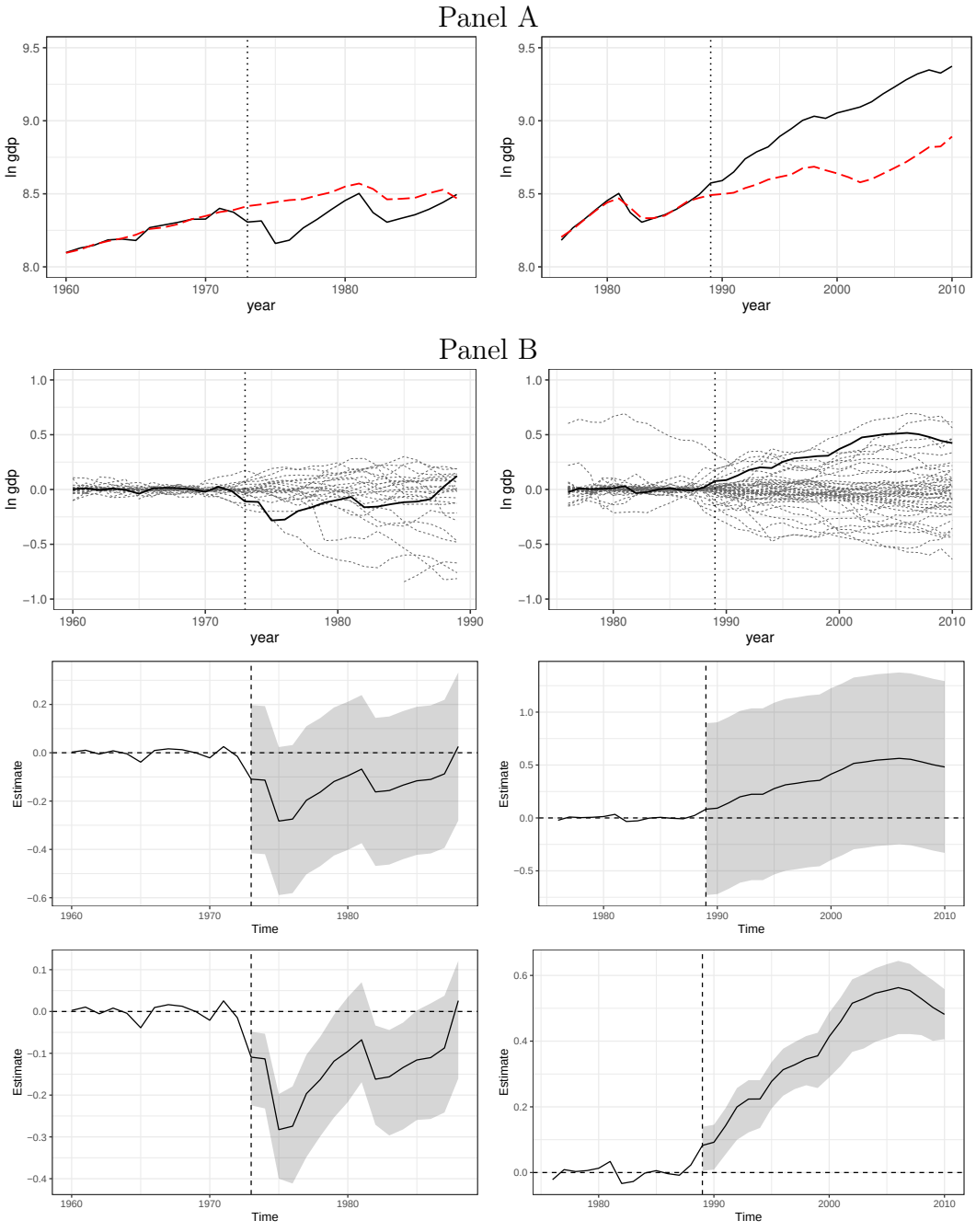
Our main goal in this paper is to highlight the issue with pre-trends and to demonstrate that in case of Chile, the SCM estimates may be highly sensitive to the choice of the donor pool and the pre-treatment period. Because of this, both the existing and our own SCM estimates for Chile should be viewed with caution.

It may be the case that new, more advanced and robust, estimation methods are needed for such settings. We attempt to use synthetic differences-in-differences (SDID), developed in Arkhangelsky et al. (2021). The results are shown in Figure 5. SDID reweighs the pre-treatment observations and corrects for the pre-treatment difference between the synthetic and actual units. However, in doing so, it primarily changes the point estimate of the average treatment effect, but it fails to capture the pre-treatment trajectory of the treated unit. In other words, it captures a one-period pre-treatment difference instead of accounting for the pre-existing diverging trends.

However, Chile may inherently be a challenging country to analyze. It underwent many political and economic changes, both before and during Pinochet's rule. Allende became president in 1970, just three years before Pinochet-led military coup; economic downturn already started in 1972 and continued throughout the early years

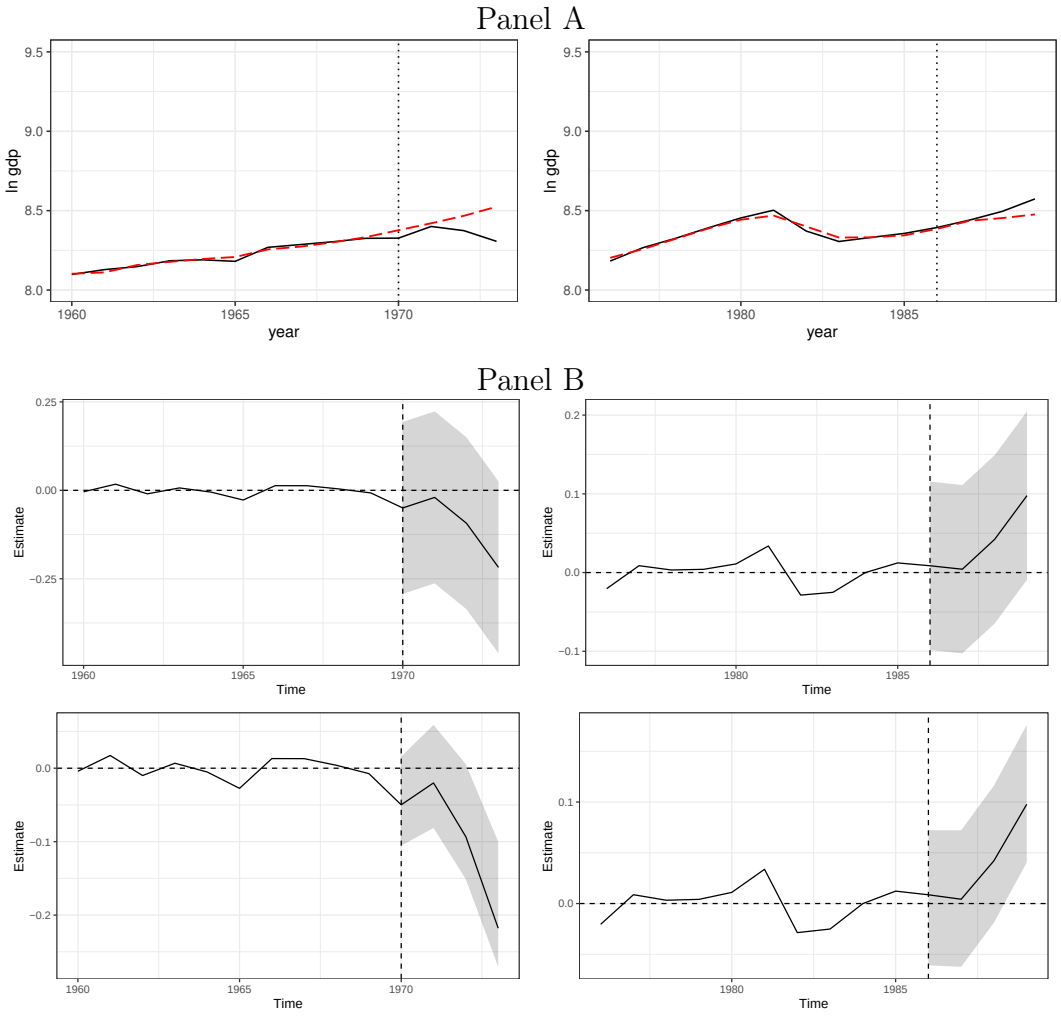
of Pinochet's presidency; another recession took place in the early 1980s. From the econometric point of view, it may be very difficult to disentangle the consequences of the recession that started in 1971-1972 from the consequences of Pinochet's rule, that started in 1973, because these two events happened in close succession. It is possible that Chile's economy experienced one or several structural breaks in the second half of the 20th century, and finding a stable relationship between Chile and the countries in the donor pool may be impossible. As such, the SCM may fail adequately capture these fluctuations and adequately disentangle different effects.

Figure 1: SCM Estimates, 1973 and 1989



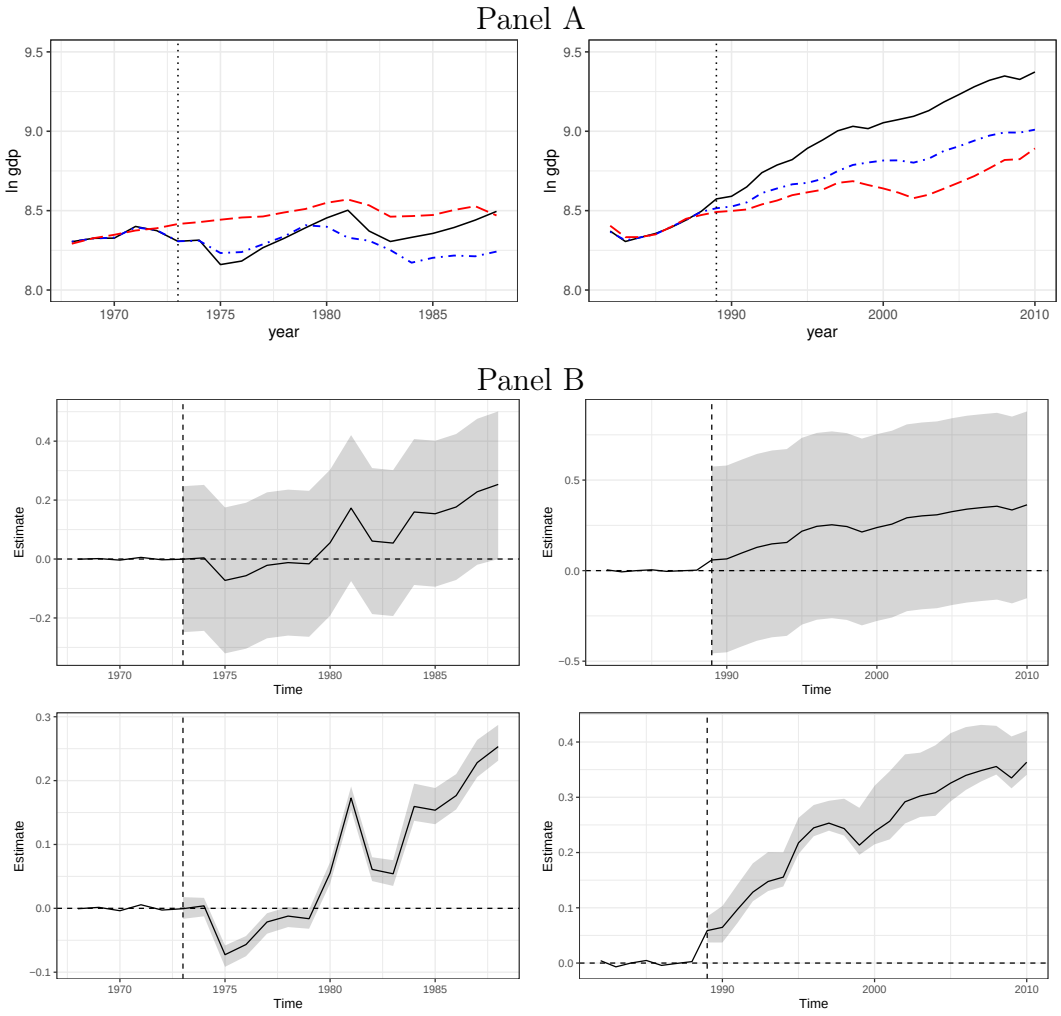
Notes. **Panel A:** Left figure – 1973. Right figure – 1989. Dark black line – Chile's actual log GDP per capita; red dashed line – Chile's counterfactual log GDP per capita. **Panel B:** Top – the synthetic control method point estimates along with the placebo tests. Middle – the synthetic control method point estimates along with the 95% confidence intervals obtained using conformal inference. Bottom – the synthetic control method point estimates along with the 95% confidence intervals obtained using the jackknife+.

Figure 2: Backdating SCM Estimates, 1970 and 1986



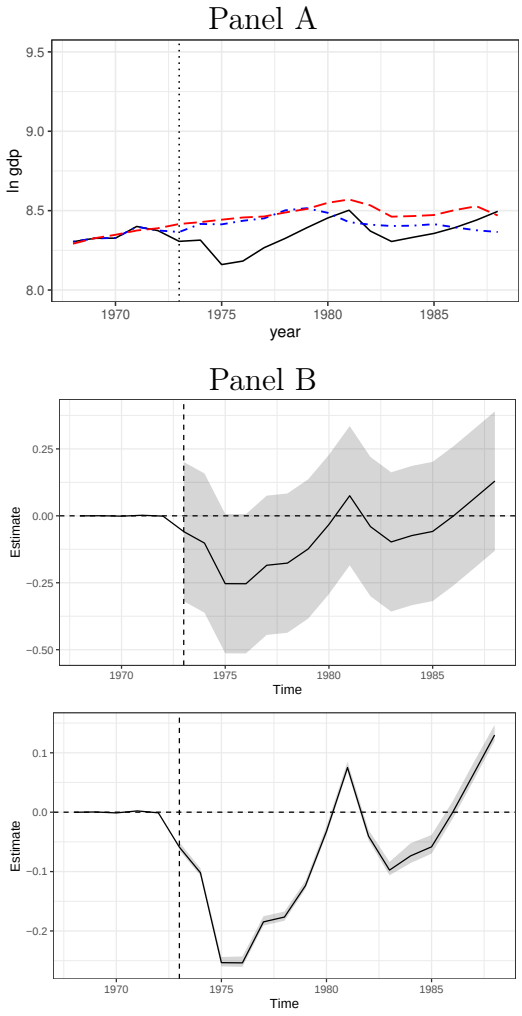
Panel A: Left figure – 1970. Right figure – 1986. Dark black line – Chile's actual log GDP per capita; red dashed line – Chile's counterfactual log GDP per capita. **Panel B:** Top – the synthetic control method point estimates along with the 95% confidence intervals obtained using conformal inference. Bottom – the synthetic control method point estimates along with the 95% confidence intervals obtained using the jackknife+.

Figure 3: Modified SCM Estimates, 1973 and 1989



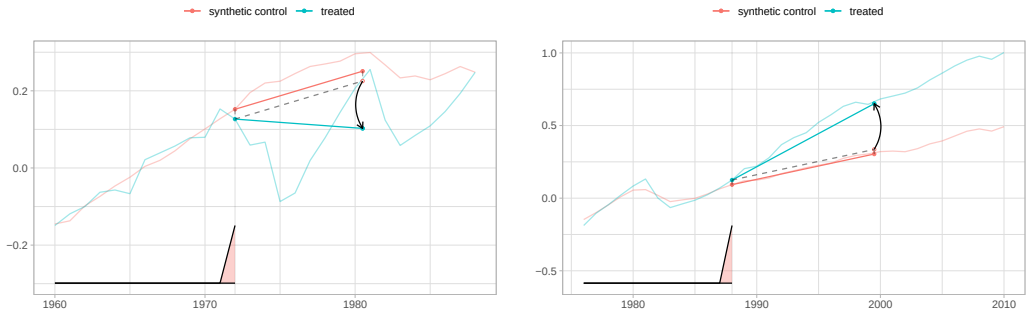
Notes: **Panel A:** Left figure – 1973. Right figure – 1989. Dark black line – Chile's actual log GDP per capita; red dashed line – Chile's counterfactual log GDP per capita using the existing specifications; blue dash-dotted line – Chile's counterfactual log GDP per capita using the expanded donor pool and shorted pre-treatment period. **Panel B:** Top – the synthetic control method point estimates along with the 95% confidence intervals obtained using conformal inference. Bottom – the synthetic control method point estimates along with the 95% confidence intervals obtained using the jackknife+.

Figure 4: Modified SCM Estimates, 1973, 92 Donors



Notes: **Panel A:** Dark black line – Chile's actual log GDP per capita; red dashed line – Chile's counterfactual log GDP per capita using the existing specifications; blue dash-dotted line – Chile's counterfactual log GDP per capita using the expanded donor pool and shorted pre-treatment period. **Panel B:** Top – the synthetic control method point estimates along with the 95% confidence intervals obtained using conformal inference. Bottom – the synthetic control method point estimates along with the 95% confidence intervals obtained using the jackknife+.

Figure 5: Synthetic DID estimates, 1973 and 1989



Notes: Left figure – 1973. Right figure – 1989. Light blue line - Chile's actual log GDP per capita; light red line - Chile's counterfactual GDP per capita. The dark blue line shows the post-pre difference for the actual unit. The dark red line shows the post-pre difference for the synthetic unit. The dashed line shows the post-pre difference for the synthetic unit corrected for the pre-treatment difference. The arrows shows the estimated average effect.

Table 1: Synthetic Control Weights

	1973 old	1973 new, 87 donors	1973 new, 92 donors	1989 old	1989 new
The Bahamas	-	0.185	-	-	-
Bangladesh	-	-	0.257	-	-
Belize	-	-	-	-	0.095
Bolivia	0.118	-	-	-	-
China	-	-	-	-	-
Congo, Dem. Rep.	0.033	-	-	-	-
Dominican Republic	0.031	-	-	-	-
Ghana	-	-	-	-	-
Honduras	0.073	-	-	0.107	-
Kenya	-	0.200	-	-	-
Malawi	-	-	0.655	-	-
Mexico	-	-	-	-	0.088
Niger	-	0.416	0.048	-	-
Nigeria	-	0.199	0.040	-	-
Panama	0.272	-	-	-	-
Paraguay	-	-	-	0.418	-
Puerto Rico	-	-	-	-	0.198
Peru	0.142	-	-	-	-
St. Vincent and the Grenadines	-	-	-	0.068	0.253
United States	0.084	-	-	-	-
Uruguay	0.246	-	-	0.407	0.366

Notes: The table presents the composition of the synthetic control units in various specifications. The columns titled "1973 old" and "1989 old" correspond to the specifications from the existing literature, shown in Figure 1. The columns titled "1973 new 1" and "1989 new" correspond to our specifications from in Figure 3. The column titled "1973 new 2" corresponds to our specification from in Figure 4.

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Appendix

Data Sources

The real GDP per capita data for Chile and all countries in the donor pool are available at the World Bank databank website: https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.PCAP.KD&country=. We have manually

downloaded the data, starting in 1960, as an Excel file and removed countries with missing data. The replication package is available from the authors upon request.