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A Monte Carlo Analysis of Robustness of the Synthetic Control Method and Dynamic Panel Estimation: A Comparative Case Study of a Policy Intervention.

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Abstract

In comparative case studies, by solving an optimization problem, the synthetic control method provides a point estimate for an intervention effect and it suffers from lack of considering an asymptotic distribution of the estimator. On the other hand, we can benefit from such considerations while working with a regression framework; and many studies have been done and many methods have been offered in order to overcome the potential shortages of a traditional regression framework in such case studies. In this paper, we use Monte Carlo simulation to compare the robustness and sensitivity between the synthetic control method and a dynamic panel data regression framework. Empirical work in based on a suitable case of a policy intervention and a comparative case study: sanctions on Iran. We conclude that the dynamic panel data model seems to be performing well with the macro level aggregate data and a comparative case study scenario, and the assumptions are appropriate. However, for the synthetic control method we observe large standard errors in the estimated values which result in insignificance of the point estimates. We also take advantage of the replicated trials, and we analyze and compare the sensitivity of the synthetic control method and the dynamic panel data model to the choice of the donor pool and the treatment assignment.

JEL classification numbers: C15, C33, C5
Keywords: Synthetic Control Method, Panel Data Model, Monte Carlo Simulation, Comparison

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1. Introduction

The synthetic control method has been a popular method in comparative case studies in which the existence of a counter-factual unit with high level of similarities and comparability is demanded. On the other hand, in such case studies we can also rely on a regression framework to predict the effect of an intervention on an outcome. A dynamic panel data model would be a suitable model to study the effect of policy interventions on the macro economic variables such as economic growth in aggregate entities such as countries. In this paper, using Monte Carlo simulations, we empirically compare the robustness of the synthetic control method with a dynamic panel data model. For the empirical analysis, we use recent sanctions on Iran as a suitable case of a policy intervention. In Section 2, we provide the empirical analysis. Section 3 provides our sensitivity analysis, and Section 4 concludes.

2. Empirical Analysis

2.1 Sample and Data

The empirical analysis is based on annual country level panel data for the period 1980-2014. As international sanctions were imposed in 2011, this yields a pre-intervention period of more than 30 years. Our control pool (called donor pool in the synthetic control method) includes eight OPEC member countries: Algeria, Ecuador, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, and the United Arab Emirates[2]. Also, in order to increase the size of the pool, we add countries from major non-OPEC oil producer countries (i.e. Canada and China) as well as the rest of non-OPEC Iran's neighbors with close economic similarities (i.e. Oman, Bahrain, and Turkey). The variables used in our analysis are listed in the data appendix along with descriptions and data sources. The outcome variable of interest, Y_{jt} is the log of real GDP for country *j* at time *t*. We also use GDP growth as the outcome variable of interest in some of the estimations. GDP is Purchasing Power Parity (PPP)-adjusted and measured in constant 2011 international dollars. Because our control countries are heavily dependent on rents from natural resources, for the pre-sanction predictors, we rely on a standard set of economic growth indicators for these countries.

[2] We left Venezuela and Iraq out of the pool due to economic fluctuations in these countries during the period of the analysis. We also left Angola out due to data limitations.

2.2 The Synthetic Control Method and the Regression Estimation Result

2.2.1 The Synthetic Control Method

First, we revisit the result from the synthetic control method by (Gharehgozli, 2017). As a result of the synthetic control estimation, the path plot (Figure 1) which is the weighted average of the donors is created which resembles the path of Iran's GDP almost perfectly before the sanction of 2011. The discrepancy between the two (actual Iran and the Synthetic Iran) is demonstrated in Figure 2, the Gap plot, and is interpreted as the effect of sanctions on the country's GDP

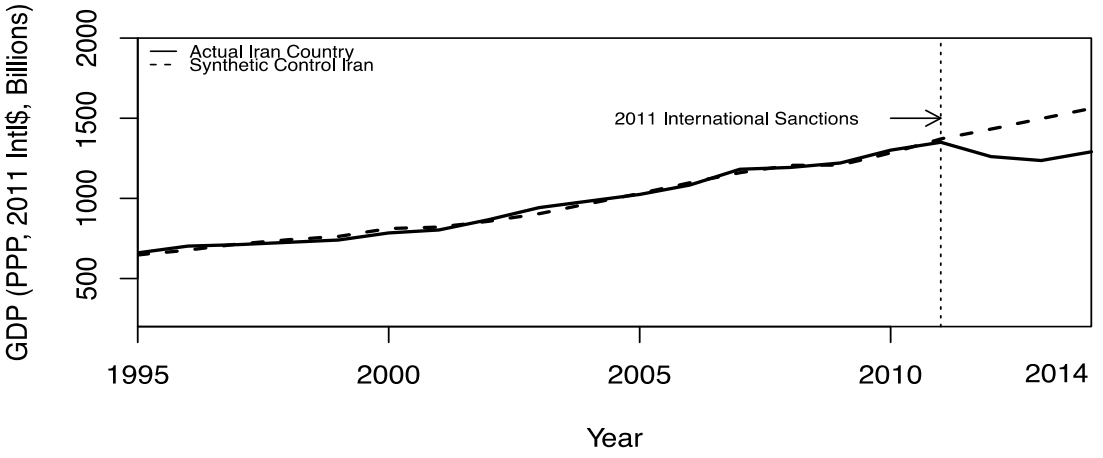

Figure 1: Real GDP: Iran Vs. Synthetic Iran

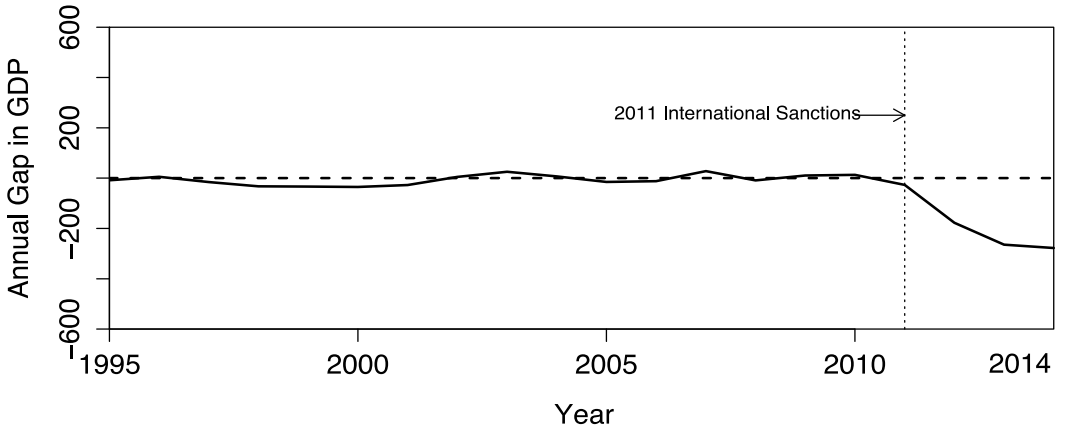

Figure 2: Annual GDP Gap Between Iran and Synthetic Iran

The Synthetic Iran follows an upward trend after the sanctions of 2011 while the actual GDP of Iran drops notably after 2011 with the gap between the two growing in magnitude. Iran's GDP in 2014 was 1289.9 billion dollars, which it is estimated to be 271.3 billion dollars less than the value it would have been had there been no sanctions imposed in or after 2011. This is equal to a 17.3 percent drop in GDP over the course of three years of heavy sanctions. The highest effect of negative 12.0 percent happens in 2012, the first year of sanctions.

We can also consider the growth to be the main variable of interest in the synthetic control estimation and the result is as follows: actual GDP growth of Iran in 2012 drops to -7.44 percent. However, Synthetic Iran grew by 3.92 percent. Thus, according to the Synthetic Iran the growth is -11.36 percent lower than what it would have been if there had been no sanctions. In 2013, the actual growth suffers a drop of -0.19, while according to the Synthetic Iran, the growth would have been positive 3.8 percent if no sanctions had been imposed. Therefore, we estimate the actual growth to be -3.99 less than what it would be without the sanctions. In 2014 the growth would be 0.498 percent more than the actual value of 4.6 percent, meaning that 5.098 would have been the growth rate in the absence of sanctions.

2.2.2 Dynamic Panel Data Estimation

We also revisit estimation the effect of sanctions on Iran's GDP using the dynamic panel data model below (Gharehgozli, 2016).

$$GDP_{it} = \rho GDP_{it-1} + X'_{it}\beta + \delta_t + \mu_i + \nu_{it} \quad (1)$$

The results of the estimations of the model mentioned above are summarized in Table 1. The first three columns predict Log GDP and the second third columns predict GDP Growth. The first three regressors are dummies representing Iran undergoing sanctions as of 2012, 2013, and 2014. For the predictors, we again rely on a set of growth predictors that are standard in analysis of countries heavily dependent on natural resources rent. Specifically, we include log of population, rents, trade, and agriculture value added as percentage of GDP. For the Fixed Effect (FE) we rely on the standard set of instruments for these models. For the Arellano-Bond (AB) and Blundell-Bond (BB) model we treat the lagged of log GDP as endogenous and other predictors as predetermined.

Table 1: Dynamic Panel Data Model Estimation Result

	(FE)	(AB)	(BB)	(FE)	(AB)	(BB)
	lgdp	**lgdp**	**lgdp**	**Growth**	**Growth**	**Growth**
Iran 2012	-0.121***	-0.111***	-0.114***	-12.13***	-10.89***	-9.98***
	(0.0153)	(0.0159)	(0.0117)	(2.211)	(0.217)	(0.364)
Iran 2013	-0.0659***	-0.0616***	-0.0666***	-2.93	-2.18***	0.905
	(0.0149)	(0.0147)	(0.0112)	(4.891)	(0.633)	(1.085)
Iran 2014	0.00150	-0.00451	-0.00414	0.27	1.027***	2.87***
	(0.0152)	(0.0161)	(0.0112)	(2.339)	(0.282)	(0.294)
L.Y	0.901***	0.979***	1.005***	0.198	0.156***	0.383***
	(0.0573)	(0.0199)	(0.00867)	(0.304)	(0.0334)	(0.098)
Population	0.0414	0.0680*	-0.000139	0.375*	0.216	0.354*
	(0.0284)	(0.0378)	(0.00306)	(0.205)	(0.036)	(0.197)
Rents	-0.128	0.0951	-0.00575	2.571	12.1***	1.888
	(0.0947)	(0.0647)	(0.0261)	(4.554)	(2.37)	(2.033)
Trade	-0.00564	-0.0452	0.0138	-7.64	-2.94	-0.086*
	(0.0445)	(0.0565)	(0.0147)	(9.261)	(7.748)	(7.405)
Agriculture	-0.173	-0.109	0.0621	20.39**	-1.71	8.876*
	(0.203)	(0.140)	(0.0625)	(10.889)	(4.319)	(4.669)
N	279	272	286	280	279	293
Time Fixed Effects	**Yes**	**No**	**No**	**Yes**	**No**	**No**
AB AR (2) (Pr > z)	-	0.252	0.228	-	0.303	0.147
Overid. (Pr > z)	-	1.000	1.000	-	1.000	1.000
Robust standard errors in parentheses. The dependent variable is log GDP. "Population" is in log for column 1 to 3, and is "population growth" for 4 to 6. "L.Y" is "lagged GDP" for column 1 to 3, and is "lagged growth" for 4 to 6. * p < 0.10, ** p < 0.05, *** p < 0.01.						

The effect of sanctions on Iran's GDP for BB model is a 11.4 percent drop in 2012, 18.12 percent drop in 2013 $(\Delta lGDP_{2013} = -0.0666 + 1.005 * \Delta lGDP_{2012} = -18.12)$ and 18.62 drop in 2014 $(\Delta \text{lGDP}_{2014} = -0.00141 + 1.005 * \Delta \text{lGDP}_{2013} = -18.62)$. The effect of sanction on Iran's growth is reported to be from -9.98 to -12.13 percent for the first year. For 2013, the coefficients are negative for most of the regressions. for 2014, growth models report a positive coefficient. The actual growth of is Iran is reported to suffer a -7.4 percent drop in 2012, followed by a -0.2 percent drop in 2013, and a change of a positive 4.6 percent for 2014. According to all the regressions in the table except the first difference model, the negative effect of sanctions is reported to be higher at least for the first year. The result of the AR test

does not show a dependency of the idiosyncratic error term to the lagged values of the growth which are being used as instruments, and the result of the over-identification test shows the in dependency of the instruments to the included predictors.

2.3 Monte Carlo Analysis Set Up

We design a Monte Carlo study to compare the methods more in depth. We involve fewer donor countries in the Monte Carlo Analysis due to the missing values of the predictors for a substantial period of time. We have Iran as the treated unit, and the donor pool consists of Algeria, Ecuador, Saudi Arabia, China, Turkey, and Nigeria and as mentioned earlier the analysis is based on annual country level panel data, but for the period 1990-2014.

As discussed earlier, the caveat of the synthetic control method is that it only gives us one-point estimate of the effect of the intervention. The method does not provide any assumption for the underlying distribution of the estimator; there is no estimation of the standard error, and the method lacks any significance analysis. With the Monte Carlo analysis, the goal in this paper is to see how well the method would perform if we replicate the intervention. The goal is to estimate a standard error of the estimation, and also check the robustness of the methods.

On the other hand, we picked a dynamic panel model to represent a traditional regression framework. This model seems to be appropriate in comparison with the synthetic control method, because usually the synthetic control method is used to study an aggregate level effect of a policy intervention on macro variables. So, with the Monte Carlo study, we also examine the performance of the panel data model.

The setup of the Monte Carlo study is as follows. We assume the dynamic panel data model below

$$y_{it} = \rho y_{it-1} + X_{it}'\beta + D_{it}'\kappa_t + \mu_i + \nu_{it} \tag{2}$$

in which $\boldsymbol{y_{it}}$ is the outcome variable (log GDP, as well as Growth) for country *i* at time *t*. $\boldsymbol{X_{it}}$ is the set of predictors, $\boldsymbol{D_{it}}$ is the set of three dummies which equal to one for Iran for 2012, 2013, and 2014. $\boldsymbol{\mu_{it}}$s are countries fixed effects.

We estimate the model above for the donor pool. As summarized in the previous section, estimation of the Equation 2 provides $\hat{\rho} = 1.0054$, $\hat{\beta}_{agriculture} = 0.062$, $\hat{\beta}_{trade} = 0.0136$, $\hat{\beta}_{rents} = -0.00531$, $\hat{\beta}_{population} = -0.000139$, $\hat{\kappa}_{2012} = -0.114$, $\hat{\kappa}_{2013} = -0.0662$, $\hat{\kappa}_{2014} = -0.0037$, and $\hat{\sigma}_{\nu} = 0.0529$. We calculate

$$\hat{\mu}_i = \bar{y}_i - \rho\bar{y}_{i,-1} - \bar{X}_i'\hat{\beta} + \bar{D}_i'\hat{\kappa} \tag{3}$$

and we use X_{it} the set of predictors we have in the actual data set for *i = 1, ... ,7* and *t =1, ..., T*. We have $\hat{\mu}_{\mu} = 0.0155$, $\hat{\sigma}_{\mu} = 0.0136$ as the mean and standard deviation of the seven values of the $\hat{\mu}_i$ calculated from Equation 3. For the Monte Carlo replications, we draw μ_i from $N(\hat{\mu}_{\mu}, \hat{\sigma}_{\mu}^2)$ where the mean and standard error are calculated from Equation 3. Moreover, for each replication we draw ν_{it} from $N(0, \hat{\sigma}_{\nu}^2)$ where the standard error is estimated from Equation 2.

We generate the outcome variable using all the information put together. For y_{i0} we use actual values of the outcome variable for the first period of the analysis. Then, for *i = 1, ... ,7* and *t =1, ..., T*, we generate a Monte Carlo value for the outcome variable for each replication using $\hat{\rho}$, $\hat{\beta}$, $\hat{\kappa}$, $\hat{\sigma}_{\nu}$, μ_i, and ν_{it} using Equation 4 below:

$$y_{it,MC} = \hat{\rho} y_{it-1,MC} + X'_{it}\hat{\beta} + D'_{it}\hat{\kappa}_t + \mu_i + \nu_{it} \quad (4)$$

Now using the Monte Carlo values for the outcome variable, we estimate different models and compare the methods we discussed in previous chapter. We estimate a dynamic panel data model using Blundell Bond method (as it seems to be the best approach). We also use the Monte Carlo values and run a synthetic control analysis. The usage of the dynamic panel model as the data generating process may initially seem to be working on behalf of the DPD method in the comparison. However, we find this an interesting set up. One should note that the synthetic control method, regardless of the underlying model of the data generating process, is supposed to solve an optimization problem to find weights on the controls that minimize RMSPE which is the disparity of the values of outcome variable of interest between the synthetic unit and the affected unit. The assumed underlying model is a factor model (see (Abadie , et al., 2010)) and the dynamic panel data we consider is just a derivation from the general factor model the synthetic control estimator is based on. Also, one should note if any of the assumption of the dynamic panel model, such as the orthogonality of the units fixed effects and the idiosyncratic error term does not hold, we would observe a distance between what we set to be the "true" coefficients and the ones we will get from the Monte Carlo replications. What we find interesting is to utilize the replication power of the Monte Carlo simulation and study the sensitivity of the methods to the assumptions, or the arbitrary choices (e.g. the donors).

We also do the same analysis with Growth instead of GDP. We use the Blundell Bond estimation result for growth as well. The list of the parameters included for growth is as follow: $\hat{\rho} = 0.38$, $\hat{\beta}_{agriculture} = 8.88$, $\hat{\beta}_{tradegrowth} = -0.086$, $\hat{\beta}_{rents} = 1.89$, $\hat{\beta}_{populationgrowth} = 0.354$, $\hat{\kappa}_{2012} = -9.98$, $\hat{\kappa}_{2013} = -0.090$, $\hat{\kappa}_{2014} = 2.912$, $\hat{\mu}_{\mu} = -3.23$, $\hat{\sigma}_{\mu} = 2.03$, and $\hat{\sigma}_{\nu} = 5.52$.

We present the initial result of the Monte Carlo estimation in Table 2.

Table 2: Monte Carlo Analysis, 100 Replications

a. DPD With Log GDP:	**Coefficient**	**SE**	**Total Effect**	**SE**
Iran 2012	-0.117**	0.054	-0.117	0.054
Iran 2013	-0.071*	0.056	-0.191	0.075
Iran 2014	0.002	0.054	-0.187	0.097
b. SCM With Log GDP:			**Gaps**	**SE**
Iran 2012			-0.109	0.231
Iran 2013			-0.196	0.229
Iran 2014			-0.203	0.238
			RMSPE	**SE**
			0.095	0.047
c. DPD With GDP Growth:	**Coefficient**	**SE**	**Total Effect**	**SE**
Iran 2012	-13.670 **	6.198	-13.670	6.198
Iran 2013	1.764	6.007	-5.203	7.068
Iran 2014	1.677	4.925	-0.999	6.428
d. SCM With GDP Growth:			**Gaps**	**SE**
Iran 2012			-13.004	8.205
Iran 2013			-4.516	8.639
Iran 2014			0.473	6.393
			RMSPE	**SE**
			5.730	0.994

$p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
SMC stands for the Synthetic Control Method and DPD stands for the Dynamic Panel Data model

The result of the 100 replications for the dynamic panel data models is as follow:

$$\begin{cases} \Delta lGDP_{2012} = \frac{1}{100}\sum_{1}^{100} \hat{\kappa}_{2012r} = -0.117 \\ \Delta lGDP_{2013} = \frac{1}{100}\sum_{1}^{100} [\hat{\kappa}_{2013r} + \hat{\rho}_r * \hat{\kappa}_{2012r}] = -0.196 \\ \Delta lGDP_{2014} = \frac{1}{100}\sum_{1}^{100} [\hat{\kappa}_{2014r} + \hat{\rho}_r * \hat{\kappa}_{2013r}] = -0.188 \end{cases}$$

Following the same calculation for growth we have:

$$\begin{cases}\Delta Growth_{2012} = -13.67\\ \Delta Growth_{2013} = -5.203\\ \Delta Growth_{2014} = -0.999\end{cases}$$

For the synthetic control method:

$$\begin{cases}\Delta lGDP_{2012} = -0.109\\ \Delta lGDP_{2013} = -0.196\\ \Delta lGDP_{2014} = -0.203\end{cases}$$

$$\begin{cases}\Delta Growth_{2012} = -13.04\\ \Delta Growth_{2013} = -4.516\\ \Delta Growth_{2014} = 0.473\end{cases}$$

As we expected, the point estimates of the synthetic control method over many replications are in line with the true estimates. However, there is a large variation in the point estimates over replications and we obtain large standard errors. In other word, in contrast to the dynamic panel data method, the coefficients provided by the synthetic control method are insignificant.

A second conclusion suggested by the result in Table 2 is the following. The standard errors of the synthetic control estimates are more in line with those of the dynamic panel data estimation when the dependent variable is GDP growth than when the dependent variable is log GDP. Tentatively, we conclude that synthetic control estimates are much less robust when the variable under study contains a unit root. We leave it for a future study to explore this in greater detail.

3. Sensitivity Analysis

3.1 Before and After the Intervention, RMSPE Analysis

The result provided in the previous section mainly refers to the post intervention period. We can also study the synthetic control method for pre-intervention period by analyzing the RMSPE as well as the dynamic of the donor pool. The RMSPE for Iran over 100 replications is 0.095. We explain below how we study this number.

The synthetic control method is usually complemented with an "In space" placebo study in which we assign the intervention to one of the donors iteratively and compare the gap plot of the treated unit with the ones driven from this exercise. RMSPE represents how well fitted the synthetic control method is able to produce a control unit. The goal of this exercise is to provide a placebo distribution for the estimator, and to confirm that the estimated effect of intervention for the treated unit is an outlier in the placebo distribution for donors with or without well-fitted synthetic control unit. Here, with having the benefit of replication, we repeat this placebo assignment. We iteratively assign the treatment to one of the donor countries, and we run the synthetic control method with 100 replications. We

preserve RMSPE for each of the 7 countries. Figure 3 below presents the box-plot of the RMSPEs for the countries in the pool. We have to exclude Ecuador and China from this exercise. For Ecuador and China, the range of the error is larger than all other five countries; for these countries finding a synthetic control as a weighted average of other donors is difficult. The reason is that China has the largest economy in terms of gross domestic product among all the donors, and Ecuador has the smallest. Synthetic control is constructed as the weighted average of the donors with weights between zero and one. Therefore, the construction of the synthetic control unit from the donors is not plausible.

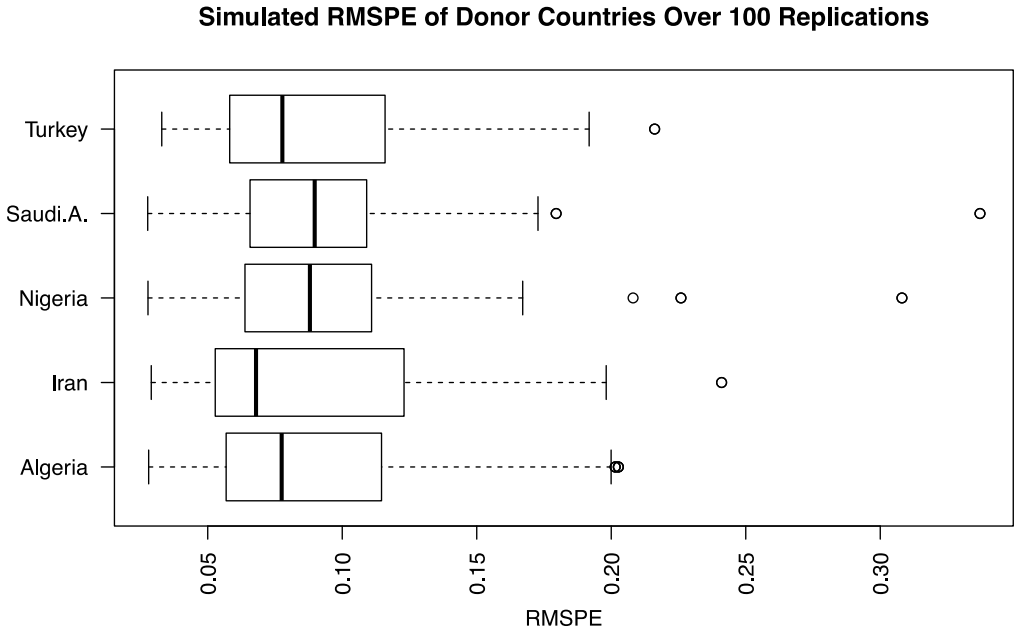

Figure 3: Density Function of the RMSPE - All Donors, 100 Replications.

Over 100 replications, the box-plot of the Iran's RMSPE seems to be similar to those of the other four countries: Algeria, Nigeria, Saudi Arabia, and Turkey (For Ecuador and China, the synthetic control is not performing well and we observe larger values of RMSPE over 100 replications).

We remove the two countries with less fitted synthetic control unit (Ecuador and China) and provide the density function of the RMSPE of all the donors combined (excluding Iran) in Figure 4 below.

Note that Iran's value of the predicted error is 0.09. This value is not an outlier in the distribution which 5 donor countries over 100 repeated trials. This means that the synthetic control method is working similar for all the remaining donors, and is providing as well fitted synthetic control as Iran for the pre-intervention period. With similar RMSPE for the donors, the analysis of the post-intervention effects

which we will provide in the next section would be reasonable. In the next section, we compare the placebo intervention effects for the donor countries, and this comparison only would be logical if we have well fitted synthetic control units for pre-intervention period.

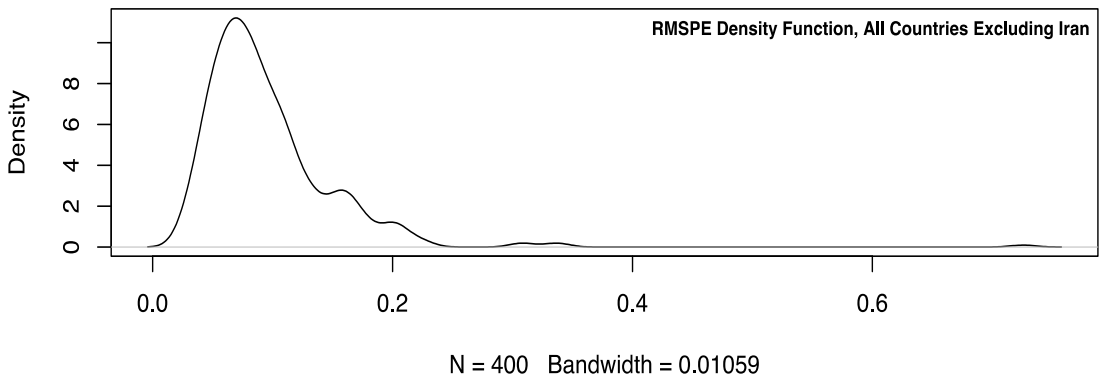

Figure 4: Density Function of the RMSPE - All Donors Combined, 100 Replications.

3.2 Before and After the Intervention, Density Functions of the Placebo Effects

We already observed large variation in the annual effects that are reported in Table 2 by the synthetic control method. However, we expand the placebo studies and we look at the reported placebo effects of sanction for all the donor countries. Figure 5 provides the density function of the estimated placebo effects of the donor countries for year 2012. Each donor is treated for 100 replications. Figure 6 provides the same information for year 2013, and Figure 7 provides the information for year 2014.

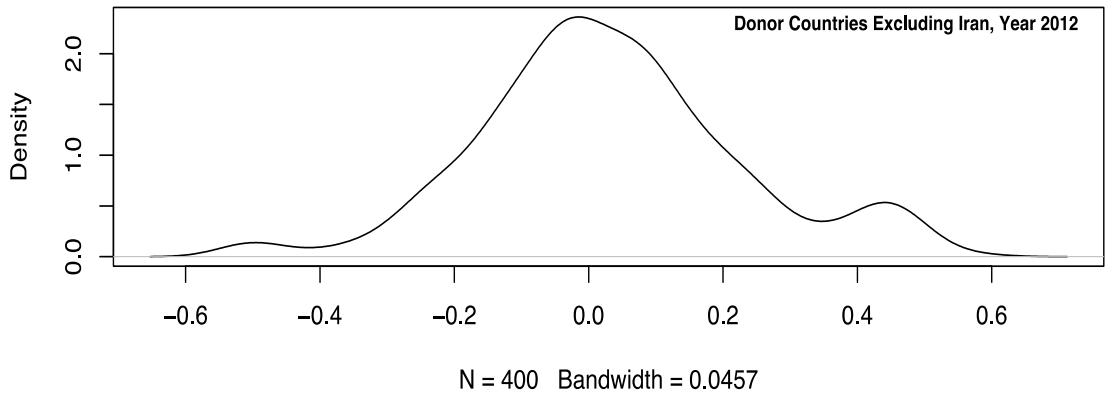

Figure 5: Density Function of the Estimated Placebo Effects - All Donors, Year 2012.

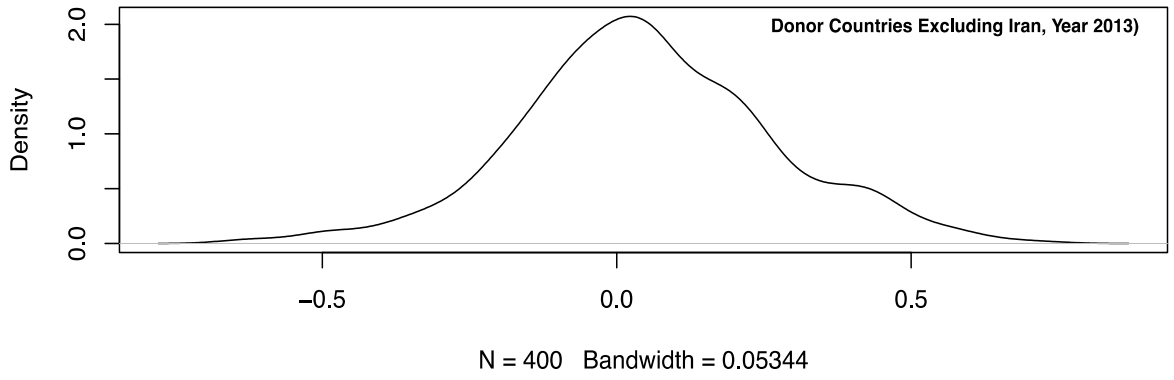

Figure 6: Density Function of the Estimated Placebo Effects - All Donors, Year 2013.

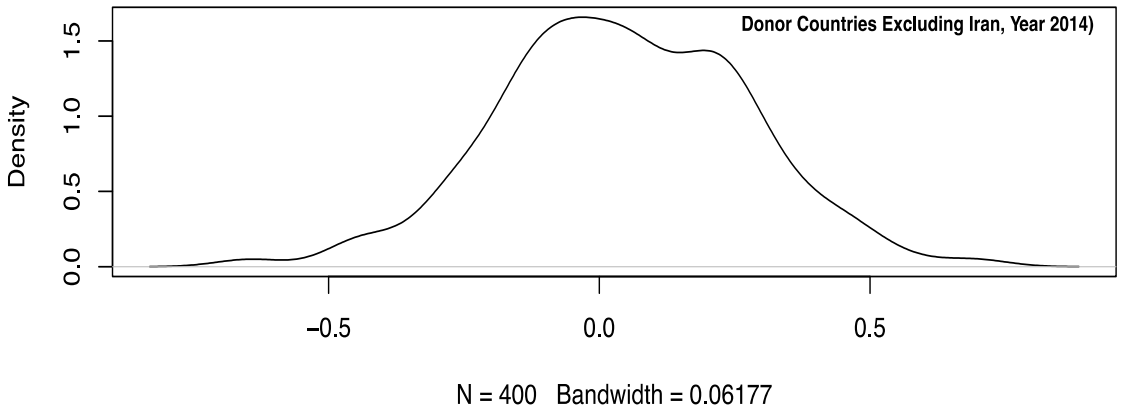

Figure 7: Density Function of the Estimated Placebo Effects - All Donors, Year 2014.

Iran's cumulative effect of sanction on log GDP, predicted by the synthetic control analysis over 100 replications is estimated to be -0.109 for 2012, followed by an estimate of -0.196 for 2013 and -0.203 for 2014 according to Table 2. The critical values of the density function ($\alpha = 0.05$), for years 2012, 2013, and 2014 are -0.339, -0.414, and -0.445. Therefore, in comparison to the distribution of the placebo effect in Figures 5, 6, and 7, Iran's effect is not statistically significant. We should note that as we move to the last year of the analysis, 2014, the cumulative effect of sanction on Iran becomes more widely spread out around the center of the distribution of the placebo effects as seen in Figure 7. Also, all the distribution of the placebo effects for 2012, 2013, and 2014 are centered around zero; this shows the method correctly does not report any effect on average for the donor countries.

3.3 Sensitivity Analysis, Assignment of the Intervention

In this exercise, we iteratively start by changing the assignment of Iran's sanctions to one of the donor countries. So, in the Monte Carlo we assign the intervention to one of the donor countries in the data generating process, and we estimate a placebo sanction for that donor country. In another trial, we do not assign any treatment to the country in the data generating process, but we treat the unit to be intervened upon and we look at the reported effect of the sanctions. Table 3 summarizes the result of this exercise. Each number is driven from 100 Monte Carlo replications.

Table 3: Sensitivity Analysis, Varying the Intervention Unit

	DPD			**Synthetic Control Method**			
	2012	**2013**	**2014**	**2012**	**2013**	**2014**	**RMSPE**
Algeria no treatment	0.002	-0.001	-0.008	0.022	0.017	0.014	0.121
	0.053	0.077	0.099	0.169	0.188	0.215	0.063
Algeria treated	-0.113	-0.182	-0.193	-0.093	-0.164	-0.171	0.121
	0.053	0.077	0.099	0.169	0.188	0.215	0.063
Ecuador no treatment	0.003	0.199	0.200	-1.301	-1.299	-1.301	1.245
	0.056	0.080	0.095	0.542	0.561	0.590	0.277
Ecuador treated	-0.111	-0.168	-0.172	-1.416	-1.480	-1.486	1.245
	0.056	0.080	0.095	0.542	0.561	0.590	0.277
Nigeria no treatment	0.001	0.005	0.001	0.064	0.072	0.077	0.142
	0.062	0.078	0.102	0.157	0.180	0.195	0.082
Nigeria treated	-0.114	-0.176	-0.185	-0.051	-0.109	-0.109	0.142
	0.062	0.078	0.102	0.157	0.180	0.195	0.082
SA no treatment	-0.009	-0.011	-0.021	-0.028	-0.028	-0.044	0.144
	0.056	0.082	0.100	0.185	0.211	0.235	0.064
SA treated	-0.123	-0.192	-0.207	-0.142	-0.210	-0.230	0.144
	0.056	0.082	0.100	0.185	0.211	0.235	0.064
China no treatment	-0.003	0.004	0.004	1.084	1.093	1.088	1.099
	0.050	0.082	0.099	0.532	0.549	0.574	0.248
China treated	-0.117	-0.177	-0.182	0.970	0.912	0.903	1.099
	0.050	0.082	0.099	0.532	0.549	0.574	0.248
Turkey no treatment	0.000	-0.001	-0.008	0.007	0.004	-0.006	0.113
	0.062	0.096	0.113	0.168	0.187	0.205	0.054
Turkey treated	-0.115	-0.182	-0.194	-0.107	-0.177	-0.192	0.113
	0.062	0.096	0.113	0.168	0.187	0.205	0.054

Each value is averaged for 100 trials.
The second number below each coefficient is the standard error.
First three columns report the dynamic pane data regressions.
The second three columns report the synthetic control method result

For Algeria, one time we assign Iran's sanctions in the data generating process, we estimate the effect of the assigned sanctions on this country, and one time we do not assign any treatment and we will look at the reported effect if any. For 2012 and for Algeria when assigned the sanction, the dynamic panel data reports significant coefficients similar to those of Iran, and when there are no assigned sanctions, the method reports almost 0 as the effect of sanctions. The synthetic control method on the other hand, reports smaller effect for 2012 when there are no assigned sanctions in the data generating process, and reports larger numbers when the country is assigned to the sanctions. Note that the RMSPE which refers to pre-sanction disparity between the synthetic unit and actual unit is the same number for both cases for all the countries.

The result of this exercise for all the countries in the donor pool is similar to Algeria. the dynamic panel data reports significant and very similar numbers for Ecuador, Nigeria, Saudi Arabia, China, and Turkey as the effect of the sanctions, when actually we assign the sanctions to them in the data generating process, while the method reports almost 0 for all countries as the effect of the sanctions when no sanctions had been assigned to the country in the data generating process. However, there is a large variation in the result reported by the synthetic control method.

3.4 Sensitivity Analysis, Donor Pool Size

We reduced the donor pool size from 13 units to 7 (including Iran) to have a precise Monte Carlo analysis and reduce the issue with missing values. This reduction had an insubstantial effect on the estimated values. Here, we want to study the sensitivity of our methods to the sample size (donor pool size in case of the synthetic control). The first row of Table 2 provides another round of 100 replications with all the donor countries same as previous trial reported in Table 4. We also report the average of the weights on each donor in this table (W1 to W7). As we can see the sum of the weights are equal to one. In the first row the RMSPE is 0.095.

In order to evaluate the sensitivity of the methods to the sample size and the dynamic of the donor pool, we remove one of the donors one by one and we rerun the Monte Carlo study. The result is reported in the second to seventh row of Table 4. As we can see, the result of the dynamic panel data is almost exactly the same as the one with all the donors included. The synthetic control method reports similar result but with a larger variation. Also, the prediction error of the synthetic control increases by reducing one donor.

We extend this exercise more by removing 2 donors from the donor pool. Following rows of Table 4 reports the result of this exercise with all possible combinations of the donor. As we can see the dynamic panel data, with fewer number of observations still reports the same coefficients and is insensitive to the removal of 2 donors.

We reduce the sample size and finally we only keep 2 units in the donor pool. The result of the methods with only 2 donors is reported in the last row. This gives the dynamic panel data model 24 years of data for only 3 units (including Iran) for each

iteration. But still the model is showing insensitivity to the small sample size. However, the average of the RMSPE of the synthetic control method over the 100 replications is very large.

Table 5: Sensitivity Analysis, Donor Pool Size

	2012	2013	2014	2012	2013	2014	RMSPE	W1	W2	W4	W5	W6	W7	Total W
	-0.118	-0.191	-0.187	-0.151	-0.229	-0.223	0.124	0.087	0.064	0.064	0.238	0.222	0.326	1.000
SE	0.054	0.075	0.097	0.160	0.183	0.204	0.069	0.175	0.112	0.152	0.164	0.137	0.270	
	-0.118	-0.190	-0.187	-0.137	-0.215	-0.204	0.143		0.082	0.065	0.274	0.182	0.398	1.000
SE	0.054	0.075	0.097	0.149	0.171	0.189	0.094		0.108	0.122	0.143	0.149	0.242	
	-0.117	-0.188	-0.066	-0.142	-0.219	-0.208	0.131	0.138		0.052	0.258	0.135	0.416	1.000
SE	0.055	0.078	0.074	0.180	0.200	0.215	0.070	0.175		0.096	0.146	0.116	0.227	
	-0.117	-0.188	-0.183	-0.117	-0.193	-0.184	0.143	0.100	0.091		0.486	0.232	0.091	1.000
SE	0.055	0.076	0.099	0.183	0.198	0.224	0.073	0.168	0.106		0.066	0.067	0.102	
	-0.119	-0.194	-0.192	-0.146	-0.221	-0.214	0.141	0.155	0.039	0.090		0.225	0.491	1.000
SE	0.054	0.076	0.098	0.187	0.209	0.226	0.075	0.174	0.100	0.151		0.157	0.310	
	-0.117	-0.190	-0.185	-0.087	-0.161	-0.152	0.157	0.033	0.016	0.033	0.363		0.555	1.000
SE	0.054	0.077	0.098	0.244	0.263	0.274	0.078	0.102	0.040	0.068	0.289		0.291	
	-0.117	-0.189	-0.184	-0.130	-0.210	-0.203	0.143	0.156	0.124	0.080	0.274	0.366		1.000
SE	0.054	0.075	0.098	0.187	0.205	0.232	0.073	0.221	0.129	0.167	0.160	0.114		
	-0.116	-0.187	-0.065	-0.201	-0.277	-0.266	0.153			0.058	0.322	0.099	0.521	1.000
SE	0.055	0.079	0.074	0.236	0.256	0.269	0.076			0.122	0.150	0.092	0.221	
	-0.117	-0.188	-0.183	-0.081	-0.157	-0.150	0.183		0.156		0.486	0.233	0.125	1.000
SE	0.055	0.075	0.099	0.178	0.193	0.216	0.096		0.116		0.075	0.080	0.129	
	-0.119	-0.193	-0.191	-0.103	-0.178	-0.171	0.187		0.067	0.029		0.089	0.815	1.000
SE	0.054	0.076	0.097	0.301	0.324	0.336	0.107		0.096	0.069		0.077	0.145	
	-0.117	-0.189	-0.185	-0.051	-0.125	-0.116	0.188		0.039	0.060	0.349		0.552	1.000
SE	0.054	0.076	0.0980	0.235	0.253	0.263	0.120		0.081	0.120	0.218		0.224	
	-0.117	-0.189	-0.184	-0.106	-0.185	-0.178	0.191		0.226	0.061	0.313	0.399		1.000
SE	0.054	0.075	0.098	0.179	0.199	0.225	0.104		0.119	0.117	0.132	0.103		
	-0.115	-0.185	-0.177	-0.147	-0.226	-0.217	0.140	0.231			0.340	0.162	0.267	1.000
SE	0.056	0.078	0.102	0.211	0.227	0.248	0.069	0.200		0.145	0.106	0.227		
	-0.119	-0.193	-0.190	-0.118	-0.194	-0.188	0.176	0.166		0.021		0.077	0.736	1.000
SE	0.055	0.079	0.099	0.275	0.295	0.310	0.087	0.176		0.052		0.086	0.229	
	-0.116	-0.186	-0.180	-0.089	-0.164	-0.155	0.174	0.065		0.053	0.313		0.570	1.000
SE	0.055	0.050	0.050	0.275	0.295	0.310	0.087	0.176		0.052	0.086		0.229	
	-0.116	-0.186	-0.179	-0.123	-0.200	-0.193	0.176	0.397		0.065	0.242	0.296		1.000
SE	0.055	0.077	0.099	0.240	0.256	0.275	0.099	0.203		0.152	0.157	0.107		

	2012	2013	2014	2012	2013	2014	RMSPE	W1	W2	W4	W5	W6	W7	Total W
	-0.118	-0.192	-0.189	0.304	0.231	0.239	0.530	0.768	0.006			0.158	0.068	1.000
SE	0.055	0.077	0.100	0.448	0.458	0.482	0.291	0.203	0.040			0.132	0.151	
	-0.117	-0.187	-0.181	-0.001	-0.075	-0.065	0.200	0.083	0.023		0.432		0.461	1.000
SE	0.055	0.077	0.0981	0.261	0.273	0.286	0.099	0.131	0.064		0.082		0.105	
	-0.116	-0.185	-0.178	-0.103	-0.178	-0.168	0.153	0.138	0.102		0.490	0.269		1.000
SE	0.054	0.075	0.100	0.216	0.226	0.253	0.078	0.175	0.112		0.077	0.065		
	-0.118	-0.192	-0.189	-0.009	-0.085	-0.078	0.241	0.074	0.014	0.106			0.805	1.000
SE	0.054	0.078	0.101	0.317	0.338	0.350	0.132	0.122	0.056	0.156			0.203	
	-0.118	-0.192	-0.189	-0.117	-0.195	-0.190	0.187	0.306	0.127	0.110		0.457		1.000
SE	0.054	0.076	0.0981	0.208	0.224	0.249	0.093	0.244	0.160	0.173		0.135		
	-0.116	-0.187	-0.182	0.085	0.006	0.016	0.372	0.179	0.007	0.288	0.525			1.000
SE	0.054	0.075	0.098	0.333	0.340	0.367	0.178	0.242	0.037	0.256	0.295			
	-0.113	-0.179	-0.166	-0.243	-0.320	-0.310	0.159				0.324	0.091	0.585	1.000
SE	0.058	0.083	0.107	0.293	0.316	0.324	0.102			0.184	0.098	0.223		
	-0.116	-0.188	-0.181	-0.149	-0.226	-0.218	0.216			0.070		0.026	0.903	1.000
SE	0.055	0.079	0.099	0.415	0.441	0.452	0.131			0.105		0.058	0.111	
	-0.114	-0.183	-0.173	-0.118	-0.194	-0.186	0.170			0.111	0.335		0.554	1.000
SE	0.055	0.078	0.099	0.301	0.320	0.333	0.080			0.169	0.276		0.280	
	-0.115	-0.184	-0.174	-0.489	-0.567	-0.561	0.381			0.108	0.573	0.319		1.000
SE	0.055	0.078	0.099	0.505	0.512	0.528	0.250			0.149	0.139	0.116		
	-0.114	-0.181	-0.172	0.733	0.665	0.676	0.923	1.000	0.000					1.000
SE	0.054	0.079	0.102	0.545	0.562	0.583	0.247	0.000	0.000					

Numbers are averaged for 100 replications. W1 to W7 are the weights on the donor countries; note that country 3 is the treated unit (“Iran”). If no weight is reported that unit is left out of the analysis.

4. Conclusion

We utilize the power of the Monte Carlo simulation to examine and compare two popular method of estimation in case of a policy intervention: the synthetic control method and the dynamic panel data model. With solving an optimization problem to minimize RMSPE, the synthetic control estimator lacks any specification of the underlying asymptotic distribution, and there is no discussion of the significance. The method is usually complemented by placebo studies with current donors in hand. We believe the power of MC simulation enables us to study the significance of the point estimates, and to examine the sensitivity of the method to the arbitrary choice of the donors.

The empirical work is based on a suitable comparative case: the international sanctions on Iran. We specifically study the effect of international sanctions against Iran on the country's GDP and economic growth. We use a Monte Carlo generated values of GDP and we run a synthetic control method, and estimate a dynamic panel data model over repeated trials. We conclude that the dynamic panel data model seems to be performing well with the macro level aggregate data, and the assumptions are appropriate. However, for the synthetic control method we observe large standard error in the estimated values. If we translate that to a significance analysis, this means that even though we observe meaningful values reported as the effect of the intervention, they are not statistically significant. We also observe that the dynamic panel data model stays powerful while the synthetic control becomes more and more sensitive when we reduce the donor size.

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Appendix

A. Data Resources

The data source employed for the analysis are as follow:

- Gross Domestic Production (PPP, Constant 2011 international dollars). Source: World Bank, International Comparison Program Database, WEI, 2017. Second source: IMF, World Economic Outlook Databases (WEO) 2017.
- Gross Domestic Production per Capita (PPP, Constant 2011 international dollars). Source: World Bank, International Comparison Program Database, WEI, 2017. Second source: IMF, World Economic Outlook Databases (WEO) 2017.
- Gross Domestic Production Growth (Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2010 U.S. dollars). Source: World Bank, International Comparison Program Database, WEI, 2017.
- GDP Deflator (100 in 2011). Source: World Bank National Accounts Data, WEI, 2017. Second source: IMF, World Economic Outlook Databases (WEO) 2017.
- PPP Conversion Factor, GDP (LCU per international dollar). Source: World Bank, International Comparison Program Database, WEI, 2017.
- Total Population. Source: OPEC Annual Statistical Bulletin, 2017.
- Total Natural Resources Rents (Percentage of GDP). Source: World Bank National Accounts Data, WEI, 2017.
- Agriculture, Value Added (Percentage of GDP). Source: World Bank National Accounts Data, WEI, 2017.
- Services, etc., Value Added (Percentage of GDP). Source: World Bank National Accounts Data, WEI, 2017.
- Industry, Value Added (Percentage of GDP). Source: World Bank National Accounts Data, WEI, 2017.

B. Descriptive Statistics

Table 5 provides descriptive statistics:

Table 5: Descriptive Statistics

Variable	Mean		Std. Dev.	Min	Max	Observations
Year	overall	1997	10.11	1980	2014	N = 490
	between		0	1997	1997	n = 14
	within		10.11	1980	2014	T = 35
ID	overall	7.5	4.04	1	14	N = 490
	between		4.18	1	14	n = 14
	within		0	7.5	7.5	T = 35
GDP	overall	764.32	1894.69	0	17406.24	N = 485
	between		1400.46	30.15	5478.43	n = 14
	within		1321.82	-4009.17	12692.13	T-bar = 34.64
Population	overall	1.11e+08	3.08e+08	223715	1.36e+09	N = 487
	between		3.17e+08	720039.6	1.21e+09	n = 14
	within		3.29e+07	-1.12e+08	2.71e+08	T-bar= 34.7857
Rents	overall	19.85	15.49	0.12	66.48	N = 477
	between		13.67	0.56	38.81	n = 14
	within		8.35	-11.77	57.45	T-bar=34.0714
Trade	overall	72.37	38.40	12.42	251.14	N = 441
	between		36.86	37.12	160.44	n = 14
	within		16.39	25.16	163.06	T-bar = 31.5
Industry	overall	46.73	24.08	23.82	213.69	N = 304
	between		25.41	29.39	122.29	n = 13
	within		13.06	-5.804	138.13	T-bar = 23.38
Agriculture	overall	11.76	10.47	0.09	48.57	N = 324
	between		9.65	0.17	33.04	n = 14
	within		4.31	-1.05	27.28	T-bar = 23.14
Growth	overall	4.15	7.11	-62.08	33.99	N = 442
	between		3.13	-1.001	11.52	n = 14
	within		6.66	-56.92	34.54	T-bar = 31.57
Services	overall	43.31	11.33	19.49	71.31	N = 324
	between		12.12	22.97	68.98	n = 14
	within		6.32	25.31	68.47	T-bar = 23.14