LaRGE Research Center

Working Paper 2023-01

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March 2023

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March 6, 2023

Abstract

This paper investigates whether Denmark, Sweden and the UK made the right choice in giving up the euro by examining the consequence of this decision on their GDP per capita. We use the synthetic control approach to create a counterfactual scenario of how their GDP per capita would have behaved if they had joined the euro area. Our estimates suggest that only Denmark would have benefited from the adoption of the euro. In contrast, for Sweden and the UK, until 2010, the euro would have had a zero or negligible positive effect on their GDP. From 2010 onwards, however, we observe a significant divergence between their GDP and the counterfactual, revealing that both countries would have lost out with the euro. Still, this effect is more significant for Sweden than for the UK.

Keywords: *Euro, per capita income, synthetic control method*
JEL classification: *F15, F33, N14, O52*

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‡This research did not receive any specific grant from funding organisms in the public, commercial or not-for-profit sectors.

1 Introduction

With the accession of Croatia in January 2023, the euro area now consists of twenty member countries. The question of the economic implications of the euro for the countries that have adopted it has been widely discussed in the field of international monetary economics. But what about the other countries, i.e. those that are (or were) members of the European Union but have decided not to join the euro? This article focuses on the economic consequences of their decision to stay out of the euro find out whether they made or not the right choice.

According to the Maastricht Treaty, all European Union (EU) member countries are required to adopt the single currency if they meet the convergence criteria. Three countries that are (or were) members of the EU however decided not to comply with this rule. This is the case of Denmark, which joined the European Economic Community in 1973. Following the rejection of the Maastricht Treaty in a referendum in 1992, the country negotiated a derogation allowing it to retain the exclusive use of the Danish krone. The United Kingdom (UK) also exercised its right not to join the single currency in 1997 despite having ratified the Maastricht Treaty. The third country, Sweden, which only joined the EU in 1995, has a de facto opt-out as it is not part of the exchange rate mechanism (ERM), which is one of the convergence criteria. The population rejected the single currency in a referendum in 2003.

So far, there is no direct evidence on whether these three countries have economically benefited or lost from their decision to stay out of the euro. This paper provides estimates of the effect of this decision on their per capita income. In doing so, it contributes to the debate on the economic effects of the euro through a new angle, that of the countries that are (or were) part of the EU but have decided not to participate to the European Monetary Union (EMU).

Several papers have provided estimates of the economic consequences of not adopting the euro. For example, Frankel and Rose (2002) suggest that non-EMU countries would have experienced an increase in per capita income of about 20% if they had adopted the euro. Barr et al (2003) are less optimistic about the benefits of the single currency. They show that for the UK, the impact on its GDP would have been no more than 0.3% per annum and less than that for other countries that opted out. According to Pesaran et al (2007), the UK, Sweden and all euro area countries would probably have experienced higher GDP if the UK or Sweden had joined the monetary union. However, except for Sweden, these gains would have been relatively small.

Despite the instructive insights provided by these papers, no definitive conclusion has been reached so far. In this paper we use a novel, non-parametric technique to provide an estimate of the GDP per capita that there would have been in Denmark, the UK and Sweden had these countries adopted the euro like their partners in the EU. A positive difference between the estimate and these countries' actual GDP per capita suggests that their decision not to adopt the euro came at a cost and vice versa. To obtain our estimates of the per capita income that would have been obtained in Denmark, Sweden and the UK (henceforth DSU) if they had joined the euro, we use the synthetic control method (SCM) pioneered by Abadie and Gardeazabal (2003) and further developed by Abadie et al. (2010). This method consists in constructing, for each of these countries, a robust counterfactual capable of reproducing their per capita income before the introduction of the euro. The counterfactual is constructed as a weighted combination of eurozone countries where the weights are chosen to minimise the difference between DSU's actual GDP and its synthetic counterpart. Comparing the evolution of DSU's actual GDP and its synthetic counterpart after the introduction of the euro then allows us to determine whether their decision not to adopt the euro was wise or not.

Several papers use the SCM to study the effects of the euro. Saia (2017), for example, examines the impact of the euro on trade flows. Like us, he considers this impact from the perspective of a country that has decided not to join the EMU, the UK. In particular, he shows that trade flows between the UK and eurozone members would have been 16% higher if the UK had adopted the euro. Puzzello and Gomis-Porqueras (2018) and Gabriel and Pessoa (2020) study the effects of the euro on real GDP in the countries that adopted it. Both papers identify the same losers (Belgium, France, Germany and Italy) and a clear winner (Ireland), which argues for the robustness of the SCM. Our analysis differs from theirs in two respects: first, we examine the effects of the euro on real GDP from the perspective of those EU countries that remained outside EMU; second, our study does not stop in 2007 but covers a longer period that takes into account the potential effects of the global financial and Eurozone crises. It seems appropriate to consider this crisis period because it allows us to identify the costs of the single currency, namely the loss of monetary policy as a means of dealing with this type of shock. Using the SCM over a long period from 1999 to 2017, Gasparotti and Kullas (2019) find that Greece benefited enormously from the euro in the first years after its introduction, but since 2011 has suffered huge losses. This result is in line with the findings of Verstegen et al (2017). Indeed, they suggest that although Greece, Portugal and Spain experienced the greatest benefits from EMU participation in the pre-crisis period, they would have been better off had they not been EMU members during the crisis.

For those EU countries that decided not to join the euro, our results show that in the first years after the adoption of the euro (from about 1999 to 2010), the trend in the observed GDP per capita and its synthetic counterpart diverge only in Denmark, which would have benefited from euro adoption. In contrast, for the UK and Sweden, before 2010, their renunciation of the euro appears to have had no or very little negative effect on their income. It is only from 2010 onwards - coinciding with the onset of the European sovereign debt crisis - that we observe a significant divergence between their observed GDP and the counterfactual, revealing that they would have lost out with the euro. Hence, not being a member of the euro area during this period of crisis appears to have benefited these countries. This effect is stronger in Sweden than in the UK.

The rest of the paper is organized as follows. Section 2 presents the synthetic control method and the data we use. Section 3 discusses our estimates of the income gains and losses from the euro renunciation and their robustness. Section 4 concludes.

2 Estimating the effects of staying out of the euro

Our objective is to evaluate the consequences in terms of per capita income of the choice of Denmark, Sweden and the United Kingdom (UK) not to adopt the euro. To do so, we need to compare the evolution of the per capita income of these countries with what it would have been if they had chosen to adopt the euro in 1999. This raises the question of how to assess the evolution of these countries' per capita income had they also joined the monetary union.

A simple method would be to arbitrarily select a country among the monetary union members and designate it as the counterfactual of the country under study (Denmark, Sweden or UK). However, this approach raises several questions. Which country in the monetary union (MU) should we choose as the counterfactual for the country under study? The solution would be to choose the MU country whose economic aggregates are most representative of those of the country studied. Is it possible to find such a country? Although the European countries are highly integrated, resulting in a certain degree of economic convergence, their demographic, social and economic characteristics remain very different. The selection would necessarily be arbitrary.

This is why we use the synthetic control method (SCM), which allows us to carry out a counterfactual study with robust analytical tools.

2.1 The SCM approach

Instead of arbitrarily selecting a counterfactual unit from the eurozone countries, the SCM approach consist of constructing a synthetic counterfactual, or clone, of the country under study (here, Denmark, Sweden or UK) as a weighted combination of countries belonging to a donor pool (or control group). This pool includes the eleven original eurozone countries, namely Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.[1] The weights of these countries in the clone are chosen so that the clone most closely resembles the behavior of the country studied before the introduction of the euro. In addition to its ability to evaluate counterfactual events, this method has the advantage of explicitly measuring the contribution of each donor country.

Once we have obtained the synthetic counterfactual, we can assess the effects of the euro renunciation on the economic activity of the countries studied by comparing the evolution of their observed income per capita with the estimated income per capita of their clone. Formally, this comparison refers to the difference:

$$\alpha_{i,t} = Y_{i,t} - Y_{i,t}^C \tag{2.1}$$

where $Y_{i,t}$ represents the observed GDP of country i in period $t = T_0+1, ..., T$; index i refers to the country under study which is either Denmark, Sweden or UK (hereafter D, S and UK respectively) and T_0 is the date of introduction of the euro (1999). Variable $Y_{i,t}^C$ stands for the estimated GDP of country i's clone in period t.

[1] We have excluded from this pool Cyprus, Estonia, Greece, Latvia, Lithuania, Malta, Slovakia and Slovenia because they adopted the euro after 1999.

To determine $Y_{i,t}^C$, we use the SCM developed by Abadie and Gardeazabal (2003) and Abadie et al. (2010). The estimated GDP of country i's clone then corresponds to:

$$Y_i^C = \sum_{j=1}^{11} w_j^* Y_j \tag{2.2}$$

where w_j^* is the estimated weight assigned to donor country $j = 1, ..., 11$.

The weights w_j^* are chosen to minimize the difference between the characteristics of the country studied i and those of its clone during the pre-euro period (i.e. for $t = 1, ..., T_0$). More precisely, let X_i denote a $((r + k) \times 1)$ vector of characteristics containing r predictors of country i's GDP and k lags of country i's pre-euro GDP. We also define X_D as a $((r+k) \times J)$ matrix that contains the same pre-euro economic characteristics for each of the J donor countries (here the J donor countries are the 11 countries that adopted the euro in 1999).

W^*, the optimal $(J \times 1)$ vector of weights w_j^* (for $j = 1, ..., 11$) is then obtained by minimizing the difference between the pre-euro characteristics of country i and those of the J countries in the donor pool. Note that the sum of these weights is equal to one.[2] Formally, W^* minimizes the following expression:

$$(X_i - X_D W^*)' V (X_i - X_D W^*) \tag{2.3}$$

where V is a $((r+k) \times (r+k))$ is a diagonal positive semi-definite matrix that contains non-negative weights assigned to each of the $r + k$ pre-euro characteristics (r predictors of country i's GDP and k lags of country i's pre-euro GDP) according to its importance in explaining $Y_{i,t}$, the evolution of country i's GDP. These weights are normalized to sum to one for identification purposes.

By solving this minimization problem, we obtain the vector $W^*(V)$ of the J donor countries' optimal weights that depend on the weights of matrix V. To determine the latter, it is necessary to minimize the Mean Square Prediction Error (MSPE) of country i's GDP in the pre-euro period :

$$\frac{1}{T_0} \sum_{t=1}^{T_0} (Y_{i,t} - \sum_{j=1}^{11} w_j^* Y_{j,t})^2 \tag{2.4}$$

[2]This condition guarantees that the inference allowed by the method remains within the convex hull and excludes any extrapolation and ensures interpolation. This avoids the issues raised by King and Zeng (2006).

Thus, country i's clone is defined as a weighted combination of the initial 11 euro area countries (donor countries). The weight of each of these countries depends in turn on the weights assigned to each pre-euro characteristic according to its importance in explaining the evolution of country i's GDP.

2.2 Description of the data

Our analysis of the effects of the renunciation of the euro is conducted on three countries: Denmark, the UK and Sweden. While Denmark and the United Kingdom joined the European Community (EC) in 1973, Sweden only became a member of the European Union (EU) in 1995, i.e. after the entry into force of the Maastricht Treaty in 1993, which laid the foundations for the creation of the euro. Nevertheless, we decide to keep Sweden in our study since its accession to the EU implied its entry into the eurozone as soon as it met the Maastricht criteria. One of the criteria for entry into the eurozone is to be a member of Exchange Rate Mechanism (ERM) II for at least two years. Yet, Sweden has decided not to join ERM II, and therefore not to adopt the euro. Moreover, although Sweden only became part of the EU in 1995, it was closely integrated with other EU countries well before that. Campos et al. (2019) showed that its entry into the EU in 1995 had little impact on its GDP. It can therefore be assumed that its accession to the EU in 1995 has not led to a massive structural change, exposing it to a shock compared to the other European countries in the control group.

The latter is limited to the 11 countries that adopted the euro in 1999. To the extent that we are constrained by the composition of our control group and cannot change its nature, as for example Puzello and Gomis-Porqueras (2018) do, we test the robustness of our results to the identity of the donor countries that enter the control group by implementing a leave-one-out analysis. This robustness test is carried out in section 3.2. It simply consists of removing one by one the donors that compose the control group and measuring the impact that this removal has on the results obtained.

Our data range from 1975 to 2019.[3] The variable of interest is real GDP

[3]Unlike Puzello and Gomis-Porqueras (2018) and Gabriel and Pessoa (2020), we do not stop our analysis at the 2008's Great Financial Crisis. Indeed, in order to construct clones of the countries under study, i.e. EMU member countries, these authors use countries outside the EU where the crisis may have had a different structural impact, thus reducing

per capita in Local Currency Unit (LCU). In order to perform a satisfactory study using the SCM, the variable of interest in the country under study must have similar dynamics to those of the control group countries. Therefore, to avoid extreme values in the variable of interest for the country under study, we decided to index real GDP per capita in LCU to the unit in 1995. The real GDP per capita data we use come from the World Bank national accounts data and the OECD national accounts data files.

Figure 1 reports real GDP per capita indexed to the unit in 1995 for the three countries studied and the donor countries. As can be seen, the countries in the control group (with the exception of Ireland) are economically close to the countries studied. Moreover, the GDP of the latter is neither the highest nor the lowest, which suggests that the set of control countries should allow for the construction of an appropriate clone.

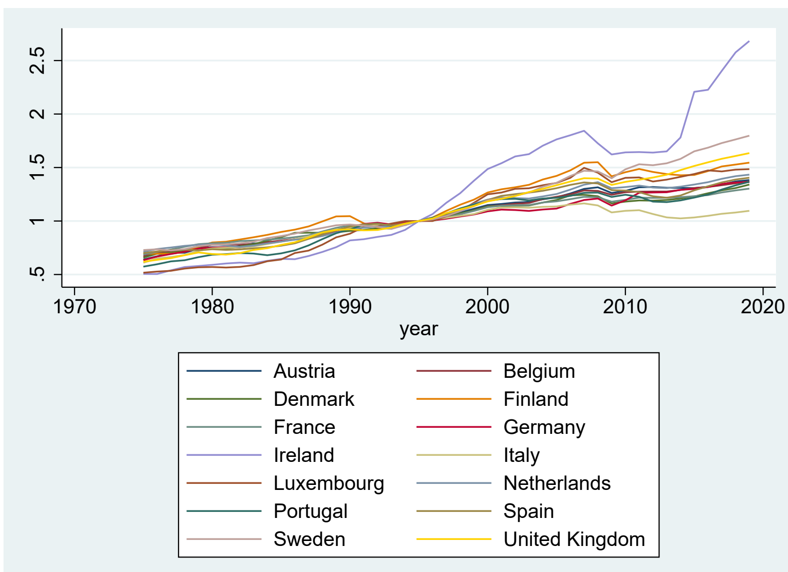

Figure 1: GDP per capita (constant LCU) - normalized to 1 in 1995.
Source: World Bank national accounts data, and OECD National Accounts data files. The indexation of the original series is authors' calculations.

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the ability of the clones to reproduce the dynamics of the countries under study. Since in our analysis, the countries studied and those in the control group are all part of the EU, we can assume that the crisis affected them in the same way and that the clones remain relevant to describe the dynamics of the countries studied even after the crisis.

The pre-euro characteristics in vector X_i were chosen to most closely replicate the economic activity dynamics of the countries studied. They include 14 predictors of country i's GDP and 2 lagged values of its pre-euro GDP in 1990 and 1998 to capture the influence of omitted variables in the model. We rely primarily on two databases: the New Generation Penn World Table, as described by Feenstra et al. (2015), and data made available by the Word Bank.[4]

The predictors used to replicate the dynamics of country i's GDP can be classified into four broad categories:[5]

First, on the demand side, following in particular Abadie et al. (2010), we incorporate predictors on public spending, private consumption, investment and the current account balance.

Specifically, we consider the *General Government final consumption Expenditure* as a percentage of GDP. We also include two measures of private household consumption. The first is *private Consumption Expenditure* as a percentage of GDP. The series is constructed by us from the Word Bank on final consumption expenditure and public consumption expenditure. The second measure of private household consumption is the Penn World Table's *Share of Household Consumption* in current PPP. Private investment is taken into account thanks to the *Gross fixed capital formation* as a percentage of GDP while the current account balance as a percentage of GDP is obtained from our own computation using the World Bank series.

Supply-side predictors consist of a measure of *Labor Productivity Growth* - calculated by taking the log difference between Real GDP in national prices (in million 2017 US$) and total employment - and a measure of *Total Factor Productivity* at constant national prices. We also take into account the level of employment by integrating the World Bank's Employment to Population Ratio.

[4] See respectively Penn World Table (PWT 10.0) - https://www.rug.nl/ggdc/productivity/pwt/ and https://databank.worldbank.org/.

[5] As mentioned in Verstegen et al. (2017), the term "predictor" is not related to a causal relationship between GDP and these variables. It simply means that we use the pre-euro values of these variables to find a clone of country i that estimates the path of its GDP if it had adopted the euro in 1999.

In order to account for the impact of human capital on economic growth, we also include measures of public spending on education in our predictors. Specifically, we use the general measure of *Government expenditure on education* as a percentage of GDP as well as measures on *Expenditure on Primary Education, Expenditure on Secondary Education* and *Expenditure on Tertiary Education* as a percentage of government expenditure on education provided by the UNESCO Institute for Statistics.[6]

Finally, we also consider two monetary predictors in order to take account of the impact of the euro on economic growth: the *Consumer Price Index* (2010 = 100) and the *Real Effective Exchange Rate index* (2010 = 100) of the International Monetary Fund.

Table 2 in the appendix reports the data source for each predictor as well as its notation. Note that the value of these predictors that is used to construct the clone corresponds to their average over the period (1985 - 1998).

The choice of these predictors is standard in the SCM literature. They will be judged relevant according to the quality of the clone they produce. In section 3.3, we propose different robustness tests to measure the sensitivity of our results to the choice of predictors as well as to the choice of the two lagged GDP values.

3 Results

3.1 On the nature of the clones

Column 1 in Tables 3 to 5 in the appendix displays the baseline results for each country i. The first row of this column presents the composition of country i's clone with the weight of each donor country.

It can be seen that the clones are composed of three to six countries. Finland and the Netherlands always have a positive weight, while Belgium, France, Portugal and Spain do not appear in any baseline clone.

[6]See http://uis.unesco.org/.

The weights of each characteristic (predictors and lagged values of real GDP per capita) in the composition of the clones are presented in table 6 in the appendix.

The synthetic counterpart of each country i ($i = D, S, UK$) is constructed based on the donor countries' weights and those of the pre-euro characteristics. Figure 2 shows the trends in real GDP per capita of Denmark, Sweden and United-Kingdom and their synthetic counterpart. We observe that during the pre-euro period (1975 to 1998), the trajectory of real GDP per capita of the three countries studied corresponds very closely to that of their synthetic counterpart.

Before commenting further on these results, the relevance of the generated clones should be assessed. For this purpose, a first evaluation consists in assessing the capacity of the clone to replicate the original predictors. Table 7 in the appendix compares the pre-euro characteristics (predictors and lagged values of real GDP per capita) of each country with those of its synthetic clone. Overall, we can see that the clones are globally successful in replicating the predictor series.

While this first result of measuring clone quality is satisfactory, it is not sufficient. The quality of our clones can be measured more precisely using two indicators: the Root Mean Squared Prediction Error (RMSPE) and Cohen's D. While the SCM literature often uses only the RMSPE, we choose to complement it with Cohen's D. The reason is that, for the latter, the literature establishes clear thresholds for determining whether the ability of the clone to reproduce the original series is satisfactory or not.

Concerning the RMSPE, it measures the average difference between the actual per capita income of country i and its synthetic counterpart. Therefore, the lower the RMSPE in the pre-euro period, the better the quality of the clone. From expression (2.1), the pre-euro RMSPE for country i can be defined as follows:

$$RMSPE_pre = \sqrt{\frac{1}{T_0}\sum_{t=1}^{T_0}\left(Y_{i,t} - \sum_{j=1}^{11} w_j^* Y_{j,t}\right)^2} \tag{3.1}$$

The value of the pre-euro RMSPE for the three countries can be found in the second row of the first column in Tables 3 to 5 in the appendix. The pre-euro RMSPE of Sweden and the UK are quite low, suggesting a good quality of the clone. Denmark's pre-euro RMSPE however is somewhat higher. Indeed, as can be seen in Figure 2, the Danish counterfactual reproduces the country's observed GDP less well than that of the UK and Sweden, but is still of good quality.

As for Cohen's D, following Cohen (2013), we calculate it with te expression:

$$d = \frac{\bar{Y}_{i,t} - \bar{Y}_{SC,t}}{\sigma^*} \tag{3.2}$$

where $\bar{Y}_{i,t}$ and $\bar{Y}_{SC,t}$ represent respectively the average GDP per capita and the average synthetic GDP per capita during the pre-euro period and σ^* is the standard deviation of the series. Namely,

$$\sigma^* = \sqrt{\frac{(n_i - 1)\sigma_{i,t}^2 + (n_{SC} - 1)\sigma_{SC,t}^2}{n_i + n_{SC} - 2}} \tag{3.3}$$

where $\sigma(.)$ is the standard deviation of a particular group (i is for the country under study and SC for its synthetic counterpart) and $n(.)$ is the number of observation of this particular group. The main advantage of the Cohen's D is that we can find significance thresholds in the literature. Thus, we know that a $d = 0.2$ reflects a small difference between the dynamics of the observed variable of interest and its synthetic counterpart while a $d = 0.5$ reflects a medium difference and a $d = 0.8$, a large difference.

The table below displays Cohen's D for the three countries while the RMSPE can be found in tables 3 to 5.

	Denmark	Sweden	United Kingdom
Cohen's D[7]	.047967	.02732521	.00436583

Table 1: Cohen's D

Thus, whatever measure is chosen, these results confirm the idea already put forward above that the dynamics of the clones closely resemble those of the three countries studied.

[7]The table displays the absolute values of Cohen's D.

3.2 Staying out of the euro: good or bad strategy?

Once the clone is constructed and its quality confirmed, we can use it to examine the effects of the euro renunciation on the countries' income. A first glance at the graphs displayed in figure 2 reveals that in the early post-euro years (from 1999 to around 2010), displayed in figure 2 reveals that in the early post-euro years (from 1999 to around 2010), the trend in real GDP per capita and its synthetic counterpart diverge only in Denmark, which would have benefited from adopting the euro. In contrast, for the UK and Sweden, before 2010, their renunciation of the euro appears to have had no or very little negative effect on their income. It is only from 2010 onwards - coinciding with the onset of the European sovereign debt crisis - that we observe a significant divergence between their real GDP and the counterfactual, revealing that the UK and Sweden would have lost out with the euro. Clearly, not being a member of the euro area during this period of crisis appears to have benefited these countries.

In order to confirm the quantitative impact of the renunciation of the euro, we calculate the χ ratio, which compares the post-euro RMSPE with the pre-euro RMSPE. Indeed, since the RMSPE provides a measure of the difference in the variable of interest between each country studied and its synthetic counterpart, the comparison of its post-euro value with its pre-euro value allows us to assess the importance of the effects of the euro renunciation. The higher the absolute value of the χ ratio, the greater the impact on income of not participating in the euro.

The χ ratio is defined as follows:

$$\chi \equiv \frac{RMSPE_{post}}{RMSPE_{pre}} = \frac{\sqrt{\frac{1}{T-T_0+1}\sum_{t=T_0+1}^{T}\left(Y_{i,t}-\sum_{j=1}^{11} w_j^* Y_{j,t}\right)^2}}{\sqrt{\frac{1}{T_0}\sum_{t=1}^{T_0}\left(Y_{i,t}-\sum_{j=1}^{11} w_j^* Y_{j,t}\right)^2}} \tag{3.4}$$

The third row of tables 3 to 5 reports the χ ratio for the three countries. For instance, Denmark's χ ratio implies that its post-euro RMSPE is 5.266 times larger than its pre-euro RMSPE. Sweden's χ ratio is quite high, due to both, a low pre-euro RMSPE and a high post-euro RMSPE. Denmark's relatively low χ ratio can be explained by a high pre-euro RMSPE which has already been discussed in section 3.1. On the other hand, the UK's relatively low *chi* ratio seems to be due, not to a high pre-euro RMSPE – the match between the country and its clone in the pre-euro period is quite satisfactory – but rather to a low post-euro RMSPE, suggesting a low income effect of its non-participation in the euro.

3.3 Placebo tests

Without any reference value for the χ ratio, we cannot draw any conclusions as to the significance of the effects of the euro renunciation. Therefore, we need to complement our χ ratio analysis with placebo tests. They consists in reassigning the treatment - here, the renunciation of the euro - to a date other than 1999 (in time placebo) and to countries that have actually adopted the euro (in space placebo). If these estimated placebo effects are not larger than those we obtained in the baseline results for Denmark, UK and Sweden, we can be confident that the gap between the actual and the counterfactual per capita income observed for these three countries are caused by their renunciation of the euro.

3.3.1 In space placebo

We first conduct *in-space placebo* tests which consist of replicating the SCM to any of the countries that form the donor pool of country i. In doing so, we act as if each of these donor countries had renounced to the euro in 1999. We can thus study the effects of this fictitious renunciation and compare them to the effects of country i's renunciation highlighted in section 3.2. If these latter are larger than any of the synthetic estimated effects of country i's donor countries, we can reasonably consider that the effects of country i's euro renunciation are significant. On the contrary, obtaining similar results would then invalidate our baseline results.

Figure 3 in the appendix shows the difference between the synthetic and actual GDP per capita for country i in black (for $i = D, S$ and UK) and their placebo countries in grey.

The results demonstrate that before 1999, the gap between each country studied and its synthetic clone is smaller than a similar gap for most placebo states. After 1999, the gap between the per capita GDP of each synthetic and actual country i becomes larger in magnitude than the gap for most placebo states. Finally, the small gap before 1999 and the large gap after

1999 strongly suggest that the renunciation of country i to the euro had a significant impact on its GDP per capita.

For more precision, we complete this graphical analysis by a second step of our in-space placebo experiment which consists in calculating the χ ratio of each placebo states and comparing it with the one obtained by country i. This is done in tables 8 to 10 in the appendix.

The first column displays the studied country and the placebo countries' pre-euro RMSPE. In the next column, we present the relative pre-euro RMSPE to the country under study, i.e. the RMSPE of the placebo country divided by the RMSPE of country i. If this ratio is higher than 4, the clone is not satisfactory and the placebo country is removed from the experiment. This is indicated in column three. Thus, Ireland is removed from the placebo experiment of the three countries while Finland and Luxembourg are removed from the Swedish and UK experiments. Finally, the last column of tables 8 to 10 shows the post- to pre-euro RMSPE, i.e the χ ratio for each country i.e. the country under study and the placebo countries).

From these tables, we can determine the p-value, i.e. the probability of observing among the placebo countries a ratio χ at least as high as that of country i.

Following Abadie et al.(2015) and Gabriel and Pessoa (2020), we calculate the p-value as follows:

$$p - value = \sum_{j=1}^{N+1} I(\chi_j \geq \chi_i)/(N+1) \tag{3.5}$$

where $I(.)$ denotes the indicator function and N, the number of donor countries.

The *p-values* for the three countries are given in tables 8 to 10.[8] To interpret the results, we take the example of Sweden. From its χ ratio, its post-euro RMSPE is 10,157 times larger than its pre-euro RMSPE. From table 9, we know that this ratio is higher than all the χ ratios obtained for the Swedish placebo countries. Hence a p-value of 1/9 for Sweden, which means that there is an 11% probability of finding a random country in the Swedish sample with a χ-ratio at least as high as that of Sweden.

The p-values for Denmark and Sweden are quite low, both remaining below 20%. This implies that their χ ratio is relatively high compared to

[8]These *p-values* can also be found in the fifth row of tables 3 to 5.

that found for their placebo countries and supports the significance of the estimated effects of their renunciation of the euro.

As for the UK, its value is slightly above 20%. This implies that we should be more cautious about the significance of the estimated loss of its renunciation of the euro. Indeed, although the pre-euro RMSPE is quite low – suggesting good quality of the clone – the χ ratio remains relatively low due to the also relatively low value of the post-euro RMSPE. Further robustness tests will help us to clarify this issue.

3.3.2 In time placebo

To further investigate the significance of our baseline results, we propose an in-time placebo experiment. Technically, this consists in re-assigning the euro adoption - and thus the euro rejection of Denmark, the UK and Sweden - to a fortuitous year other than 1999. We choose to re-estimate each model for the case where the break date is set to 1987.

The results are presented in the second columm (entitled "in-time pl.") of the first row of tables 3 to 5. The χ ratio obtained with the in-time placebo test is lower than that obtained in the baseline result for Denmark and Sweden, suggesting that the income effects of their non-participation in the euro are significant. However, we should be cautious about the significance of the estimated gain of UK's non-participation in the euro since the χ ratio obtained in the in-time placebo test is higher than that obtained in the baseline result. Nevertheless, we also observe that with the in-time placebo test, the p-value is higher, suggesting a less significant result than that obtained in the baseline test.

3.3.3 Other robustness tests

Leave-one-out analysis

In our analysis, the choice of control group countries is limited to those countries that adopted the euro in 1999. This implies that we can not change the composition of our control group as is done in Puzzello and Gomis-Porqueras (2018) for example. We therefore have to check the robustness of our results to the identity of the donors that enter into the construction of our clones. To do this, we implement a "leave-one-out" analysis which consists of removing one by one the donors that compose the clone of country i and observing the impact that this removal has on the results obtained. If our baseline results of the effects of the euro renunciation are robust, they should not be overly influenced by the change of the control group composition.

The main results of this robustness test are presented in the last three columns of Tables 3 to 5. Results with other withdrawn countries are available on request.

Our baseline results for Sweden are robust to our leave-one-out experiment as the estimated income gains from not adopting the euro remain statistically significant regardless of which country is removed. The RMSPE even slightly improves when Austria is excluded as a control country.

The robustness of the results for Denmark and the UK is more questionable. We observe that, for both countries, the p-value deteriorates significantly when the Netherlands is excluded from the donors, suggesting that the baseline result is sensitive to the composition of the donor group. This sensitivity can be explained by the fact that the composition of the donor group is imposed and limited to the original euro member countries. Given that the donors consist of only a few countries, excluding one country immediately affects the results, thus calling into question their robustness.

Change in the indexation year

So far, we have indexed real GDP per capita to the unit in 1995. In columns 1 and 2 of the second part of tables 3 to 5, we study the robustness of our basic results to a change in the indexation year. We observe that using 1980 or 1990 as the indexation year deteriorates the RMSPE and thus the quality of the match with the synthetic clone in the pre-euro period for the three countries. This in turn reduces the χ ratio and thus the significance of the estimated effects, with the exception of the UK where the significance increases by choosing 1990 as the indexation year (the p-value decreases from 2/9 to 2/11).

Change in the choice of predictors

Columns 3 to 5 of Part 2 of tables 3 to 5 show the results we get when we remove one or both lags of real GDP per capita. The results for Denmark are relatively robust to this change. For Sweden, removing either *lag 90* or *lag 98* slightly improves the pre-euro RMSPE and hence the quality of the clone as well as the χ ratio and the p-values. χ ratios and p-values also improve for the UK either by removing a single lag or both lags. Another interesting observation for the UK is that the sign of the estimated effects of non-participation in the euro changes when we remove the '98 lag', becoming negative and suggesting that the UK would have benefited from participation in the euro. Thus, the sign of the estimated effects of non-participation in the euro is not clearly defined. These estimated effects cannot therefore be considered significant.

3.3.4 1999, a relevant date?

Finally, in order to check the sensitivity of our results to the date chosen for the introduction of the euro (1999), we re-estimate the model for the case where the adoption of the euro is reassigned to three other dates: 1994, 1996 and 1998. These earlier dates allow us to account for anticipation effects. Indeed, although EMU was formally established in 1999, most member countries had to take prior actions to meet the Maastricht criteria established in 1992. These actions certainly affected their GDP, creating an income divergence within the EU between the countries that were to adopt the euro in 1999 and the others.

The results for these three dates are displayed in the last three columns of Part 3 of the tables 3 to 5. Moreover, figures 4 to 6 in the appendix present a graphical analysis of these anticipation effects from 1992 to 1998.

Our results for Denmark and Sweden are robust to the choice of the starting date of the euro effects. For the UK, however, compared to the baseline results, we observe that the estimated effects of its non-participation in the euro become negative when considering 1994 and 1996. This suggests that the UK would have been better off if it had decided to join the euro area by agreeing to meet the Maastricht entry criteria in 1992. Yet a closer look at Figure 6 reveals that the benefits of the euro would have been felt only until 2009, the start of the sovereign debt crisis in the euro area. Beyond that, the euro would have been costly to GDP in the UK.

4 Conclusion

Although Denmark, Sweden and the UK are (or were) part of the EU, they decided not to join EMU. This paper investigates whether these countries made the right choice in giving up the euro by examining the consequence of this decision on their per capita income. Using the synthetic control method, we construct for each of these countries a counterfactual unit as a convex combination of eurozone countries. The convex combination allows us to estimate these countries' per capita income that would have been observed, had they joined the European currency union. Our results distinguish two periods: in the first, from about 1999 to 2010, i.e. before the European sovereign debt crisis, only Denmark's GDP per capita diverges from its counterfactual, suggesting that the country would have benefited from the adoption of the euro. In contrast, for the UK and Sweden, prior to 2010, their renunciation of the euro does not appear to have had an effect on their income or a very small negative effect. However, during the crisis period, from 2010 onwards, our results indicate a significant divergence between the GDP per capita of the UK and Sweden and their counterfactual, implying that not being a member of the euro seems to have benefited these countries. Yet, further robustness tests have shown that these estimated gains from non-participation in the euro are more significant for Sweden than for the UK. As for Denmark, the estimated loss from non-participation in the euro seems to hold during the crisis period, suggesting that even during this period it would have gained from the euro.

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Name of the variable	Notation	Source
Current Account (% of GDP)	CA	Own computation using World Bank series
Consumer price index (2010 = 100)	cpi	IMF
Expenditure on Primary Education (% of government expenditure on education)	epe	UNESCO Institute for Statistics
Expenditure on secondary education (% of government expenditure on education)	ese	UNESCO Institute for Statistics
Expenditure on tertiary education (% of government expenditure on education)	ete	UNESCO Institute for Statistics
Employment to population ratio	ETP	World Bank
Government expenditure on education (% of GDP)	gee	UNESCO Institute for Statistics
Gross fixed capital formation (% of GDP)	gfcf	World Bank
General government final consumption expenditure (% of GDP)	gge	World Bank
Labor productivity growth	lpg	Own computation using PWT 10.0
Private consumption expenditure (% of GDP)	pce	Own computation using World Bank series
Real effective exchange rate index (2010 = 100)	reer	IMF
Total Factor Productivity at constant national prices (2017=1)	rtfpna	PWT 10.0
Share of household consumption at current PPPs	shcppp	PWT 10.0

Table 2: Choice of predictors

	Baseline	In-time pl.	w/o Aus	w/o Fin	w/o Net
Donor countries	Aus (,515) Fin (,202) Irl(,009) Lux (,019) Net (,255)	Bel (,637) Fin (,297) Irl(,003) Lux(,064)	Fin (,153) Fra (,585) Irl (,128) Net (,134)	Aus (,749) Fra (,158) Net (,094)	Aus (,849) Fin (,151)
RMSPE	0,0218512	0.02049467	0,0245097	0,0229819	0,0216052
χ ratio	5,266	4.5470738	5,3529811	2,7840016	4,3046508
Post-euro GDP p.c gap ("actual - synthetic")	-2.3012427	-2.5305705	-2.642507	-1.1637914	-1.787277
$p-value$	2/11	4/11	3/11	5/11	6/11
	Indexation year		*Choice of predictors*		
	1980	1990	w/o lag 90	w/o lag 98	w/o both lags
Donor countries	Aus (,175) Fin (,395) Lux(,126) Net (,303)	Aus (,154) Irl (,001) Lux (,013) Net (,832)	Aus (,26) Fin (,238) Lux (,067) Net (,435)	Aus (,193) Fin (,263) Irl (,03) Lux (,04) Net (,474)	Fin (,221) Fra (,248) Irl (,102) Net (,428)
RMSPE	0,0361046	0,0348779	.02329232	.0240848	.02515485
χ ratio	5,1274142	2,3992677	5.4425764	6.0510836	6.2531734
Post-euro GDP p.c gap ("actual - synthetic")	-3.7751228	-1.6236431	-2.564496	-2.9706081	-3.2011652
$p-value$	3/12	6/12	1/12	2/11	2/11
		Anticipation effects			
	1994	1996	1998		
Donor countries	Fin (,376) Irl (,135) Net (,489)	Fin (,373) Irl (,132) Net (,495)	Bel (,137) Fin (,289) Irl (,045) Lux (,074) Net (,455)		
RMSPE	0,0238823	0,0228951	0,0232397		
χ ratio	7,9817991	7,9325051	6,3779101		
Post-euro GDP p.c gap ("actual - synthetic")	-4.6364379	-4.6070192	-3.3142996		
$p-value$	1/7	1/11	2/12		

Table 3: Results for Denmark

	Baseline	In-time pl.	w/o Aus	w/o Fin	w/o Neth
Donor countries	Aus (,007) Fin (,484) Net (,51)	Fin(,666) Spa(,334)	Bel (,206) Fin (,452) Net (,342)	Fra (,918) Net (,082)	Aus (,402) Fin (,51) Ger (,088)
RMSPE	0,016484	0.01151085	0,0148091	0,0239802	0,0214391
χ ratio	10,157	7.4955316	11,358414	12,07134	7,9084773
Post-euro GDP p.c gap ("actual - synthetic"))	2.1296677	1.5324476	2.4524977	5.3281368	2.5536357
$p - value$	1/9	4/12	1/8	1/9	1/8
	Indexation year		*Choice of predictors*		
	1980	1990	w/o lag 90	w/o lag 98	w/o both lags
Donor countries	Fin (,574) Net (,426)	Fin (,502) Net (,498)	Aus (,061) Fin (,48) Net (,459)	Fin (,484) Net (,516)	Fin (,723) Ger (,169) Por (,108)
RMSPE	0,0221357	.01817316	.0154282	.01534838	.02686439
χ ratio	9,7784653	9.852128	10.405856	10.354961	5.7313032
Post-euro GDP p.c gap ("actual - synthetic")	3.1139627	2.6630668	2.2074227	2.1518286	2.0157062
$p - value$	1/10	1/11	1/10	1/10	2/11
		Anticipation effects			
	1994	1996	1998		
Donor countries	Fin (,505) Net (,495) Por (,054)	Fin (,506) Net (,44)	Fin (,498) Net (,502)		
RMSPE	0,0115108	0,01353	0,0133084		
χ ratio	8,2961607	9,4098186	10,263673		
Post-euro GDP p.c gap ("actual - synthetic")	1.9980985	2.081583	2.0749843		
$p - value$	1/7	1/8	2/12		

Table 4: Results for Sweden

	Baseline	In-time pl.	w/o Fin	w/o Irl	w/o Net
Donor countries	Fin (,199) Ger (,156) Irl(,132) Ita (,235) Lux (,171) Net (,107)	Fin(,066) Ger(,541) Irl(,031) Lux(,233) Spa(,129)	Fra (,22) Irl (,171) Ita (,526) Lux (,083)	Fin (,111) Ita (,373) Lux (,218) Net (,033) Spa (,257)	Fin (,267) Ger(,165) Irl (,163) Ita (,25) Lux (,155)
RMSPE	0,0149094	0.00929536	0,0183822	0,0184661	0,015607
χ ratio	4,521	9.3555326	7,8198853	9,1986017	3,4893031
Post-euro GDP p.c gap (”actual - synthetic”)	0.83133232	2.0306787	2.4740038	2.8143759	0.41444283
$p-value$	2/9	2/8	2/8	1/9	6/8
	Indexation year		*Choice of predictors*		
	1980	1990	w/o lag 90	w/o lag 98	w/o both lags
Donor countries	Aus (,01) Fin (,321) Ger (,282) Irl (,084) Lux (,227) Spa (,076)	Fin (,122) Irl (,188) Ita (,477) Spa (,213)	Fin (,152) Ger (,02) Irl (,142) Ita (,417) Lux (,127) Net (,142)	Fin(,278) Ger(,232) Irl(,137) Lux(,21) Net(,143)	Fin(,154) Irl(,23) Ita(,608) Por(,009)
RMSPE	0,0267008	0,0172565	0,01472932	0,01534838	0,02686439
χ ratio	2,322329	6,2682014	6,7931733	10,354961	5,7313032
Post-euro GDP p.c gap (”actual - synthetic”)	0.39265015	1.4684553	1.4368536	-0.3654449	1.4320483
$p-value$	6/10	2/11	1/10	1/10	2/11
		Anticipation effects			
	1994	1996	1998		
Donor countries	Fin (,296) Irl (,304) Ita (,153) Spa (,247)	Aus (,147) Fin (,252) Ger (,081) Irl (,116) Lux (,188) Por (,027) Spa (,19)	Fin (,178) Irl (,246) Ita (,353) Spa (,223)		
RMSPE	0,0161913	0,01595	0,0156693		
χ ratio	5,1685653	3,0866876	4,0971055		
Post-euro GDP p.c gap (”actual - synthetic”)	-1.7129002	-.15807176	.14689637		
$p-value$	2/10	5/10	3/10		

Table 5: Results for UK

Predictors	Denmark	Sweden	United-Kingdom
CA	.039	.043	<.01
cpi	.070	.042	.049
epe	.056	<.01	.037
ese	<.01	.074	.716
ete	.050	<.01	<.01
ETP	.045	.058	<.01
gdplcui(1990)	.024	.087	.102
gdplcui(1998)	.044	.054	.011
gee	.028	.032	.02
gfcf	<.01	.122	<.01
gge	.021	<.01	<.01
lpg	.112	.313	<.01
pce	<.01	<.01	<.01
reer	<.01	<.01	.016
rtfpna	.500	.058	.012
shcppp	<.01	.089	<.01

Table 6: Composition of the clones: Pre-euro characteristics' weight (in%)

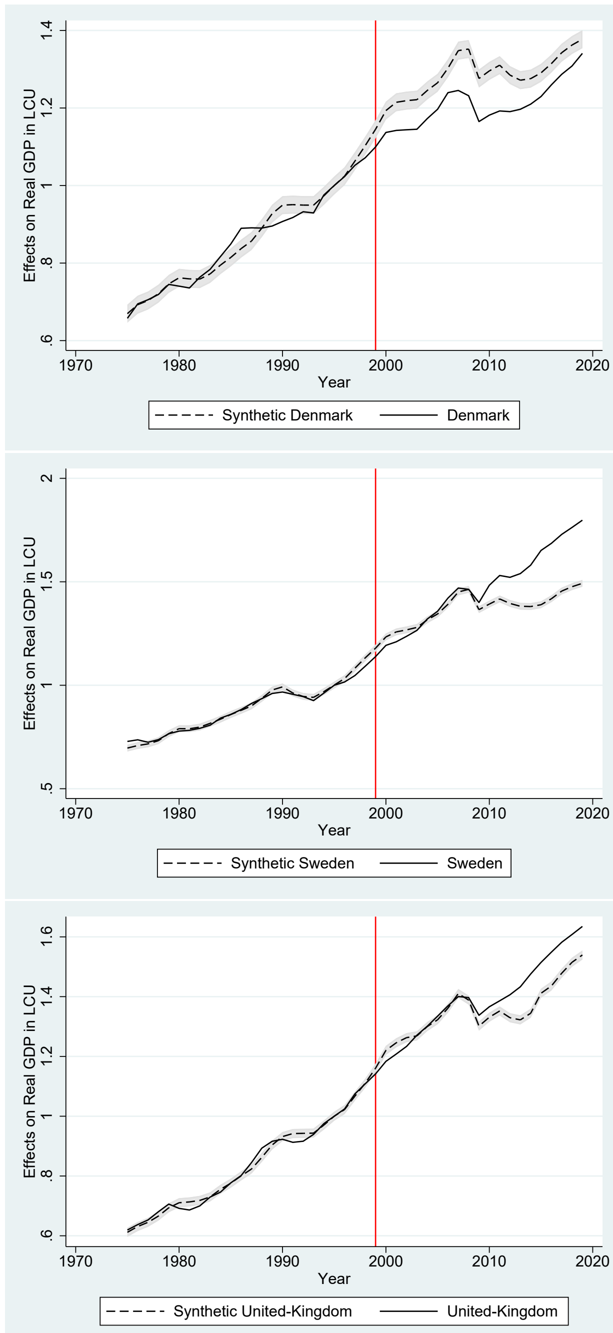

Figure 2: Real GDP per capita - actual vs. counterfactual *Note: Shaded area is one standard deviation of difference prior to the refusal of the euro*

	Denmark		Sweden		United Kingdom	
Predictors	*Actual*	*Synthetic*	*Actual*	*Synthetic*	*Actual*	*Synthetic*
CA	5.548	2.304	3.492	5.0319	-.750	5.507
cpi	71.672	74.349	80.311	75.079	71.628	72.458
epe	21.351	22.229	40.964	24.319	27.924	27.295
ese	40.872	43.325	30.411	38.974	45.172	45.214
ete	24.554	24.9555	24.097	29.35	22.178	19.982
ETP	60.86	54.495	63.101	53.780	56.863	49.909
gdplcui(1990)	.907	.948	.967	.983	.923	.932
gdplcui(1998)	1.072	1.104	1.092	1.132	1.108	1.111
gee	7.384	5.411	5.924	5.668	4.401	4.791
gfcf	19.611	23.833	21.968	21.935	19.081	21.446
gge	24.217	20.359	5.924	22.076	4.401	19.137
lpg	7.915	8.298	8.280	8.340	9.967	8.550
pce	50.132	52.951	68.812	50.742	80.600	52.739
reer	96.767	105.826	128.6127	107.610	115.983	105.671
rtfpna	203973.5	338506.6	.773	375634.400	.899	1087261
shcppp	.527	.554	.507	.516	.659	.547

Table 7: Pre-euro characteristics

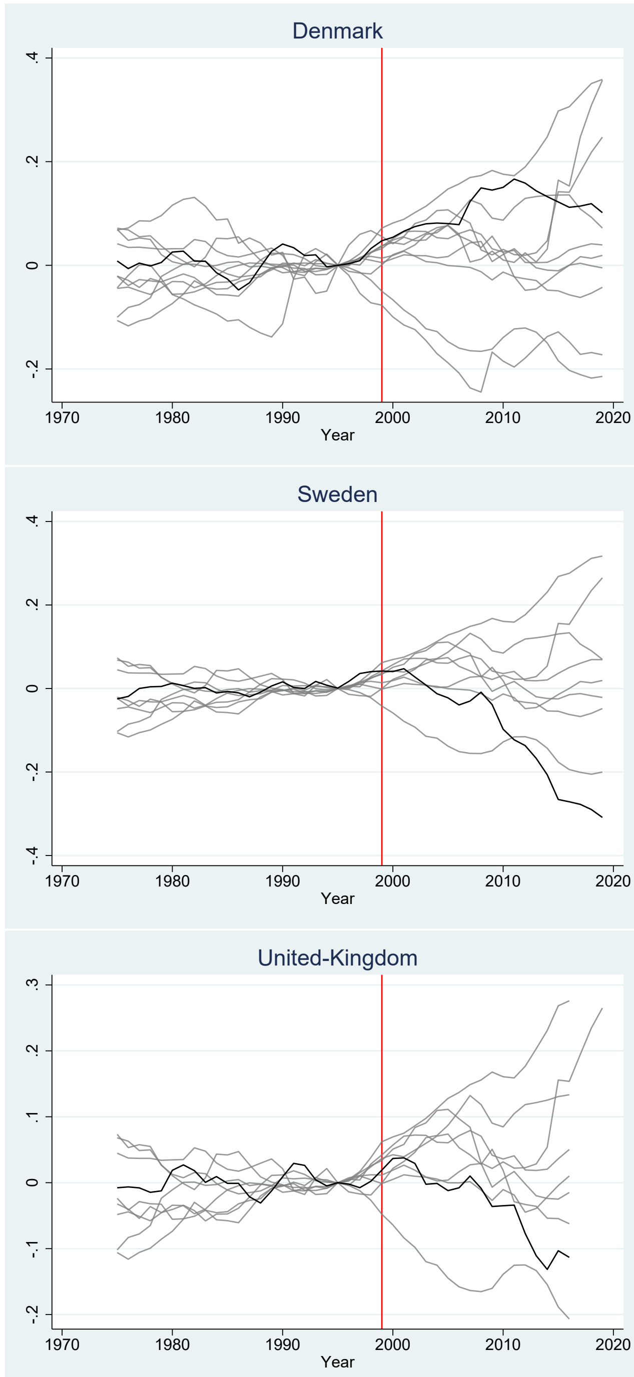

Figure 3: In-space placebo *Note: The black line represents the gap between the per capita GDP of each synthetic and actual country i, while the grey line represents the similar gap for the placebo countries.*

Country j	pre-euro RMSPE	Relative pre-euro RMSPE to Denmark	Decision	χ ratio
Denmark	0,0218512	1	kept	5,266
Austria	0,023252	1,064106319	kept	0,923
Belgium	0,0304513	1,393575639	kept	1,476
Finland	0,0733028	3,354634986	kept	2,29
France	0,0270296	1,236984696	kept	0,753
Germany	0,0274798	1,257587684	kept	1,803
Ireland	0,1065451	4,875938164	rejected	5,579
Italy	0,0268519	1,22885242	kept	7,901
Luxembourg	0,0743562	3,402842864	kept	1,77
Netherlands	0,0568927	2,603641905	kept	1,88676
Portugal	0,034663	1,586320202	kept	2,783
Spain	0,0344594	1,577002636	kept	4,408
p-value				2/11

Table 8: In-space placebo results for Denmark

Country j	pre-euro RMSPE	Relative pre-euro RMSPE to Sweden	Decision	χ ratio
Sweden	0,016484	1	kept	10,397734
Austria	0,0319376	1,9374909	kept	0,62201798
Belgium	0,0309877	1,879865324	kept	1,7682692
Finland	0,0778062	4,720104344	rejected	2,2135558
France	0,0281774	1,709378792	kept	0,5455035
Germany	0,0293634	1,781327348	kept	1,6532981
Ireland	0,1124399	6,821153846	rejected	4,2224474
Italy	0,0282637	1,714614171	kept	5,8496933
Luxembourg	0,0665184	4,03533123	rejected	2,1468165
Netherlands	0,0570198	3,459099733	kept	2,0291812
Portugal	0,0310156	1,881557874	kept	3,105267
Spain	0,0351889	2,134730648	kept	3,956707
p-value				1/9

Table 9: In-space placebo results for Sweden

Country j	pre-euro RMSPE	Relative pre-euro RMSPE to UK	Decision	χ ratio
UK	0,0149	1	kept	4,521
Austria	0,031938	2,143489933	kept	0,62272459
Belgium	0,030988	2,079731544	kept	1,7682692
Finland	0,077806	5,221879195	rejected	2,2135558
France	0,028177	1,891073826	kept	0,5455035
Germany	0,029363	1,970671141	kept	1,6532981
Ireland	0,11244	7,546308725	rejected	4,2224474
Italy	0,028264	1,896912752	kept	5,8496933
Luxembourg	0,066518	4,464295302	rejected	2,1468165
Netherlands	0,05702	3,826845638	kept	2,0291812
Portugal	0,027224	1,827114094	kept	3,1370049
Spain	0,035189	2,361677852	kept	3,956707
p-value				2/9

Table 10: In-space placebo results for United-Kingdom

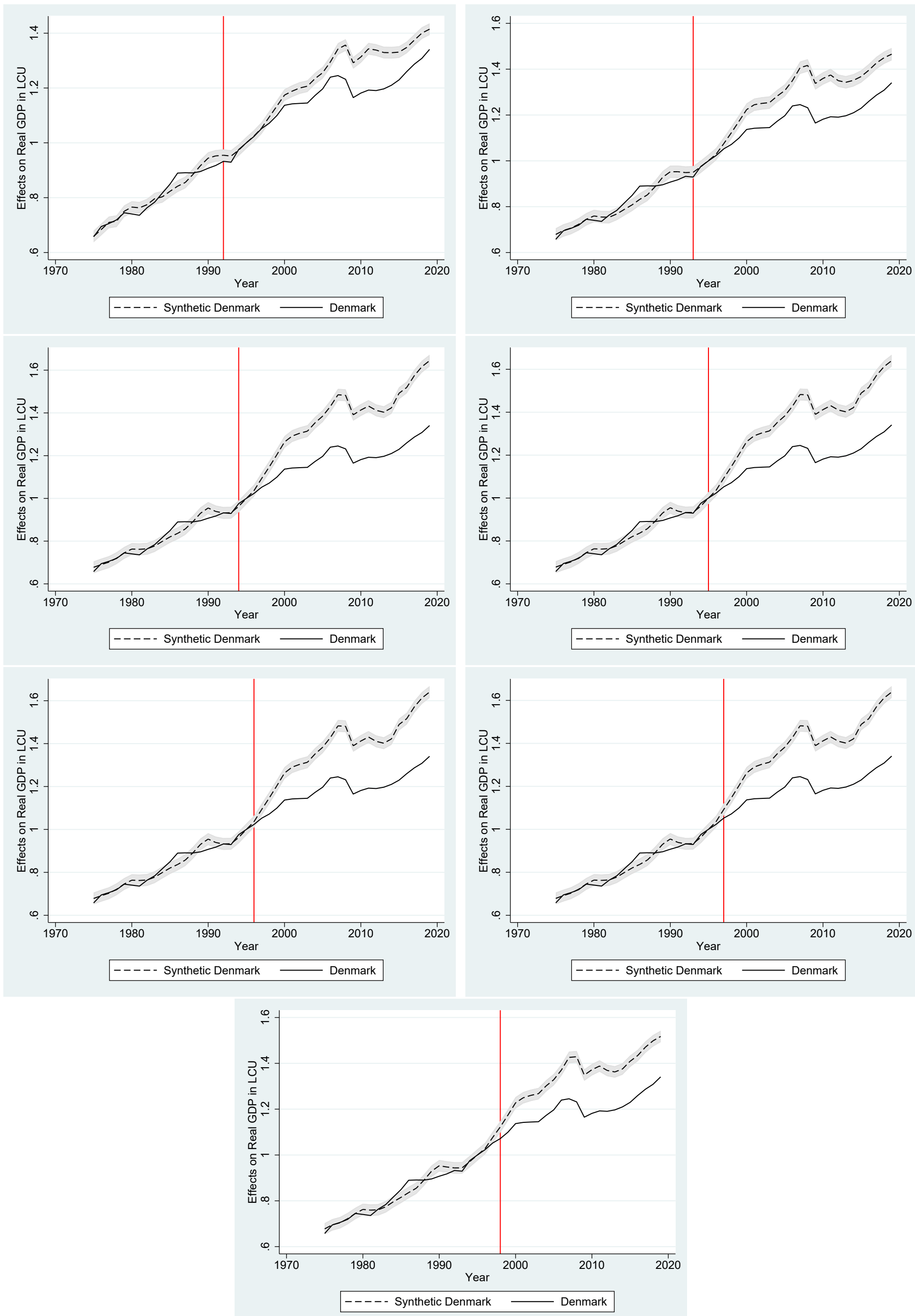

Figure 4: Anticipation effects - Denmark

For the years 1992 and 1993, the education variables are removed from the model due to lack of data before 1994 for some countries.

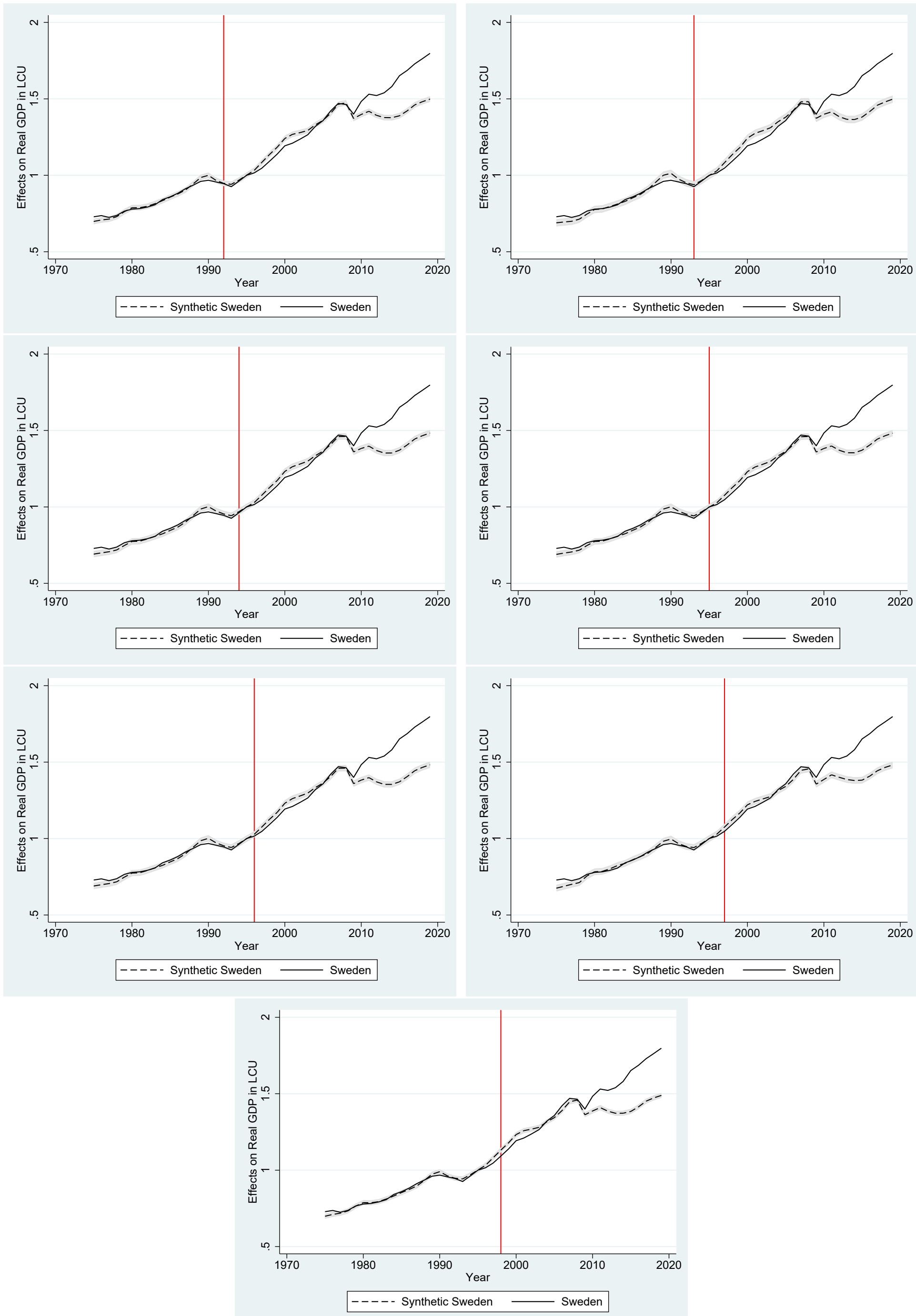

Figure 5: Anticipation effects - Sweden

For the years 1992 and 1993, the education variables are removed from the model due to lack of data before 1994 for some countries.

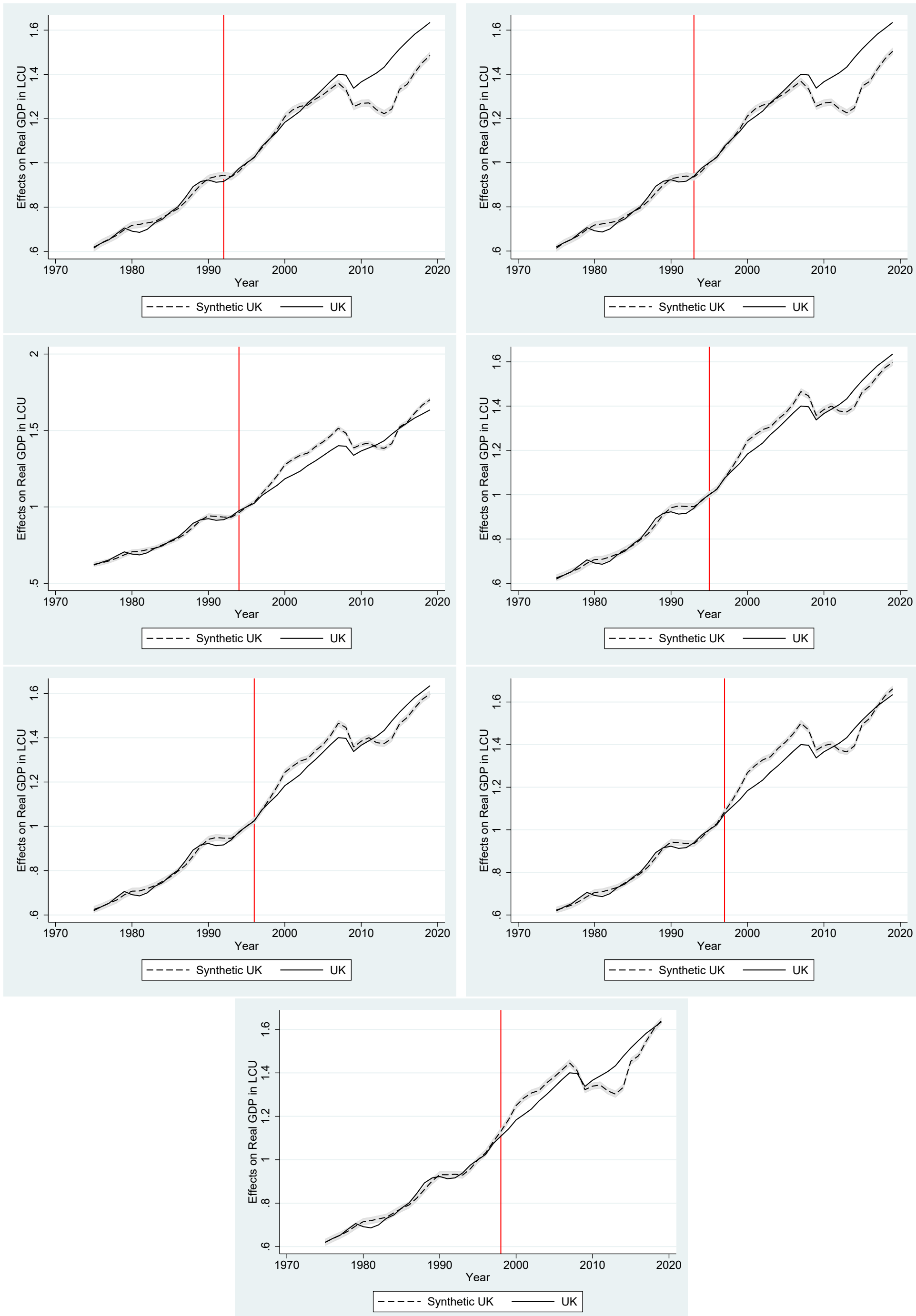

Figure 6: Anticipation effects - UK
For the years 1992 and 1993, the education variables are removed from the model due to lack of data before 1994 for some countries.