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Assessing the Growth Effect of Common Currency Adoption: Synthetic Control Approach

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Abstract This study empirically assesses the growth effect of adopting the euro by applying a recently developed econometric technique, the synthetic control method (SCM), to implement data-driven comparative case studies for the euro zone. For analytical purposes, we classify the 12 euro-adopting countries into two country groups: core and peripheral countries. The results from the SCM algorithm show that the patterns of per capita GDP in the core (peripheral) countries are generally lower (higher) than those of their counterfactual units. However, the outcomes of the placebo tests indicate that these differences are statistically insignificant, thus implying that the introduction of the euro system neither improves nor impairs the economic growth of these two groups of countries that adopted the euro during 1991-2013. As for the three European Union countries that did not adopt the euro, the results of the inverse SCM analysis show that Denmark would be better off if it had adopted the euro. However, in the cases of Sweden and the United Kingdom, not adopting the euro system may have been a better choice, especially following the sovereign debt crisis.

Keywords: *economic growth, synthetic control method, euro, euro zone*

JEL Classification: O43, O52

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1. Introduction

To secure a lasting peace following World War II, six countries, namely, Belgium, France, Germany, Italy, Luxembourg, and the Netherlands, established the European Coal and Steel Community (ECSC) in 1951 to unite among them both economically and politically. Since then, countries on the European continent have undergone a battery of experiments aimed at political and economic integration. For instance, in 1957, the Treaty of Rome was signed to establish the European Economic Community (EEC) and the European Atomic Energy Community (Euratom). The aim of the EEC was to create a common market to eliminate tariffs among members and to promote the free movement of labor, goods, capital, and services. In 1965, the Merger Treaty was signed to unite these three communities, i.e., the ECSC, EEC, and Euratom, as one institution, referred to as the “European Communities” (EC). Furthermore, the Single European Act signed by the members in 1986 allowed for the free movement of goods traded among the member countries, thus forming a “single market.” The ongoing integration reached its peak when the Treaty of Maastricht was signed in 1992 to establish the European Monetary Union (EMU). Based on the provisions of the Treaty of Maastricht, the European Union (EU) was established in 1993, and a common currency system was established by January 1, 1999. Now there are 19 countries in the EU that have adopted a common currency—the euro. An interesting question arises: How does the introduction of a common currency system affect the economic performance of the euro zone economies?

The foundation of forming of a common currency system lies in the Optimum Currency Area Theory proposed by Mundell [1]. According to this theory, there are several reasons for establishing an optimum currency area. First, it can eliminate the risks associated with volatile exchange rates as well as promote specialization in production, international trade, and investment among the member countries. As such, producers can benefit from a unified market due to economies of scale. Second, implementing a common currency system is equivalent to permanently fixing the exchange rates among members, which can help stabilize the price level in the common currency area. This can smoothen cross-border transactions by avoiding barter trading due to inflation and can save the costs that would result from speculation in the foreign exchange market among member countries. By contrast, the biggest drawback of an optimum currency area is that each member state has to relinquish its sovereignty over monetary policy. In addition, the quasi-fixed exchange rate system lacks the flexibility to properly adjust the balance of payments. Thus, to form a successful monetary union, it is required that there are no huge economic gaps among member states, otherwise imbalances in payments among members may occur, which would result in higher unemployment or inflation rates in some or all of the member countries.

Many empirical studies assessing the economic effects of adopting the euro system have mostly focused on the fields of bilateral trade, the development of financial markets, and investment activities. For instance, the vast majority of studies conclude that the euro will exert a positive effect on bilateral trade, e.g., Rose and Stanley [2], Flam and Nordström [3], Micco et al. [4], Faruqee [5], Bun and Klaassen [6], Eichengreen and Boltho [7], and Camarero et al. [8], whereas some others believe that the euro has no significant effect on bilateral trade, such as Santos Silva and Tenreyro [9] and Figueiredo et al. [10]. Moreover, with regard to the impact of adopting the euro on the financial sector, Bartram and Karolyi [11] suggest that the introduction of the euro leads firms, either within or outside Europe, to be less exposed to market risk. Furthermore, a few studies, such as Galati and Tsatsaronis [12], Danthine et al. [13] and Cappiello et al. [14], also show that the adoption of the euro will have a positive effect on the development of financial markets within the euro zone. Lastly, introducing the common currency union will lower the cost of capital [15,16] and increase investment activity and corporate valuation within the euro zone [17,18].

In comparative terms, the literature evaluating the impact of joining a common currency union on the economic performance is relatively sparse. For instance, Conti [19] uses a differences-in-differences (DID) framework to analyze the impact of initiating the euro system at the level of per capita GDP for a sample of 17 European countries (the EU15 along with Norway and Iceland) over the period 1990-2010. He finds that the adoption of the euro might have had a positive effect on the level of per capita GDP. In addition, Conti [19] also shows that the impact of the euro has been small in the case of countries with a high debt-to-GDP ratio in 1999 upon introduction of the euro. Next, Dubois et al. [20] use a global macroeconomic framework (GVAR) to assess the macroeconomic impact of the EMU membership for 30 OECD countries over the years 1992-2005. They use counterfactual analysis and find that monetary unification promoted lower interest rates and higher output in most euro area countries, except for those that have followed a German-type of monetary policy. However, if national monetary policies had been based on the adoption of British monetary preferences after September, 1992, this would have led to higher interest rates, depreciation, and output in most countries that adopted the euro, especially from 1992 to 1998.

Several problems have arisen in previous studies that used cross-country regressions. For example, cross-country studies that drew their conclusions based on averaging the data usually ignored the heterogeneous experiences and circumstances faced by different countries and, hence, failed to generate any reliable inference for the concerned individual countries. In addition, cross-country estimators usually suffer from the problem of endogeneity and, therefore, are likely to result in biased estimations. Thus, country-specific case studies may be a possible alternative in this strand of research. For this reason, in this study, we reinvestigate the effect of the adoption of the euro on per capita GDP by implementing a set of empirical country specific case studies. In particular, we apply an econometric technique recently developed by Abadie and Gardeazabal [21] and Abadie et al. [22], namely, the synthetic control method (SCM) to implement data-driven comparative case studies.

The study sample used in this research includes 12 European countries that introduced the euro in 1999 or 2001. For analytical purposes, we classify them into two country groups: core and peripheral countries[1]. Moreover, 24 European countries that did not adopt the euro are considered in the donor pool. By applying the SCM to construct a counterfactual unit for each euro-adopting country, we can take the difference between the realized per capita GDP of the adopting country and that of the synthetic counterfactual unit as the treatment effect resulting from adopting the euro. Our results show that the impact of adopting the euro on the per capita GDP is generally low in the core countries and high in the peripheral countries compared with how it would be if they did not adopt the euro system. However, the results of the placebo tests generally indicate that the economic impact of adopting the euro is not statistically significant, neither in the core countries nor in the peripheral countries. Furthermore, we perform an inverse SCM algorithm to evaluate whether Denmark, Sweden, and the United Kingdom would be better or worse off if they were to join the euro system. We find that Denmark would be better off if had adopted the euro, and the effect is statistically significant. As for Sweden and the UK, we find that the economic performance of these two economies did not change by a lot right after the adoption of the euro in 1999. However, their robust economies appeared to be capable of adjusting to the shocks that occurred a few years later, especially after 2010, when the sovereign debt crisis occurred. This outcome reveals that, for Sweden and the UK, not adopting the euro system would have been a better choice.

The remainder of this study is organized as follows. Section 2 briefly outlines the synthetic control approach applied to assess the treatment effect of adopting the euro in the euro zone. Section 3 describes the data sources and the construction of the relevant variables. Section 4 presents the empirical results and Section 5 provides the concluding remarks.

2. Methodology

The SCM, an econometric technique recently developed by Abadie and Gardeazabal [21] and extended by Abadie et al. [22], is applied to conduct data-driven comparative case studies. The basic framework of the SCM involves constructing an artificial control unit that better resembles the treatment unit in the pre-treatment period than that for any individual unit within the control group. Thus, the SCM provides an attractive data-driven algorithm to make up the composition of control units for the study of the effect of policies or events that are likely to intervene in the performance of a region or a country at

[1] The core country group includes Austria, Belgium, France, Germany, Italy, and the Netherlands, and the peripheral country group includes Finland, Greece, Ireland, Luxembourg, Portugal, and Spain.

an aggregate level. In what follows, we will outline the SCM framework.

Suppose there are $N + 1$ countries over T periods. Only country i accepts the treatment, i.e., the event of introducing the euro at time T_0, where $T_0 < T$ and while the remaining N potential control countries do not adopt the euro. Then, the treatment effect of country i at time t can be defined as

$$\tau_{it} = Y_{it}(1) - Y_{it}(0) \quad (1)$$

where $Y_{it}(0)$ is the outcome of the dependent variable (GDP per capita) that would be observed for country i at time t in the absence of adopting the euro and $Y_{it}(1)$ is the outcome (GDP per capita) that would be observed for country i at time t if it introduces the euro in periods $T_0 + 1$ to T. The outcome of τ_{it} is defined as the effect of adopting the euro for country i at time t. Our ultimate goal is to estimate the vector of $(\tau_{i,T_0+1},...,\tau_{i,T})$. However, only $Y_{it}(1)$ is observable in periods $T_0 + 1$ to T, but $Y_{it}(0)$ is not. As such, to estimate the effect of adopting the euro on economic performance, an estimate of $Y_{it}(0)$ is necessary.

To identify the treatment effect of adopting the euro, we follow Abadie et al. [22] to define the potential outcomes of all units as

$$Y_{nt}(0) = \phi_t + \alpha_t Z_n + \beta_t \mu_n + \varepsilon_{nt} \quad (2)$$

$$Y_{nt}(1) = \tau_{nt} + \phi_t + \alpha_t Z_n + \beta_t \mu_n + \varepsilon_{nt} \quad (3)$$

where $n = 1,2,...,N+1$, ϕ_t is an unknown common factor with a constant factor loading across all units, Z_n is a vector of observed covariates that are not affected by the intervention, α_t is a vector of parameters of Z_n, β_t is an unobserved common factor, μ_n is a country-specific unobservable factor, the error terms ε_{it} are unobserved transitory shocks with zero mean, and τ_{nt} is different from zero when $n = 1$ and $t > T_0$.

Suppose that the first country is the target country that has introduced the euro, where $i = 1$, and the remaining N countries ($n = 2, . . ., N+1$), which serve as the control group, have not. By employing the observed characteristics of the countries in the control group as proposed by Abadie et al. [22], we can find an $(N \times 1)$ vector of weights $W = (w_2,...,w_{N+1})$, with $w_n \geq 0$ and $\sum_{n=2}^{N+1} w_n = 1$, such that the weighted average of all countries in the control pool imitates the treated country with respect to the outcome variable in the pre-intervention period and all other observable aspects, i.e., Z_n. Specifically, we will find W for $t \leq T_0$ such that

$$Y_{1t} = \sum_{n=2}^{N+1} w_n^* Y_{nt} \quad (4)$$

$$Z_1 = \sum_{n=2}^{N+1} w_n^* Z_n \quad (5)$$

Based on the above model, we can use $\sum_{n=2}^{N+1} w_n^* Y_{nt}$ for $t > T_0$ as an estimate of the unobserved counterfactual outcome level $Y_{it}(0)$. Accordingly, the treatment effect can be estimated as follows:

$$\hat{\tau}_{it} = Y_{it} - \sum_{n=2}^{N+1} w_n^* Y_{nt}, \ t > T_0 \quad (6)$$

The synthetic control weights w^* are estimated with a nonparametric algorithm and are selected so that conditions (4) and (5) approximately hold. We briefly sketch the algorithm as follows. Let X_1 be the $(k \times 1)$ vector of pre-treatment characteristics of the treated unit and let X_0 be the $(k \times J)$ matrix comprising the vectors of the control countries in the donor pool. The vector W^* is solved to minimize the following distance:

$$\|X_1 - X_0 W\|_v = \sqrt{(X_1 - X_0 W)' V (X_1 - X_0 W)} \quad (7)$$

where V is a $(k \times k)$ symmetric and positive semi-definite matrix that weights the relative importance of the various traits considered in X. It is obvious that the optimal weight W^* is chosen to minimize the mean squared error of pre-treatment outcomes that depends on the weighting matrix V. Following Abadie and Gardeazabal [21], the vector V can be obtained by minimizing the mean square prediction error (MSPE) of the outcome variable in the pre-treatment period. In addition, an iterative optimization procedure can be implemented to search all positive semi-definite matrices V and the set of best weights (W^*) for the best-fitting convex combination of the control countries.

These weights are estimated in an algorithm so that the pre-treatment outcome and the covariates of the synthetic control unit are as close as possible to those of the treated country. Compared with conventional comparative case studies that usually subjectively pick a country as a comparison unit, the composed counterfactual unit constructed by weighting the countries chosen from the J potential controls with the weights being objectively estimated by the synthetic control algorithm, can make the underlying comparison more meaningful. In addition, while conventional panel data models control only for confounding factors that are time-invariant or share a common trend, the synthetic control method allows the effect of unobservable confounding factors to vary with time[2].

However, according to Billmeier and Nannicini [23], the SCM comes with a limitation in that it provides no statistic to assess the significance of the results using standard inferential techniques because the number of observations in the control pool and the number of periods covered by the sample are usually quite small. To overcome this drawback, Abadie et al. [22] propose a

[2] In equation (2), if we impose the limitation that β_t cannot vary with time, this equation will become the differences-in-differences model.

placebo experiment in a permutation format to evaluate the statistical significance of the treatment effect. This placebo test sequentially applies the synthetic control algorithm to every country in the pool of potential controls and then compare the placebo with the baseline results. Only when the gap between the actual outcome level and the synthetically predicted one is the largest (or smallest) for the country where the treatment really occurred can we conclude that the effect of adopting the euro system on the economic performance of the treated country is significant.

3. Data

There are 19 countries using the euro within the EU. Because seven of these 19 countries acceded to the EU and adopted the euro between 2007 and 2015, we exclude them from our sample as they provide insufficient data for our analysis [3]. Accordingly, we have the remaining 12 countries as our treatment countries. Table 1 displays information regarding the economic performance, population, and year of launching the euro for these 12 treated countries. In addition, a set of control countries that did not adopt the euro throughout the study period is considered to effectively provide a pool of economies to make potential comparisons. These control countries are chosen from European countries as they are geographically proximal, culturally similar, and economically related to our treated countries. After deleting those countries with insufficient data, we have 24 countries remaining in the control group [4].

Table 1. Euro-Launching Episodes of the Treated Countries

Country	Official Launch of the Euro	GDP per capita (US Dollars) 1991–1998	GDP per capita (US Dollars) 1999–2013	Population in 1999
Austria	1999	31,274	38,750	8,094,156
Belgium	1999	30,206	36,734	10,235,655
Finland	1999	27,820	38,405	5,158,097
France	1999	29,500	34,746	60,823,977
Germany	1999	30,863	35,934	82,100,240
Greece	2001	16,465	21,207	10,536,749
Ireland	1999	28,167	48,282	3,774,856
Italy	1999	27,930	31,223	57,655,527
Luxembourg	1999	58,259	79,119	432,527
Netherlands	1999	33,320	42,072	15,801,947
Portugal	1999	15,591	18,711	10,283,381
Spain	1999	20,476	25,780	40,251,434

"Official Launch of the Euro" is the date of the implementation of the single monetary policy by the European System of Central Banks. "GDP per capita" is based on data of the World Bank from 1991 to 2013.

Other covariates in the vector Z that are drawn based on the cross-country growth regressions include: *Secondary school* as a proxy for human capital and defined as ln[school enrollment (secondary, % gross)]; *Openness* as an indicator of a country's degree of openness and defined as ln[imports of goods and services (% of GDP) + exports of goods and services (% of GDP)]; *Investment* as the value of acquisitions of new or existing fixed assets and defined as ln[gross fixed capital formation (% of GDP)]; and *Population* as the growth rate of population and defined as ln[population growth (annual %)]. The data source used to construct these variables is the dataset of World Development Indicators (WDI) from the World Bank. It is noted that when implementing the SCM algorithm, all the covariates are averaged out over the study period and augmented by adding three pre-treatment years of outcome variables.

4. Results

For illustrative purposes, according to Zipfel [24], we classify our treated countries into two clusters—core and peripheral countries—to perform the SCM analyses [5]. Specifically, the core countries comprise Austria, Belgium, France, Germany, Italy, and the Netherlands, and the peripheral countries comprise Finland, Greece, Ireland, Luxembourg, Portugal, and Spain. In addition, as the SCM analyses are performed as discussed above, the three conventional EU members, Denmark, Sweden, and the UK, have been the most picked or highly weighted as part of the estimated counterfactual. This observation causes us to ask what might have happened if these three countries had also adopted the euro. To further explore this possibility, we perform an inverse SCM procedure to address this question. In what follows, we will present the SCM outcomes and corresponding placebo tests in relation to these three different country groups.

4.1. The Growth Effect of Adopting the Euro in the Core Countries

Table 2 presents a numerical comparison between each treated country and its synthetic counterfactual counterpart. The explanatory variables used to characterize the growth pattern of each country, including *Secondary school*, *Openness*, *Investment*, and *Population*, are all transformed into logarithmic form. In addition, some of the pre-treatment outcome variables, e.g., the log of GDP per capita in 1991, 1995, and 1998, are used to improve the pre-treatment fit. Lastly, the value of the root mean squared prediction error (RMSPE) of (the log of) GDP per capita is reported to calibrate the overall treatment fit. The lower the value of the RMSPE, the higher is the pre-treatment quality. Table 3 presents all the countries in the donor pool and the corresponding weights used to construct the counterfactuals. The weights are chosen in such a manner that the RMSPE of (the log of) GDP per capita is minimized for the pre-intervention period.

[3] The euro-adopting countries excluded from our sample are Cyprus, Estonia, Latvia, Lithuania, Malta, Slovakia, and Slovenia.

[4] Please refer to Tables 3 and 5 for a complete list of our control countries.

[5] The core countries located in central Europe are associated by geographical proximity and historical experience, whereas the peripheral countries located in eastern and southern Europe and among the Nordic countries, are positioned around central Europe.

Table 2. Means of the Covariates of Core European Countries (GDP per capita)

	Austria (1999)	
Variables	Treated	Synthetic
Secondary school	4.6470	4.6310
Openness	4.2434	4.3200
Investment	3.2539	3.1846
Population	0.0048	0.0047
GDP per capita (1991)	10.3007	10.3055
GDP per capita (1995)	10.3521	10.3522
GDP per capita (1998)	10.4290	10.4234
RMSPE	0.0044	

	Belgium (1999)	
Variables	Treated	Synthetic
Secondary school	4.8616	4.7132
Openness	4.7607	4.2725
Investment	3.0761	2.9890
Population	0.0029	0.0030
GDP per capita (1991)	10.2727	10.2760
GDP per capita (1995)	10.3204	10.3198
GDP per capita (1998)	10.3859	10.3884
RMSPE	0.0032	

	France (1999)	
Variables	Variables	Treated
Secondary school	4.7070	4.5706
Openness	3.7738	4.0289
Investment	3.0241	3.0083
Population	0.0037	0.0037
GDP per capita (1991)	10.2566	10.2578
GDP per capita (1995)	10.2935	10.2923
GDP per capita (1998)	10.3546	10.3562
RMSPE	0.0075	

	Germany (1999)	
Variables	Treated	Synthetic
Secondary school	4.7630	4.7024
Openness	4.0823	4.1972
Investment	3.0466	2.9628
Population	0.0041	0.0041
GDP per capita (1991)	10.2016	10.1996
GDP per capita (1995)	10.2217	10.2222
GDP per capita (1998)	10.3622	10.3475
RMSPE	0.0072	

	Italy (1999)	
Variables	Treated	Synthetic
Secondary school	4.4528	4.5408
Openness	3.7016	4.1208
Investment	2.9704	3.0798
Population	0.0004	0.0047
GDP per capita (1991)	10.1986	10.2053
GDP per capita (1995)	10.2466	10.2421
GDP per capita (1998)	10.2925	10.2968
RMSPE	0.0061	

	The Netherlands (1999)	
Variables	Treated	Synthetic
Secondary school	4.8625	4.7072
Openness	4.6943	4.2887
Investment	3.0956	3.0901
Population	0.0061	0.0045
GDP per capita (1991)	10.3578	10.3644
GDP per capita (1995)	10.4216	10.4184
GDP per capita (1998)	10.5182	10.5174
RMSPE	0.0046	

†The table shows the mean values of the covariates. The outcome variable is the log of GDP per capita. For detailed definitions of these covariates, please refer to the section entitled "Data Sources and Description."

Table 3. Weights in Each Synthetic Country (GDP per capita) for Core Countries

Control Countries	Austria	Belgium	France	Germany	Italy	Netherlands
Albania	0	0	0	0	0	0
Armenia	0	0	0	0	0	0
Azerbaijan	0	0	0	0	0	0
Belarus	0.012	0.017	0	0	0	0.056
Bulgaria	0	0.035	0	0	0	0
Czech Republic	0.209	0	0	0	0	0.074
Denmark	0	0.806	0	0	0	0
Georgia	0	0	0	0.068	0	0
Hungary	0	0	0	0	0	0
Iceland	0	0	0	0.068	0	0
Kazakhstan	0	0.052	0	0	0	0
Latvia	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0
Macedonia, FYR	0	0	0	0	0	0
Moldova	0	0	0	0	0	0
Norway	0.286	0	0	0.543	0	0.521
Poland	0	0	0	0.098	0	0
Romania	0	0	0	0	0.089	0
Russian Federation	0	0	0.053	0	0	0
Sweden	0.122	0	0	0.223	0	0.242
Switzerland	0.356	0.09	0.226	0	0.428	0.107
Turkey	0.015	0	0.017	0	0.052	0
Ukraine	0	0	0	0	0	0
United Kingdom	0	0	0.704	0	0.431	0

†Six countries that introduced the euro are presented in the first row. Control group countries are presented in the left-hand column. For example, the table indicates that synthetic Austria consists of 35.6% Switzerland, 28.6% Norway, 20.9% Czech Republic, 12.2% Sweden, 1.5% Turkey, and 1.2% Belarus. The weights in each column add up to one.

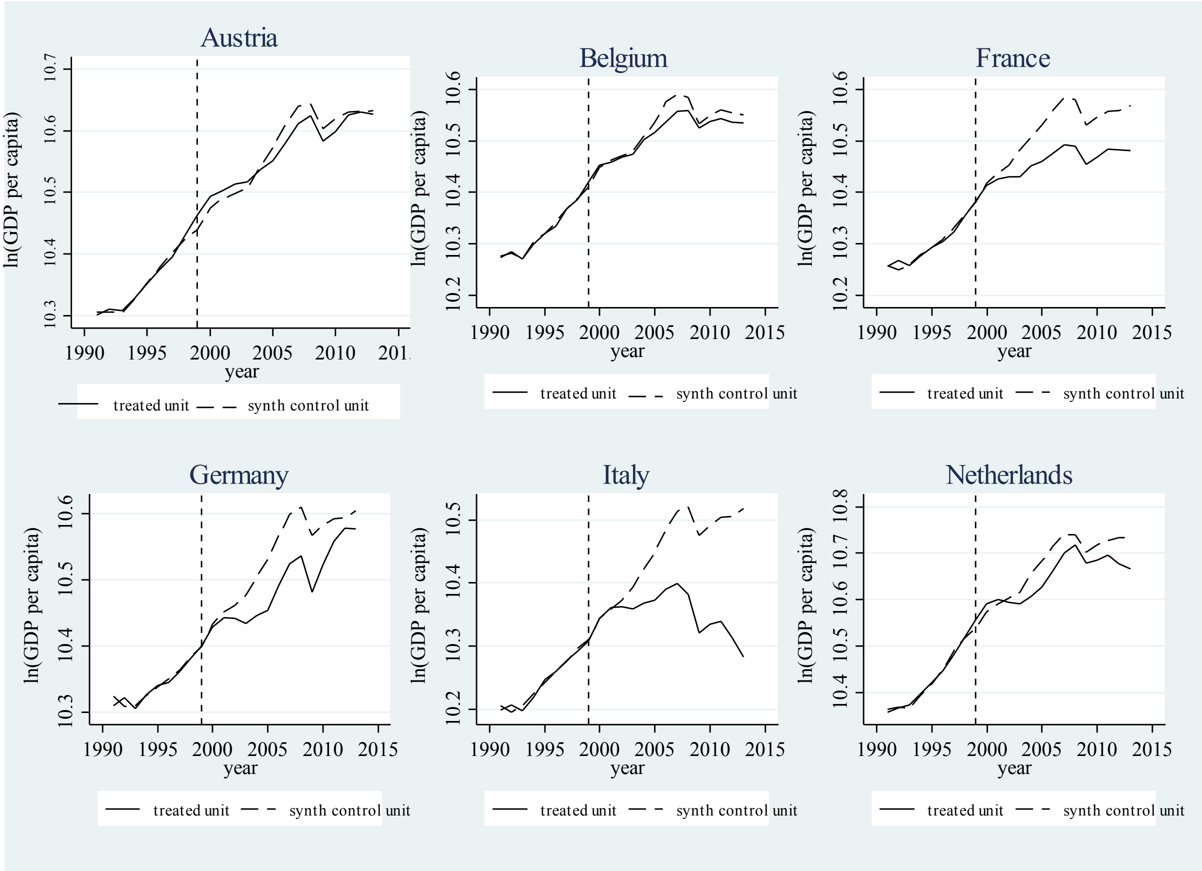

Figure 1. SCM results for core countries (the log of GDP per capita)

Furthermore, Figure 1 outlines the paths of economic performance measured by (the log of) GDP per capita over the entire study period, where the solid line represents the realized path of the per capita GDP of the treated country and the dashed line denotes its synthetic counterpart drawn from the control pool. In addition, a vertical dotted line added in each graph denotes the year (T_0) of launching the euro system in each treated country. As the synthetic counterpart for each treated country is the weighted outcome of its corresponding controls in the donor pool, the closer the coincidence between the solid and dashed lines before T_0, the higher is the quality of the pre-initiation fit achieved by the SCM. Consequently, the difference between the solid and dashed lines after T_0 reveals the treatment effect resulting from the adoption of the euro, with a larger gap between the solid and dashed lines after T_0, indicating a greater treatment effect.

By first focusing on the case of Austria, we can find that the average of (the log of) per capita GDP over the years before the launch of the euro system tracks closely with that based on the synthetic control unit, with an RMSPE value of 0.0044 being reported in Table 2. In addition, according to Table 3, the synthetic control unit constructed from the donor pool for Austria consists of 35.6% in Switzerland, 28.6% in Norway, 20.9% in Czech Republic, 12.2% in Sweden, 1.5% in Turkey, and 1.2% in Belarus. Moreover, Figure 1 shows that the adoption of the euro in Austria seems to improve its economic performance immediately following the launch of this common currency; however, it becomes worse after 2004 as the realized path of (the log of) GDP per capita after 1999 (the euro launch year) is observed to be higher than that of the synthetic control unit before 2004, but to be lower after 2004. However, the difference between the realized and the counterfactual paths of (the log of) GDP per capita after 1999 is not virtually large.

As to the remaining countries in the core country group, we can find that they all have a good pre-treatment fit as shown by the values of the RMSPE reported in Table 2 and the close coincidence between the actual path of (the log of) GDP per capita of the treated countries and that of their corresponding counterfactual control units displayed in Figure 1. It is observed that the launch of the euro system in these countries has obviously worsened their economic performance as the realized path of (the log of) GDP per capita is observed to be lower than that for the synthetic control units after 1999, when the euro system was officially launched. In particular, for France, Germany, and Italy, the obvious gaps between the realized and counterfactual paths of (the log of) GDP per capita after 1999 imply that they have been harmed economically by joining a common currency union.

As regards the statistical inference, a series of placebo experiments is performed and the test results are provided in Figure 2. In particular, for each treated economy, the dashed lines show the gap in (the log of) GDP per capita between each country in the control group and its corresponding synthetic counterpart while the superimposed dark line reveals the difference in (the log of) GDP per capita between the treated country and its synthetic control unit. In the placebo experiments, because countries with poor fits prior to the adoption of the euro provide relatively imprecise information to measure the postintervention gaps, countries with pre-intervention RMSPE values higher than a certain level of the pre-intervention RMSPE for the treated country in question are excluded. In general, we exclude the control units with RMSPE values greater than 10 times the RMSPE value of the treated country. It can be seen that the gaps between the realized and synthetic outcomes for these treated countries do not appear to be the largest or the smallest among all comparison units after the treatment period. As such, we cannot decisively conclude that the adoption of the euro has improved or harmed the per capita GDP in the core country group.

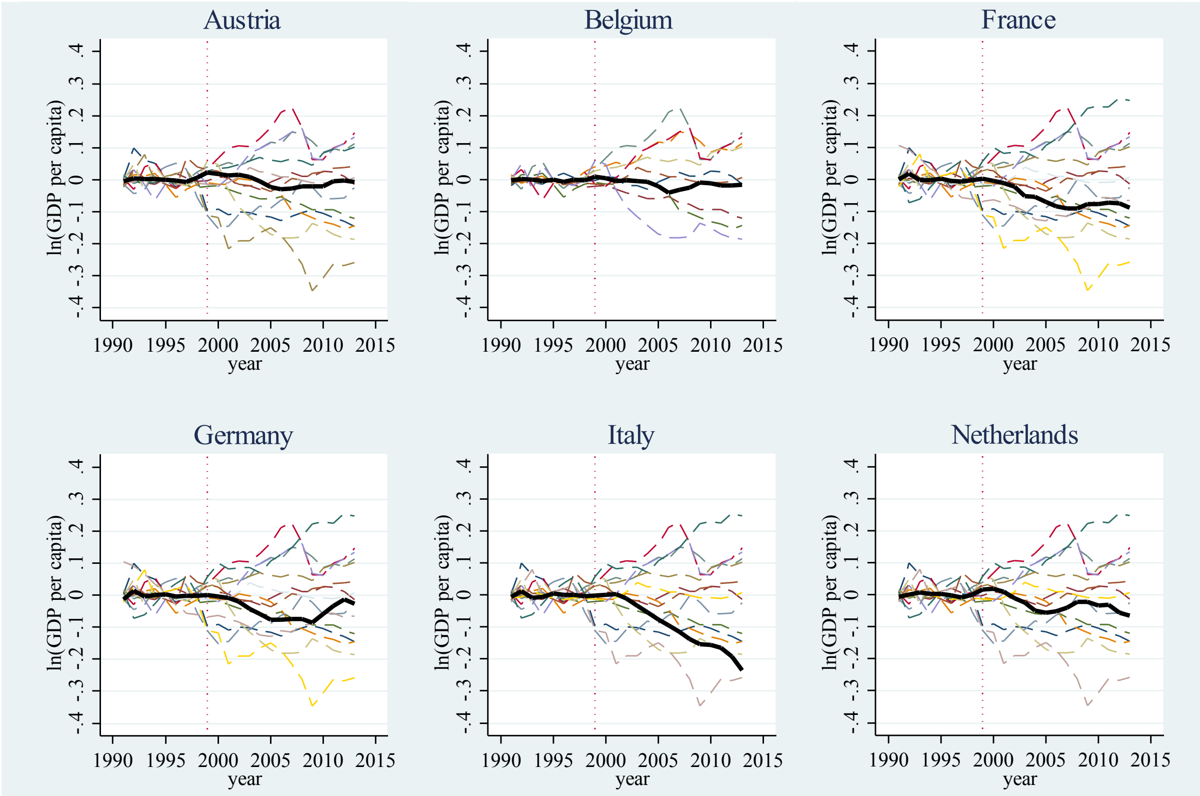

Figure 2. Placebo experiments for core countries (excludes countries with an RMSPE ten times higher than that of the target country)

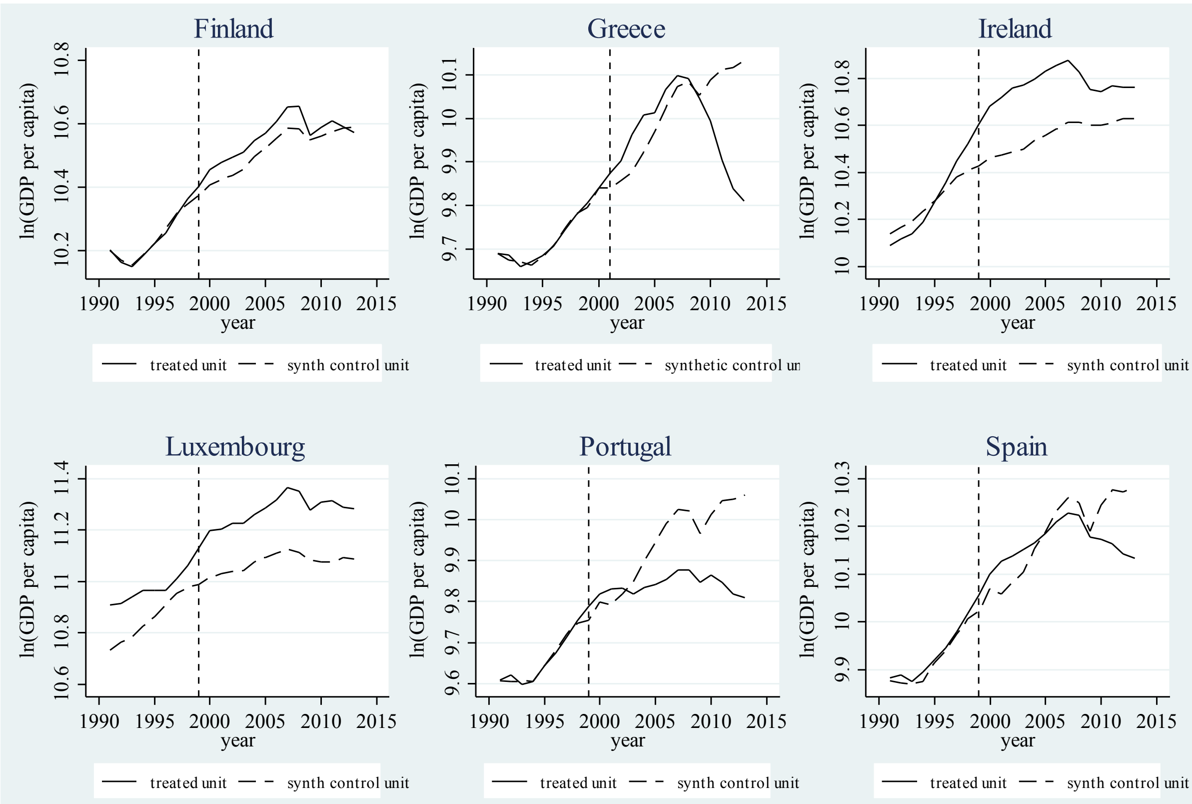

Figure 3. SCM results for peripheral countries (the log of GDP per capita)

Table 4. Means of the Covariates of Peripheral Countries (GDP per capita)

	Finland (1999)	
Variables	**Treated**	**Synthetic**
Secondary school	4.7630	4.7024
Openness	4.0823	4.1972
Investment	3.0466	2.9628
Population	0.0041	0.0041
GDP per capita (1991)	10.2016	10.1996
GDP per capita (1995)	10.2217	10.2222
GDP per capita (1998)	10.3622	10.3475
RMSPE	0.0084	

		Greece (2001)
Variables	**Treated**	**Synthetic**
Secondary school	4.5180	4.5179
Openness	3.7075	4.1294
Investment	3.1203	3.1205
Population	0.0072	0.0072
GDP per capita (1991)	9.6895	9.6893
GDP per capita (1995)	9.7068	9.7087
GDP per capita (1998)	9.8402	8.8396
RMSPE	0.0063	

	Ireland (1999)	
Variables	**Variables**	**Treated**
Secondary school	4.6992	4.6851
Openness	4.8552	4.1546
Investment	2.9223	2.9948
Population	0.0069	0.0045
GDP per capita (1991)	10.0900	10.1386
GDP per capita (1995)	10.2765	10.2789
GDP per capita (1998)	10.5195	10.4074
RMSPE	0.0589	

		Luxembourg (1999)
Treated	**Treated**	**Synthetic**
Secondary school	4.3913	4.7024
Openness	5.2630	4.1972
Investment	2.9864	2.9628
Population	0.0132	0.0041
GDP per capita (1991)	10.9079	10.1996
GDP per capita (1995)	10.9644	10.2222
GDP per capita (1998)	11.0614	10.3475
RMSPE	0.1228	

	Portugal (1999)	
Variables	**Treated**	**Synthetic**
Secondary school	4.5198	4.5192
Openness	4.0809	4.0817
Investment	3.1931	3.1205
Population	0.0022	0.0069
GDP per capita (1991)	9.6092	9.6076
GDP per capita (1995)	9.6444	9.6453
GDP per capita (1998)	9.7556	9.7482
RMSPE	0.0079	

		Spain (1999)
Variables	**Treated**	**Synthetic**
Secondary school	4.7149	4.5842
Openness	3.7548	4.0366
Investment	3.1134	3.0837
Population	0.0028	0.0074
GDP per capita (1991)	9.8830	9.8771
GDP per capita (1995)	9.9212	9.9153
GDP per capita (1998)	10.0175	10.0061
RMSPE	0.0056	

†The table shows the mean values of the covariates. The outcome variable is the log of GDP per capita. For detailed definitions of these covariates, please refer to the section entitled "Data Sources and Description."

Table 5. Weights in Each Synthetic Country (GDP per capita) for Peripheral Countries

Control Countries	Finland	Greece	Ireland	Luxembourg	Portugal	Spain
Albania	0	0	0	0	0	0
Armenia	0	0	0	0	0	0
Azerbaijan	0	0.055	0	0	0	0
Belarus	0	0	0.017	0	0.032	0
Bulgaria	0	0	0.035	0	0	0
Czech Republic	0	0	0	0	0.095	0
Denmark	0	0	0.806	0	0	0
Georgia	0.068	0	0	0	0	0
Hungary	0	0	0	0	0	0
Iceland	0.068	0.059	0	0	0	0
Kazakhstan	0	0	0.052	0	0	0
Latvia	0	0	0	0	0	0
Lithuania	0	0	0	0	0.027	0
Macedonia, FYR	0	0	0	0	0	0
Moldova	0	0	0	0	0	0
Norway	0.543	0	0	1	0.149	0
Poland	0.098	0.165	0	0	0.009	0
Romania	0	0	0	0	0	0
Russian Federation	0	0	0	0	0	0
Sweden	0.223	0.131	0	0	0.392	0.681
Switzerland	0	0.355	0.09	0	0	0.049
Turkey	0	0.189	0	0	0.296	0.269
Ukraine	0	0	0	0	0	0
United Kingdom	0	0.046	0	0	0	0

†Six countries that introduced the euro are presented in the first row. Control group countries are presented in the left-hand column. For example, the table indicates that synthetic Finland consists of 6.8% Georgia, 6.8% Iceland, 54.3% Norway, 9.8% Poland, and 22.3% Sweden. The weights in each column add up to one.

4.2. The Growth Effect of Adopting the Euro: the Peripheral Countries

Table 4 again illustrates the means of the covariates for each peripheral country in the common currency union. We find that four countries—Finland, Greece, Portugal, and Spain—have good fits, with values of the RMSPE less than 0.01. However, Ireland and Luxembourg are characterized by poor quality in terms of their pre-treatment fit, with RMSPE values of 0.0589 and 0.1228, respectively. Table 5 presents the weights used to construct the counterfactuals for each treated country. Figure 3 shows the realized (solid line) and the counterfactual (dashed line) paths of economic performance, measured by (the log of) GDP per capita for each treated country over the entire study period.

As for having low confidence regarding the results of the fit for the cases of Ireland and Luxembourg, we focus our discussion on the remaining four countries. It can be seen in Figure 3 that Finland is slightly better off after having adopted the euro because the realized path of (the log of) GDP per capita is shown to be slightly higher than that of the counterfactuals after the euro was officially launched in 1999. As for the cases of Greece, Portugal, and Spain, we can see that these countries temporarily claim an economic gain after the euro launch, but this gain deteriorates shortly after 2003 and falls sharply around the occurrence of the debt crisis in 2010.

Finally, we resort to the placebo experiments to infer the statistical significance of the SCM results. Again, we exclude the control units having RMSPE values 10 times greater than that of the treated country and the results of the placebo experiments are presented in Figure 4. It can be seen that the gaps between the realized and synthetic outcomes (superimposed dark line) for these treated countries are not the largest or the smallest among all comparison units (colored dashed lines) after the treated period. Once again, we cannot conclusively claim that the adoption of the euro has improved or harmed the per capita GDP in these peripheral countries.

4.3. What Would Happen if Denmark, Sweden, and the UK also Adopted the Euro?

When we apply the SCM to assess the economic effect of adopting the euro, we find that three conventional EU members—Denmark, Sweden, and the UK—have been the most picked or highly weighted as part of the estimated counterfactual. This leads us to ask what would happen if Denmark, Sweden, and the UK were also to introduce the euro in their economic systems. Would they be better or worse off? To answer this question, we proceed to construct and apply an inverse SCM algorithm. In particular, we respectively construct synthetic controls and match them to these three "pseudo-treated" countries before 1999. The set of eligible countries in the donor pool includes 11 EU countries that adopted the euro system in 1999[6].

Table 6 presents a numerical comparison between each "pseudo-treated" country and its synthetic counterfactual counterpart. For all three countries, we find that the average of (the log of) per capita GDP over the years before 1999, when the euro was launched, tracks closely with that based on the synthetic control unit, with RMSPE values all around 0.01. In addition, Table 7 reveals the weights used to construct the counterfactuals for each "pseudo-treated" country. In addition, Figure 5 graphically presents the SCM results (upper panel) and their corresponding placebo experiments (lower panel). Again, the solid line represents the realized path of per capita GDP of the "pseudo-treated" country and the dashed line outlines that of the synthetic counterpart made up of the countries in the control pool. As such, the dashed pattern denotes what would happen if these "pseudo-treated" countries were to adopt the euro. First, by focusing on the case of Denmark, we find that Denmark would be better off if it were to adopt the euro as the dashed line is higher than the solid line after the euro system was adopted in the euro zone (1999). In addition, the corresponding placebo test shows that this growth-enhancing effect of adopting the euro for Demark is statistically significant. As to the cases of Sweden and the UK, we can find that the economic performance of these two economies has either not changed much or is slightly worse right after the adoption of the euro in 1999. However, their robust economies seem to adjust well to the shocks a few years later as the solid lines are higher than the dashed lines in later years. The corresponding placebo tests also show that the shock resulting from the adoption of the euro is not statistically significant right after 1999, and not adopting the euro makes Sweden and the UK better off later, especially after 2010, when the sovereign debt crisis occurred.

4.4. Additional Discussion

Our results from the SCM algorithm show that adopting the euro generally results in low per capita GDP in the core countries and high per capita GDP in the peripheral countries, compared with what would be the case if they did not adopt the euro system. However, the results from further placebo tests indicate that the economic impact of adopting the euro is not statistically significant, neither in the core countries nor in the peripheral countries. These outcomes are contrary to those of Conti [19] who applies a DID cross-country analysis and concludes that adopting the euro may have raised the per capita GDP of countries joining this common currency union. Such cross-country estimators usually suffer from the endogeneity problem and, thus, are likely to result in biased estimations. In addition, cross-country studies that draw their conclusions based on averaging the data usually ignore the heterogeneous experiences and circumstances faced by different countries and, hence, generate no reliable inferences for the concerned individual countries. As such, we believe that our country-specific case studies may be a better alternative for this strand of the research.

With respect to the core countries, we find that five of the six countries are founding states of the EU (Austria became a member in 1995). These six countries make up most of the central Europe. Badinger [25] showed that these core countries would have a higher GDP per capita

[6] These countries are Luxembourg, the Netherlands, Austria, Germany, Belgium, France, Ireland, Italy, Finland, Spain, and Portugal.

having joined the EU. However, our SCM results show that they do not gain any further significant economic benefit from forming a common currency union. As such, we infer that forming a common currency union enables these core countries to pursue political objectives, such as engaging in supranational cooperation to compete with the USD and become a weighted currency in the special drawing rights of the IMF to prevent individual currencies from being marginalized in the world market, rather than seeking economic benefits.

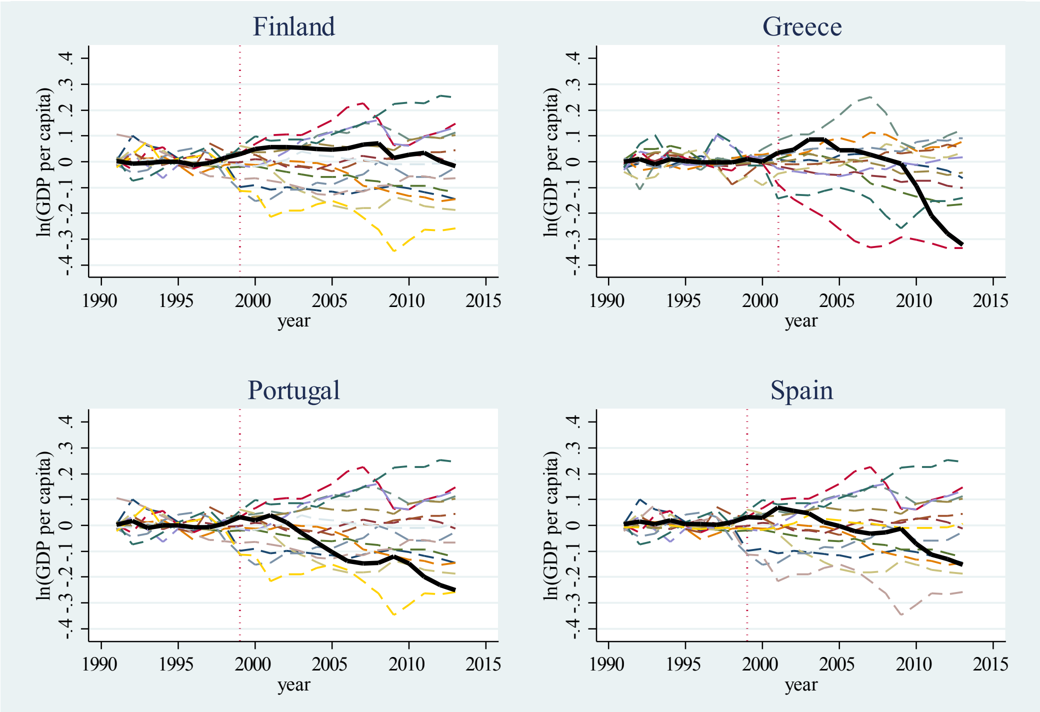

Figure 4. Placebo experiments for peripheral countries (excludes countries with an RMSPE value ten times higher than that of the target country)

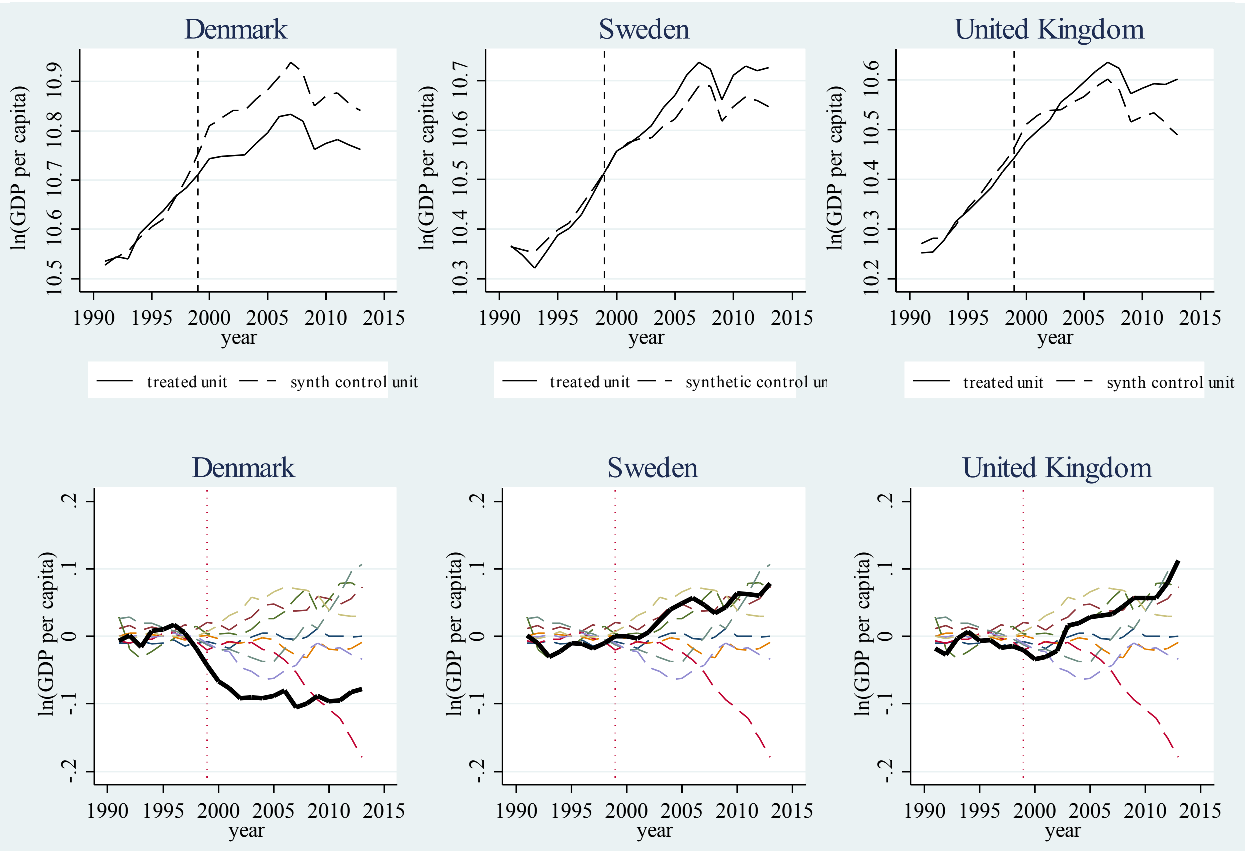

Figure 5. SCM results for non-euro countries (the log of GDP per capita) and placebo experiments (excludes countries with an RMSPE value five times higher than that of the target country)

Table 6. Means of the Covariates (GDP per capita)

	Denmark (1999)	
Variables	**Treated**	**Synthetic**
Secondary school	4.7477	4.4552
Openness	4.2286	4.6263
Investment	2.9689	2.9719
Population	0.0039	0.0076
GDP per capita (1991)	10.5280	10.5345
GDP per capita (1995)	10.6154	10.6052
GDP per capita (1998)	10.6846	10.7025
RMSPE	0.0118	
	United Kingdom (1999)	
Variables	**Treated**	**Synthetic**
Secondary school	4.5792	4.4934
Openness	3.9232	4.0836
Investment	2.9269	2.9667
Population	0.0027	0.0030
GDP per capita (1991)	10.2519	10.2699
GDP per capita (1995)	10.3366	10.3432
GDP per capita (1998)	10.4146	10.4294
RMSPE	0.0098	
	Sweden (1999)	
Variables	**Treated**	**Synthetic**
Secondary school	4.5792	4.4934
Openness	3.9232	4.0836
Investment	2.9269	2.9667
Population	0.0027	0.0030
GDP per capita (1991)	10.2519	10.2699
GDP per capita (1995)	10.3366	10.3432
GDP per capita (1998)	10.4146	10.4294
RMSPE	0.0098	

† The table shows the mean values of the covariates. The outcome variable is the log of GDP per capita. For detailed definitions of these covariates, please refer to the section entitled "Data Sources and Description."

Table 7. Weights in Each Synthetic Country (GDP per capita)

Control Countries	Denmark	United Kingdom	Sweden
Austria	0	0	0
Belgium	0	0	0
Finland	0	0	0.314
France	0	0	0
Germany	0	0	0.335
Ireland	0.133	0.175	0
Italy	0.373	0.713	0.187
Luxembourg	0.494	0.113	0.165
Netherlands	0	0	0
Portugal	0	0	0
Spain	0	0	0

†Three "pesudo- countries" that introduced the euro are presented in the first row. Control group countries are presented in the left-hand column. For example, the table indicates that synthetic "pseudo" Denmark consists of 13.3% Ireland, 37.3% Italy, and 49.4% Luxembourg. The weights in each column add up to one.

As to the peripheral countries, one can find that they all are small economies that to a large degree depend economically on larger economies. As such, relying upon the EU and joining the monetary union to benefit from the free trade bloc and eliminate fluctuations in the exchange rate are very important to them[7]. During the first two postwar decades, peripheral countries encountered some economic shocks, such as cost-push inflation during the 1960s, the collapse of the Bretton Woods fixed exchange rate system, and a quadrupling of oil prices in the 1970s. To overcome these economic obstacles that hindered the prosperity of the domestic economies, these countries sought greater cohesion [26]. By using SCM analysis, Campos et al. [27] conclude that peripheral countries benefited from membership in the EU. However, our SCM analysis shows that the benefits accruing to the peripheral countries from joining the monetary union are not that significant.

The results of the inverse SCM analysis for the three countries that did not adopt the euro show that Denmark would have been better off if it had joined the euro system. However, for Sweden and the United Kingdom, not adopting the euro system could have been a better choice for them, especially following the sovereign debt crisis. These three non-euro countries opted not to adopt the euro through referenda, yet their outcomes regarding the decision not to adopt the euro are quite different. Why is this so? We think the differences depend on the economic structure and the degree of openness of these three economies. For instance, Denmark, with the most frontier technology in the agricultural and green-tech sectors, exports most of its agricultural products and green-tech equipment to euro zone countries. As such, the decision not to adopt the euro could largely impair its economic performance. On the other hand, the economies of Sweden and the UK are more globally oriented. For example, Sweden has world-famous wood furnishings and industrial sectors while the UK has a world-class financial center in the City of London. They do business with countries within Europe as well as outside Europe. As such, not joining the monetary union does not greatly impair their economies. In addition, not adopting the euro can enable them not only to maintain their sovereignty over their monetary policy, but also to avoid market risk induced by the euro.

5. Conclusion

This study reinvestigates the impact of joining a common currency union on the per capita GDP of 12 countries that have adopted the euro. By employing a recently developed synthetic control approach, we conduct a data-driven comparative case study over the period 1991–2013. For analytical purposes, we classify these 12 countries into two groups: core and peripheral countries. The results from the SCM algorithm show that the patterns of per capita GDP in the core (peripheral) countries are generally lower (higher) than those of their counterfactual units. However, the outcomes of the placebo tests indicate that these differences are statistically insignificant, thus delivering no strong evidence to show that adopting the euro system will have a significant impact on the overall economic performance of these 12 euro-adopting countries. In addition, we also construct an inverse SCM algorithm to assess whether Denmark, Sweden, and the United Kingdom, the three conventional EU members, would be better off if they were to join the euro system. The results of the inverse SCM show that

[7] Luxembourg was the founder, Ireland joined in 1973, Greece, Portugal, and Spain in the 1980s, and Finland in 1995.

Denmark would be better off if it were to adopt the euro, but for the cases of Sweden and the United Kingdom, not adopting the euro system may be a better choice for them. The formation of a common internal market is likely the cornerstone of European integration and Campos et al. [27] have substantiated the economic gains from forming such a common market in Europe. Introducing a common currency system is the last piece to complete the fully integrated European market—for political, historical and economic reasons—and our results indicate that the former two factors may outweigh the last one.

References

[1] Mundell, R. (1961). "A Theory of Optimal Currency Areas." *American Economic Review*, 51: 657-65.

[2] Rose, A.K. and Stanley, T.D. (2005). "A Meta-Analysis of the Effect of Common Currencies on International Trade." *Journal of Economic Surveys*, 19:341-365.

[3] Flam, H. and Nordström, H. (2003). "Trade Volume Effects of the Euro: Aggregate and Sector Estimates." Institute for International Economic Studies, Stockholm University.

[4] Micco, A., Stein, E. and Ordonez, G. (2003). "The Currency Union Effect on Trade: Early Evidence from EMU." *Economic Policy*, 37: 315-356.

[5] Faruqee, H. (2004). "Measuring the Trade Effects of EMU." International Monetary Fund, WP No. 04/154.

[6] Bun, M. and Klaassen, F. (2007). "The Euro Effect on Trade is not as Large as Commonly Thought." *Oxford Bulletin of Economics and Statistics*, 69: 473-496.

[7] Eichengreen, B. and Boltho, A. (2008). "The Economic Impact of European Integration." Centre for Economic Policy Research, DP No. 6820.

[8] Camarero, M., Gomez, E. and Tamarit, C. (2013). "EMU and Trade Revisited: Long-Run Evidence Using Gravity Equations." *The World Economy*, 36: 1146-1164.

[9] Santos Silva, J.M.C. and Tenreyro, S. (2010). "Currency Unions in Prospect and Retrospect." *The Annual Review of Economics*, 2: 51-74.

[10] Figueiredo, E., Lima, L.R. and Schaur, G. (2016). "The Effect of the Euro on the Bilateral Trade Distribution." *Empirical Economics*, 50:17-29.

[11] Bartram, S.M. and Karolyi, G.A. (2003). "The Impact of the Introduction of the Euro on Foreign Exchange Rate Risk Exposures." Unpublished Working Paper, Ohio State University.

[12] Galati, G. and Tsatsaronis, K. (2001). "The Impact of the Euro on Europe's Financial Markets." Bank for International Settlements, WP No. 100.

[13] Danthine, J.P., Giavazzi, F. and Thadden, E. (2000). "European Financial Markets after EMU: A First Assessment." National Bureau of Economic Research, WP No. 8044.

[14] Cappiello, L., Hordahl, P., Kadareja, A. and Manganelli, S. (2006). "The Impact of the Euro on Financial Markets." European Central Bank WP No. 598.

[15] Hardouvelis, G., Malliaropulos, D. and Priestley, R. (2004). "The Impact of Globalization of the Equity Cost of Capital." Centre for Economic Policy Research, DP No. 4346.

[16] Bris, A., Koskinen, Y. and Nilsson, M. (2003). "The Euro Is Good After All: Evidence from Corporate Valuations." Centre for Economic Policy Research, DP No. 3910.

[17] Bris, A., Koskinen, Y. and Nilsson, M. (2006). "The Real Effects of the Euro: Evidence from Corporate Investment." Review of Finance, 10: 1-37.

[18] Bris, A., Koskinen, Y. and Nilsson, M. (2009). "The Euro and Corporate Valuations." *The Review of Financial Studies*, 22: 3171-3209.

[19] Conti, M. (2014). "The Introduction of the Euro and Economic Growth: Some Panel Data Evidence." *Journal of Applied Economics*, 17: 199-212.

[20] Dubois, E., Hericourt, J. and Mignon, V. (2009). "What if the Euro Had Never Been Launched? A Counterfactual Analysis of the Macroeconomic Impact of Euro Membership." *Economics Bulletin*, 29: 2241-2255.

[21] Abadie, A. and Gardeazabal, J. (2003). "The Economic Costs of Conflict: A Case Study of the Basque Country." *American Economic Review*, 93: 113-132.

[22] Abadie, A., Diamond, A. and Hainmueller, J. (2010). "Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program." *Journal of the American Statistical Association*, 105: 493-505.

[23] Billmeier, A. and Nannicini, T. (2013). "Assessing Economic Liberalization Episodes: A Synthetic Control Approach." *Review of Economics and Statistics,* 95: 983-1001.

[24] Zipfel, F. (2012). "The Impact of Tax Systems on Economic Growth in Europe." Deutsche Bank DB Research, Oct. 5, 2012, https://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD0000000000295266.pdf.

[25] Badinger, H. (2005). "Growth Effects of Economic Integration: Evidence from the EU Member States," *Review of World Economics*, 141: 50-78.

[26] Mayne, R. (1986), *WESTERN EUROPE,* Facts on File Publications, pp. 336-458.

[27] Campos, N.F., Coricelli, F. and Moretti, L. (2014). "Economic Growth and Political Integration: Estimating the Benefits from Membership in the European Union Using the Synthetic Counterfactuals Method." IZA DP No. 8162.