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Working Paper

Quantifying the Effects of the CNB's Exchange Rate Commitment: A Synthetic Control Method Approach

IES Working Paper, No. 17/2016

Provided in Cooperation with:

Charles University, Institute of Economic Studies (IES)

Suggested Citation: Opatrny, Matej (2016) : Quantifying the Effects of the CNB's Exchange Rate Commitment: A Synthetic Control Method Approach, IES Working Paper, No. 17/2016, Charles University in Prague, Institute of Economic Studies (IES), Prague

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Bibliographic information:

Opatrný M. (2016). "Quantifying the Effects of the CNB's Exchange Rate Commitment: A Synthetic Control Method Approach" IES Working Paper 17/2016. IES FSV. Charles University.

This paper can be downloaded at: <http://ies.fsv.cuni.cz>

Quantifying the Effects of the CNB's Exchange Rate Commitment: A Synthetic Control Method Approach

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August 2016

Abstract:

In this paper I evaluate the quantitative effects of the Czech National Bank's commitment to keep the Koruna from appreciating that were put in place in 2013. I focus its on the impact on output, unemployment, and inflation. I use the synthetic control method, which allows me to compute the counter-factual development of the Czech economy in the absence of the commitment. I find that, until the end of 2015, the commitment helped create about 100,000 jobs. The effect on overall output is also strongly positive, almost 2% for growth in 2015, but only marginally statistically significant, which might be connected to disturbances created by changes in excise taxes. The effect of the commitment on inflation is positive but not statistically significant at standard levels.

Keywords: Inflation, Unemployment, Output, Currency, Monetary Policy,
Synthetic Control Method

JEL: E42, E47, E50, E51, E52, E58

Acknowledgements: An online appendix with data and code is available at: <https://drive.google.com/file/d/0B19QDPEjcz9tZDRpSnZvMUxheDg/view?usp=sharing>. The author is grateful especially to Doc. PhDr. Tomáš Havránek, Ph.D. for his valuable comments and suggestions.

1 Introduction

The exchange rate commitment of the Czech National Bank (CNB) had been a topic of policy and academic debate for a while when it was launched in the period Q4 2013. Since the CNB decreased the interest rate to “technical zero” in order to fight the falling of the Harmonized Consumer Price Index (HCPI), there was a demand for different monetary tool to achieve an inflation target set by CNB. Finally, in November 2013, CNB initiated a weakening of the Czech currency to the minimum level of 27 CZK per 1 Euro with the goal of increasing HCPI and therefore avoiding a risk of deflation.

The objective of this paper is to evaluate the effect of the intervention on the Czech macroeconomic indicators – Gross Domestic Product (GDP) per capita, unemployment rate and HCPI – using the synthetic control method. The method provides a possible development of Czech macroeconomic indicators in the absence of the intervention. The principle of using this method is constructing a counter-factual for the Czech economy without the intervention by finding the weighted average of countries that match the development of key Czech indicators before the intervention. The important fact is that the counter-factual is not constructed by extrapolating pre-event trends from the treated unit but rather, as Abadie & Gardeazabal (2003) proposed, by building a synthetic control group. So far, there can be found many empirical studies related to the evaluation of the exchange rate intervention on a small open economy. However, thanks to the synthetic control method, this empirical study provides quantitative inference without excluding the application of qualitative approaches.

From the outset, we would like to stress out that we are not testing the relationship between Czech macroeconomic indicators and exchange rate commitment introduced by CNB. Instead, we attempt to establish a possible path of macroeconomic indicators and magnitude of the effect of the intervention on the Czech key macroeconomic indicators. As a result, we find that, thanks to CNB’s exchange rate commitment, the unemployment rate decreased on the level of 4.5% until the end of the year 2015 – in other words creating around 100,000 working positions. Consequently, we demonstrate a slight positive effect on the GDP per capita and indecisive effect on HCPI.

This paper is structured as follows. In section 2 we describe the core literature used to establish this empirical study. In section 3, we refer to the methodological background of the synthetic control method. There, the reader

can also find a brief subsection discussing the inference provided by the synthetic control method. Finally, we provide the results for GDP per capita, unemployment rate, and HCPI, respectively, computed by the synthetic control method. Moreover, for each variable there are included robustness tests to check the credibility of the results. The conclusion can be found in section 5.

2 Applications of the Synthetic Control Method

In this section I will present core papers to familiarize the reader with the synthetic control method. Since the synthetic control method was developed in 2003 by Abadie & Gardeazabal (2003), there are several empirical studies using the method.

Abadie & Gardeazabal (2003) introduce the synthetic control method in *The economic costs of conflict: a case study of the Basque country*, where they present evidence of the negative economic impact of the terrorist conflict in the Basque Country. Moreover, the study shows a 10 % average gap between the synthetic control group per capita GDP and Basque per capita GDP over the period of twenty years.

Adopting the synthetic control method, Lee (2010) challenges if the inflation targeting tool is an effective policy in emerging economies. His study shows that inflation targeting helped reduce the inflation rate in Columbia, the Czech Republic, Hungary, and Poland, when they adopted such policies in 1990s and 2000s. On the other hand, his study finds that no significant effect was found when there was a later start date of the policy.

The next Abadie (2011) paper *Using Synthetic Controls to Evaluate an International Strategic Positioning Program in Uruguay: Feasibility, Data Requirements, and Methodological Aspects* thoroughly describes the use of the synthetic control method. Furthermore, this paper provides a potential way to adapt the synthetic control method if some of the requirements are not met.

Abadie *et al.* (2012) also use the synthetic control method to estimate the effect of California's tobacco control program - Proposition 99. In this paper, they extend the synthetic control method by a procedure to produce inference that involves uncertainty about the validity of the control unit. Finally, they demonstrate that annual per-capita cigarette sales would have been about 26 packs higher in the absence of Proposition 99.

Billmeier & Nannicini (2013) apply the synthetic control method (SCM) to find consequences of economic liberalization. They investigate the impact

of economic liberalization on real per capita GDP in a worldwide sample of countries. As a result, they demonstrate positive effect in most regions, but they also mention that the most recent liberalization, mainly in Africa, had no significant impact.

The next application of SCM is on the estimation of a natural disaster on economic growth by Cavallo *et al.* (2013). In this paper, they focus mainly on large natural disaster and its consequences. By researching 196 countries covering the period 1970–2008 they find that natural disasters do not have any significant effect on subsequent economic growth.

Using the synthetic control method, Jinjark *et al.* (2013) examine changes in Brazil’s capital account regime during the period 2008–2011. They find that there is no evidence that any tightening of controls is effective in decreasing the level of capital inflows. On the other hand, they observe some modest success in preventing capital inflows when the capital controls are relaxed.

In the next paper related to SCM, Acemoglu *et al.* (2013) demonstrate the connectivity of financial firms with a political scene, namely with the Secretary of the Treasury in the USA. The paper shows that the announcement of Timothy Geithner as a nominee for the Secretary of the Treasury produced an abnormal cumulative return for financial firms connected with him. Expressed in numbers, this return was about 6% after the first day of trading and about 12% after 10 days of trading.

Aytug (2014) develops a model using the propensity score matching (PSM) and the synthetic control method techniques to evaluate the average effect of adopting the euro on economic growth. These techniques allow him to assess the effect for the member of Eurozone (using PSM) and also how each Eurozone member would have performed in the absence of the euro adoption (using SCM). As Aytug (2014) comments, the findings confirm the significant relationship between the exchange rate regimes and growth, even though the effect of adopting the euro on growth is negative.

Campos *et al.* (2014) present the economic benefits from membership with the European Union. They estimate GDP per capita and labour productivity for countries that joined the European Union in 1970s, 1980s, 1995 and 2004, in the absence of membership with the European Union. They find that, without political and economic integration, GDP per capita would have been, on average, approximately 12% lower.

As Abadie *et al.* (2015) point out in the empirical study *Comparative Politics and the Synthetic Control Method*, the synthetic control method might be

used as a bridge between qualitative and quantitative approaches in empirical case studies. The core merit of this method lies in a systematic way of choosing comparison units in comparative case studies. Consequently, Abadie *et al.* (2015) apply the synthetic control method on German reunification, which took place in 1990. Their results indicate a negative effect of reunification over the entire period 1990-2003 on West Germany per capita GDP by approximately 1,600 USD per year on average.

The next application of the synthetic control method is performed by Gomis-Porqueras *et al.* (2015), where they estimate the effect of joining the monetary union on per capita income. The results show that, in contrast with Belgium, France, Germany and Italy, where the income per capita would have been higher without the Euro, that of Ireland would have been lower. For the Netherlands they observe an indecisive effect. In addition, they provide an explanation for those income effects, claiming that those countries which had adopted the euro earlier, had synchronized business cycles with the union, and were more open in intra union trade and migration, lost less or gained more from the euro adoption.

In their paper *Examination of the Synthetic control method for evaluation health policies with multiple treated units*, Kreif *et al.* (2015) extend the original synthetic control method approach to a setting where there are multiple treated units. By using this improvement on the synthetic control method, they examine the effect of a pay-for-performance initiative, the Advancing Quality scheme, in contrast to difference-in-differences (DiD) estimation method. The main distinction between these two methods is that DiD estimation assumes constant effect of unobserved con-founders over time, while the synthetic control method allows changes in those effects over time.

3 Technical Aspects of the Synthetic Control Method

In comparative case studies, there is often stress to choose comparison units because using improper comparisons may lead to faulty conclusions. The synthetic control method provides a systematic way of choosing comparison units (Abadie *et al.* 2012). In addition, as Abadie *et al.* (2015) pp. 2 claim:

Formalizing the way comparison units are chosen not only represents a way of systematizing comparative case studies ..., but it also has direct implications for inference. We demonstrate that the main barrier to quantitative inference in comparative studies comes not from the small-sample nature of the data, but

from the absence of an explicit mechanism that determines how comparison units are selected. By carefully specifying how units are selected for the comparison group, the synthetic control method opens the door to the possibility of precise quantitative inference in comparative case studies, without precluding qualitative approaches to the same data set.

3.1 Description of the Method

Suppose that we gather data for $J + 1$ countries. Without loss of generality, we assume that only the first country is exposed to the intervention of interest. Therefore, there are J countries remaining as eventual control units not influenced by the intervention. Also, without loss of generality, we assume that the first country is continuously exposed to the intervention from the period when the intervention was launched (Abadie *et al.* 2015).

Let Y_{it}^N denote the potential outcome of interest in the absence of the intervention for country i in period t where $i \in \{1, \dots, J + 1\}$ and $t \in \{1, \dots, T\}$. Consequently, let T_0 be the number of pre-intervention periods fulfilling the condition $1 \leq T_0 \leq T$ (Abadie *et al.* 2015).

Let Y_{it}^I denote the outcome of interest for country i in period t under the intervention which takes place in periods $T_0 + 1$ to T . Naturally, we assume that the intervention has no effect on the outcome in pre-intervention periods, therefore $Y_{it}^N = Y_{it}^I$. When setting the intervention periods T_0 there is necessity to take into account any anticipation effect, so that T_0 can be reset to the period when the first effect of the intervention is assumed to appear (Abadie *et al.* 2015).

The constructing of control units requires certain attention. Firstly, the country which adopted the similar intervention should be excluded from a data set to avoid a potential bias of the output. For this reason, we omitted Switzerland¹ from a sample. Secondly, for a good fit of counter-factual outcome, there is a need for comparison units to have similar economic performance as a unit exposed to the intervention. Taking this assumption into account, we consider only European countries as suitable comparison units. Moreover, countries which may be affected by the intervention in the “treated” country should be excluded from a sample (Abadie *et al.* 2015).

The effect of the intervention with $t > T_0$ is represented as follows:

$$v_{it} = Y_{it}^I - Y_{it}^N \quad (1)$$

¹See section 4 for more details.

Given that Y_{it}^I is observed in equation (1), we must now estimate Y_{it}^N . The key aspect of a synthetic control is that it is defined as a weighted average of the control units with weights $w = \{w_2, \dots, w_J\}$ with $0 \leq w_j \leq 1$ for $j = 2, \dots, J$ and

$$\sum_{j=2}^J w_j = 1$$

These restrictions are made to avoid an extrapolation (Abadie & Gardeazabal 2003). Using given weights $\{w_2, \dots, w_J\}$ the synthetic control estimators of Y_{it}^N and v_{it} ² are :

$$\begin{aligned}\hat{Y}_{it}^N &= w_2 Y_{2t} + \dots + w_J Y_{Jt} \\ \hat{v}_{it} &= Y_{it}^I - \hat{Y}_{it}^N\end{aligned}$$

The next step is to choose weights $\{w_2, \dots, w_J\}$. According to Abadie & Gardeazabal (2003) and Abadie *et al.* (2012), the weights should best reflect the pre-intervention features of the affected unit. Furthermore, Abadie & Gardeazabal (2003) and Abadie *et al.* (2012) choose $w^* = \{w_2^*, \dots, w_J^*\}$ which minimizes:

$$v_1(X_{11} - w_2 X_{12} - \dots - w_J X_{1J})^2 + \dots + v_k(X_{k1} - w_2 X_{k2} - \dots - w_J X_{kJ})^2 \quad (2)$$

where $\{v_1, \dots, v_k\}$ represent the relative importance of the synthetic control assigned to predictors $\{X_{11}, \dots, X_{k1}\}$.

Therefore, the problem comes down to choosing $\{v_1, \dots, v_k\}$. In this paper,³ the weights are chosen so that the synthetic controls minimize the size of the prediction error, $Y_{it}^I - \hat{Y}_{it}^N$, in a selected pre-intervention period, this can be done by solving a nested optimization problem with v selected so that w minimizes the root mean square predicted error Root Mean Square Predicted Error (RMSPE) during a selected periods. Therefore, each choice of v results in different country weights $w(v)$, which then gives a value for the RMSPE⁴.

3.2 Inference using the Synthetic Control Method

This paper uses three inferential methods. Two of these methods were initially introduced by Abadie & Gardeazabal (2003), in which they run “placebo” effects. The third method is based on constructing of a confidence interval

²See Abadie *et al.* (2012) where it is proved that \hat{v}_{it} is an unbiased estimator of v_{it} .

³See Abadie (2011) which describes several methods for choosing the weights $\{v_1, \dots, v_k\}$

⁴The RMSPE has following formula: $RMSPE = \left(\frac{1}{T_0} \sum_{t=1}^{T_0} (Y_{it} - \sum_{j=2}^{J+1} w_j^* Y_{jt})^2 \right)^{\frac{1}{2}}$

using RMSPE for the computation. As Abadie *et al.* (2015) note, these tests provide good results only if there is a sufficiently large number of periods when no significant shocks to the outcome of interest took place.

The first method to construct a placebo study suggests applying the synthetic control method to all control units. In this way, we obtain a synthetic control for countries not exposed to the intervention. This allows researchers to evaluate the estimation of the effect between the treated unit and the units not exposed to the intervention. In other words, the confidence about the result would decrease if the synthetic control method were to estimate a large effect to a unit where the intervention was not set up.

The second method related to the placebo study applies the synthetic control method to the period when the intervention did not occur in a treated unit. As Abadie *et al.* (2015) mention, a large placebo estimate would undermine the credibility of a result. For example, if there is a significant effect of intervention in an earlier period,⁵ the confidence of the effect would greatly diminish.

The third, and last, method is based on the construction of a 95% confidence interval. To create the confidence interval we assume that the outcome of interest follows the student's distribution due to small a number of pre-intervention periods.⁶ Using the RMSPE calculated by the synthetic control method, we can construct respective confidence intervals. Using a generated confidence interval, if the outcome of the interest exceeds the bounds of the interval, we would infer that the intervention has the effect on the output. In the empirical section below, we can see that there is an effect on the unemployment rate, and also a slight effect on the GDP per capita in the Czech Republic.

⁵We can choose random periods prior to the intervention.

⁶The number of pre-intervention periods depends on the starting period of our data related to a chosen variable.

4 Quantifying the Effects of the CNB's Exchange Rate Commitment

In this paper we use quarter panel data collected from the Eurostat database for the periods Q1 2005–Q4 2015.⁷ For the Seasonally Adjusted GDP per capita, however, we also provide additional results for the period Q1 2001–Q4 2015, and for HCPI for the period Q4 2007–Q4 2015. Our sample periods end in Q4 2015, because during the writing of this paper it was the last available data.⁸ The intervention of CNB occurred in Q4 2013, which means more than 35⁹ pre-intervention quarters. As Abadie *et al.* (2015) mention, nearly a decade-long period after the intervention, in our case 8 post-intervention quarters, seems like a plausible span for a prediction.

The control units include 22 European states: Austria, Belgium, Bulgaria, Croatia, Denmark, Estonia, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Since the synthetic Czech Republic should reproduce the output in the absence of the intervention, we omitted Switzerland from the control units, because the Swiss Central Bank adopted the exchange rate mechanism in Q1 2015 to achieve the inflation target. Moreover, we exclude Norway, because there are no data for Index of Wage in the Industry Sector¹⁰, which turn into the main predictor.¹¹ Furthermore, we omit Malta from the control units, because of the small size of its economy. We also exclude Finland due to its strong economical relationship with Russia¹², which could negatively affect the performance of the Czech Republic after the intervention.

As the output variables, we use Seasonally Adjusted GDP per capita, unemployment rate, and HCPI. A list of variables and their sources are provided

⁷The starting period Q1 2005 is chosen because of the Czech economy's close convergence with the European Union economy. Moreover, the Czech Republic joined the EU in 2004.

⁸Data for explanatory variables – Final Consumption per Capita, Real Exchange Rate, and Index of Wage in Industry Sector are provided until the period Q2 2015, which, in fact, does not have an impact on the results. The synthetic control method averages predictors prior to the intervention. In our case, prior to the period Q4 2013.

⁹The number of pre-intervention periods depends on the starting period. The period Q1 2005 is used here.

¹⁰During the writing of this paper, the Eurostat database did not provide data for the Index of Wage in Industry Sector for Norway.

¹¹See tables 1, 7, 4 for details.

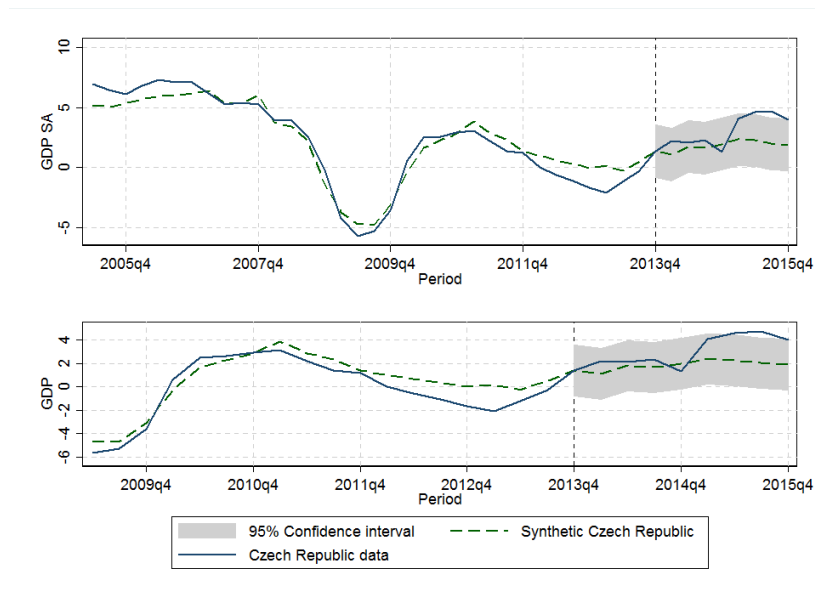
¹²The Ukrainian crisis and a fall in the price of oil caused Russian economy to slow down, which consequently negatively affected Finish economical performance.

in the appendix B. The set of predictors consists of Seasonally Adjusted GDP per capita, HCPI, Final Consumption per Capita, Real Exchange Rate, Index of Wage in Industry Sector, and unemployment rate.¹³

4.1 Seasonally Adjusted GDP per Capita

In the figure 1 we can see per capita seasonally adjusted GDP and its synthetic counterpart during the period Q1 2005–Q4 2015. Moreover, the reader can see additional results for the period Q1 2001–Q4 2015 in the figure 2. Take in consideration that all tables provided in this section are related to the period Q1 2005–Q4 2015.¹⁴

Figure 1: Seasonally Adjusted GDP per capita Q1 2005–Q4 2015

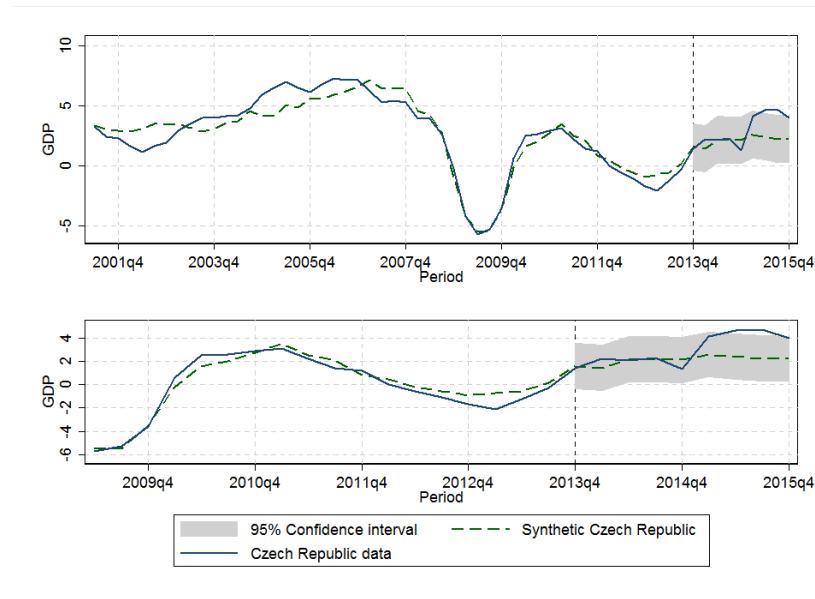


Source: Synthetic control method computation.

¹³See appendix for details about predictors.

¹⁴See Appendix A for the results related to the figure 2 during the period Q1 2001–Q4 2015.

Figure 2: Seasonally Adjusted GDP per capita Q1 2001–Q4 2015



Source: Synthetic control method computation.

The difference between per capita GDP and its synthetic version is the effect of the intervention. Consequently, it can be seen in figure 1 that the synthetic per capita GDP precisely follows the real version until Q4 2014. After the period Q4 2014 the real per capita GDP significantly increases. Furthermore, it slightly exceeds the 95% confidence interval of the estimation of the synthetic counterpart. Therefore, we can recognize the effect of the intervention. Nevertheless, it is necessary to take into account that the increase in GDP per capita could be contributed to several idiosyncratic events, such as an accelerated pumping of European structural funds in the period Q4 2014, which is described in detail in Ministry of regional development (2014), and increasing indirect taxes on tobacco products, which is discussed in the end of this section.

Table 1 displays weights computed by the synthetic control method using the nested optimization process. As Abadie & Gardeazabal (2003) suggest, the outcome of interest can be included in synthetic control predictors during the pre-intervention period. We can see that the power of predictors decrease in the following order: Index of Wage in Industry Sector, Seasonally Adjusted GDP per capita, Real Exchange Rate, unemployment rate, HCPI, and Final Consumption per Capita.

Table 1: Predictor Weights

Country	Synthetic Control Predictor Weight
Seasonally Adjusted GDP per capita	0.0544
Final Consumption per Capita	0.0001
Real Exchange Rate	0.0013
Index of Wage in Industry Sector	0.9442
HCPI	0.0001
Unemployment Rate	0.0002

Source: Synthetic control method computations.

The Index of Wage in Industry Sector in table 1 obtains unusually high prediction weight. In other words, this high prediction weight indicates that the weight of countries is chosen mainly according to the Index of Wage in Industry Sector.¹⁵ On the other hand, the outcome is very comparable to figure 2.

In table 2 we compare predictor means of the synthetic control units and those of the treated unit before the intervention. The synthetic control units provide very similar results in terms of Seasonally Adjusted GDP per capita, Real Exchange Rate and Index of Wage in Industry Sector. The magnitude of the differences between Final Consumption per Capita, HCPI, unemployment rate and its synthetic counterpart are slightly larger but, as can be seen in table 1, its predictive power is small.

Table 2: Predictor Means Before the Intervention

Country	Treated Unit	Synthetic Unit
Seasonally Adjusted GDP per capita	2.214	2.213
Final Consumption per Capita	0.840	1.776
Real Exchange Rate	113.451	113.012
Index of Wage in Industry Sector	88.060	87.977
HCPI	2.455	3.122
Unemployment Rate	6.590	7.884

Source: Synthetic control method computations.

In table 3 the reader can see weights of the control units related to the Seasonally Adjusted GDP per capita. The synthetic counterpart is created by combining the following countries: Netherlands, Bulgaria, Slovakia, Denmark,

¹⁵See Appendix A with the results related to figure 2.

and Estonia. Note that Ireland and Luxembourg are excluded from the initial control units. The reason for Ireland's exclusion is that, during the whole sample period, the Eurostat database does not provide values for the seasonally adjusted GDP per capita. Luxembourg is excluded from the control units because its economy is more highly developed than that of the Czech Republic in terms of per capita GDP.

Table 3: Country's Weights

<i>Country</i>	<i>Synthetic Control Weight</i>
Austria	0
Belgium	0
Bulgaria	0.227
Croatia	0
Denmark	0.130
Estonia	0.132
France	0
Germany	0
Hungary	0
Italy	0
Latvia	0
Lithuania	0
Netherlands	0.365
Poland	0
Portugal	0
Slovakia	0.145
Slovenia	0
Spain	0
Sweden	0
United Kingdom	0

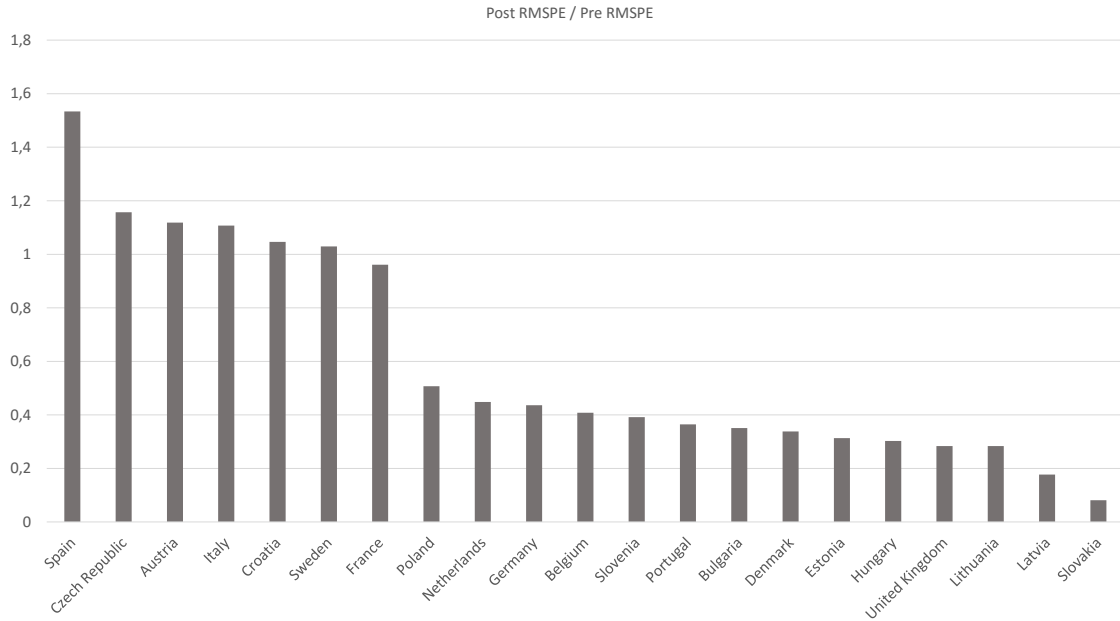
Source: Synthetic control method computations.

4.1.1 Robustness Tests

The credibility of the results can be clarified by running placebo studies, as described in Chapter 3. Firstly, we reassign the intervention to all control units and evaluate the ratio of post-intervention RMSPE to pre-intervention RMSPE. As Abadie *et al.* (2015) point out, a large post-intervention RMSPE is not indicative if the synthetic output of interest does not closely reproduce the real output of interest prior to the intervention. In other words, if the ratio between post-intervention RMSPE and pre-intervention RMSPE is large,

then the effect of the intervention is also large. In figure 3 we can see that the Czech Republic comes in second for the largest effect of the intervention. This indicates that the intervention has an impact on the Seasonally Adjusted GDP per Capita in the Czech Republic.

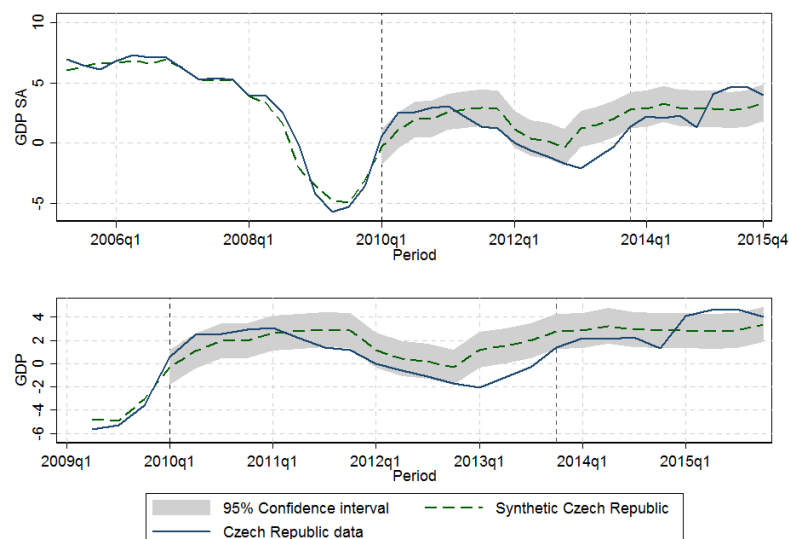
Figure 3: Ratio of Post-intervention RMSPE and Pre-intervention RMSPE related to Seasonally Adjusted GDP per Capita



Source: Synthetic control method computation.

Secondly, we change the period of the intervention to Q1 2010 using the same technique of choosing control units weights. Figure 4 displays the output of the interest when the intervention period is set to Q1 2010. It can be seen that before the period Q4 2013 (which indicates the non-labelled dash line) the real output exceeds a lower bound of the 95% confidence interval of its synthetic counterpart. This exceeding might be due to the difference between per capita GDP and its synthetic counterpart in figure 1 during the period Q3 2011 – Q4 2013. On the other hand, comparing figures 4 and 1, the fit is very analogous in period Q1 2010 – Q4 2013. Moreover, figure 4 shows that the real output exceeds an upper bound of the 95% confidence interval of its synthetic counterpart in the same period (Q1 2015) as in figure 1 with a very similar magnitude. This suggests that the effect of the intervention is not negligible in terms of Seasonally Adjusted GDP per Capita.

Figure 4: Seasonally Adjusted GDP per Capita Reassigned to the period Q1 2010.



Source: Synthetic control method computation.

Taking into account figures 1 and 3, there might be an effect of the intervention on per capita GDP. Nevertheless, there are several events which had an impact on the effect of the intervention. For instance, the changes in indirect taxes mainly for tobacco products. As Holub (2013) comments, the acceleration of GDP growth was largely due to the increased collection of duty on tobacco products.

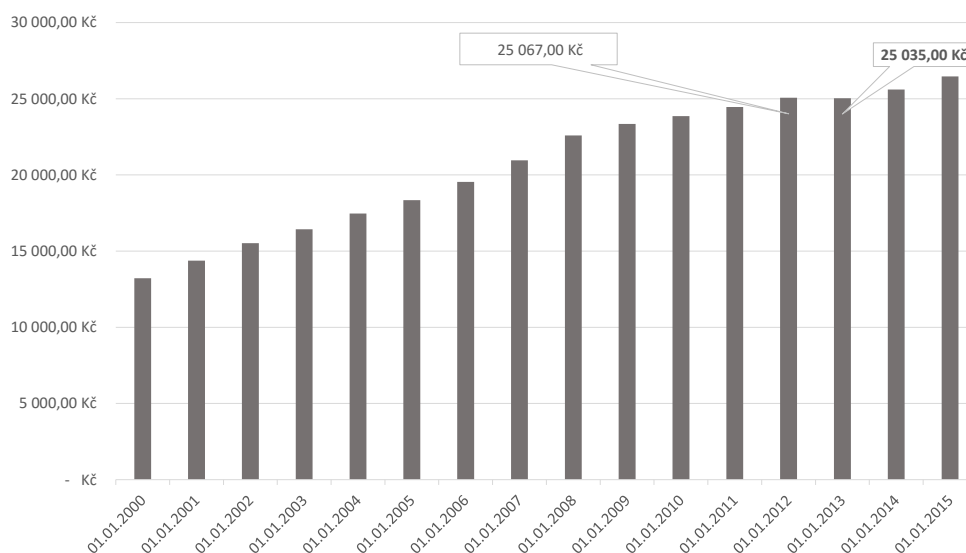
Another factor influencing the Czech economy is the restrictive fiscal policy at the beginning of the intervention. Together with the intervention, the restrictive policy might lead to an increase in net export and, therefore, to an increase in GDP growth.

Holub (2015) pp. 2 also adds:

The Czech economy did not begin 2013 in good shape: it was still in a prolonged recession and falling ever deeper below its potential. In the middle of the year it reached the bottom of the economic downturn; nonetheless, even subsequent to this milestone it was still not possible to point to any significant recovery. At the same time, the growth of wages significantly slowed and unemployment increased. The anti-inflationary domestic conditions caused a decline of inflation at the beginning of the year below the 2% CNB target, despite a January increase in indirect taxes, while at the same time core inflation remained negative.

Moreover, as can be seen in figure 5, the nominal wages decreased in the year 2013.

Figure 5: Annual Nominal Wage



Source: CNB ARAD time series database.

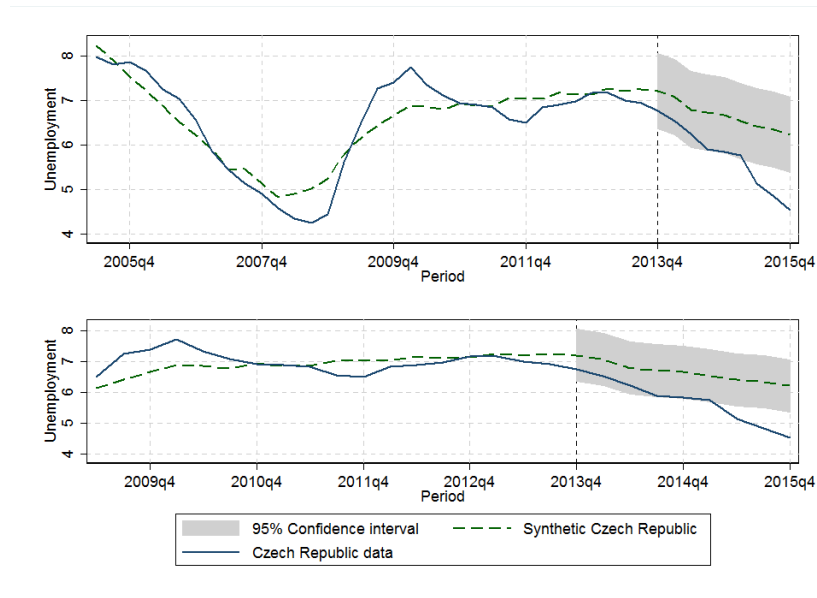
In summary, all of these idiosyncratic events had an undoubted impact on the performance of the Czech Republic. Therefore, these events should be considered when evaluating the synthetic counterpart in figures 1 and 4.

4.2 Unemployment

Figure 6 displays the effect of the intervention on the unemployment rate in the Czech Republic during the period Q1 2005–Q4 2015. The synthetic Czech Republic data mildly fit that of the real unemployment data in the pre-intervention period. Together with the close fit of predictor means (HCPI, Seasonally adjusted GDP per capita, Index of Wage in Industry Sector, and unemployment rate itself) in table 5, we can conclude that there exists a combination of other European countries that reproduces economic characteristics of the Czech Republic before the intervention. Moreover, there is a significant positive effect of the intervention on the unemployment rate.

According to Český statistický úřad (2016), the exact number of unemployed people¹⁶ in the Czech Republic is 239 000 (4.5% in terms of unemployment rate) at the end of the period Q4 - 2015. The synthetic Czech Republic in figure 6 indicates that the unemployment rate would be 6.3% without the intervention at the end of the period Q4 - 2015. In other words, there are 95 600¹⁷ fewer unemployed people in the Czech Republic than there would be without the intervention, with a 95% level of significance.

Figure 6: Unemployment Rate



Source: Synthetic control method computation.

¹⁶Any person between 15 and 64 years old. See chapter A for detailed information.

¹⁷Based on the author's computation, assuming that 4.5% is equal to 239 000, meaning that 6.3% is equal to 344 600. Finally, after deduction, the result is 95 600.

In table 4 we can see the predictor weights, which are computed by the nested optimization process. The weights selected by the process indicate that the most important predictors are unemployment rate, Seasonally Adjusted GDP per capita, HCPI, Real Exchange Rate, Final Consumption per Capita, and Index of Wage in Industry Sector in this order.

Table 4: Predictor Weights

Country	Synthetic Control predictor weight
Seasonally Adjusted GDP per capita	0.285
Final Consumption per Capita	0.007
Real Exchange Rate	0.014
Index of wage in Industry Sector	0.003
HCPI	0.206
Unemployment Rate	0.486

Source: Synthetic control method computations.

Table 5 compares the pre-intervention characteristics of the Czech Republic to those of the synthetic Czech Republic. The synthetic units is very similar to the treated units in terms of Seasonally Adjusted GDP per Capita, Index of wage in Industry Sector, HCPI, Final Consumption per Capita, and unemployment rate. On the other hand, the differences between the Real Exchange Rate and its synthetic counterpart is larger. However, as table 4 indicates, its predictive power is nearly negligible.

Table 5: Predictor Means Before the Intervention

Country	Treated Unit	Synthetic Unit
Seasonally Adjusted GDP per capita	2.214	1.967
Final Consumption per Capita	0.840	0.915
Real Exchange Rate	113.451	105.544
Index of wage in Industry Sector	88.060	90.373
HCPI	2.455	2.468
Unemployment Rate	6.590	6.601

Source: Synthetic control method computations.

Table 6 shows the weights of each country from the control units. The synthetic Czech Republic related to the unemployment rate is a weighted average of Denmark, Luxembourg, Poland, and Germany with weights decreasing in

this order. All other countries¹⁸ obtain zero weights.

Table 6: Countries Weights

<i>Country</i>	<i>Synthetic Control Weight</i>
Austria	0
Belgium	0
Bulgaria	0
Croatia	0
Denmark	0.362
Estonia	0
France	0
Germany	0.054
Hungary	0
Italy	0
Latvia	0
Lithuania	0
Luxembourg	0.362
Netherlands	0
Poland	0.222
Portugal	0
Slovakia	0
Slovenia	0
Spain	0
Sweden	0
United Kingdom	0

Source: Synthetic control method computations.

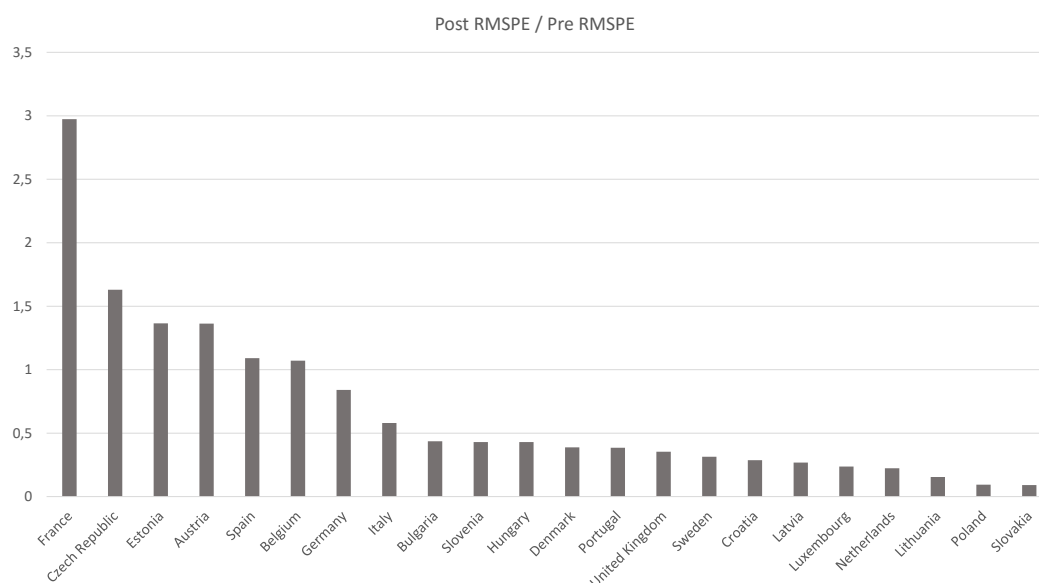
4.2.1 Robustness tests

To evaluate the significance of our estimates, we run placebo studies in the same manner as used to determine the Seasonally Adjusted GDP per capita.

Firstly, we reassign the intervention to each country in its control unit. Therefore, we obtain the RMSPE for both pre-intervention and post-intervention periods. Figure 7 shows the ratio of the post-intervention RMSPE and pre-intervention RMSPE. In this case, the Czech Republic has the second highest ratio. In other words, figure 7 indicates that the effect of the intervention on the unemployment rate is large in comparison with other countries in the control unit.

¹⁸Again we exclude Ireland because of missing values for Seasonally Adjusted GDP per capita for whole sample period.

Figure 7: Ratio of Post-intervention RMSPE and Pre-intervention RMSPE Related to the Unemployment Rate



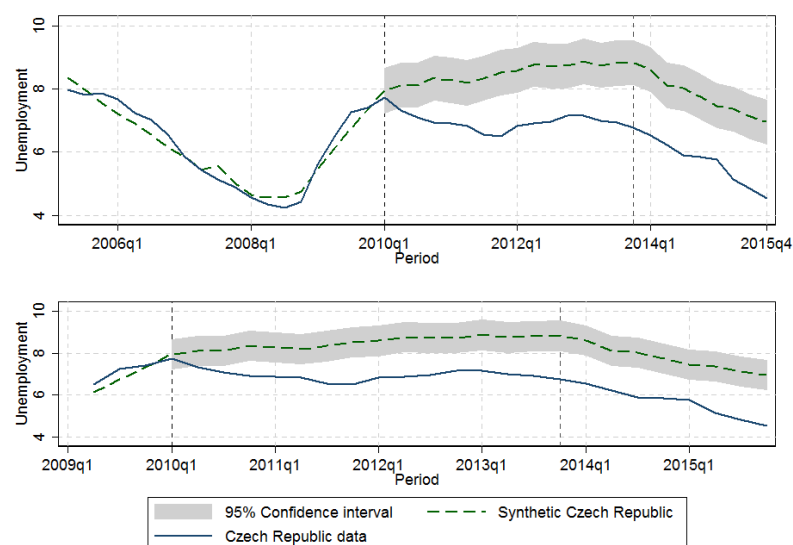
Source: Synthetic control method computation.

Secondly, we rerun the model with the intervention reassigned to the period Q1 2010, which is about 13 quarters earlier than when the intervention was launched. Again, we use the same technique for choosing the weights for the control units. In figure 8 we can see the results.

The synthetic Czech Republic precisely reproduces the trajectory of the unemployment rate until the period Q1 2010. Nevertheless, unemployment rate trajectories of the Czech republic and its synthetic counterpart do differ during the period Q1 2010 - Q4 2013¹⁹ period. The possible reason might be low unemployment rate in the Czech republic in comparison with the average unemployment rate of countries in control unit during Q1 2010 - Q4 2013, what indicates figure 9. However, the trajectory of the synthetic Czech republic follow the same path as that in figure 6 during the period Q4 2013 - Q4 2015. This supports the finding of positive effect from figure 6.

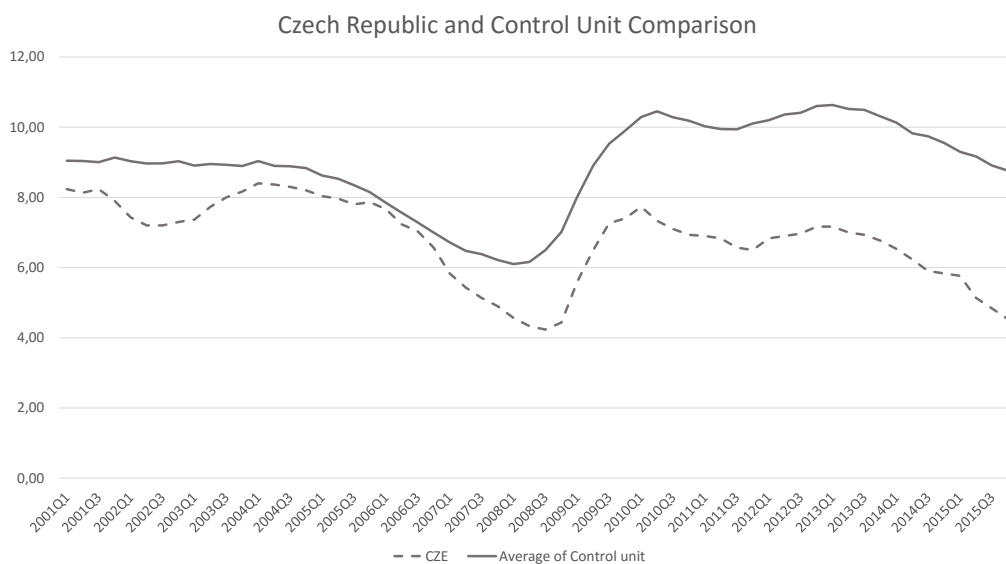
¹⁹Indicated as a non-labelled dash line on figure 8

Figure 8: Unemployment Reassigned to the Period Q1 2010.



Source: Synthetic control method computation.

Figure 9: Comparison of Unemployment



Source: Based on author's computation using data from Eurostat database.

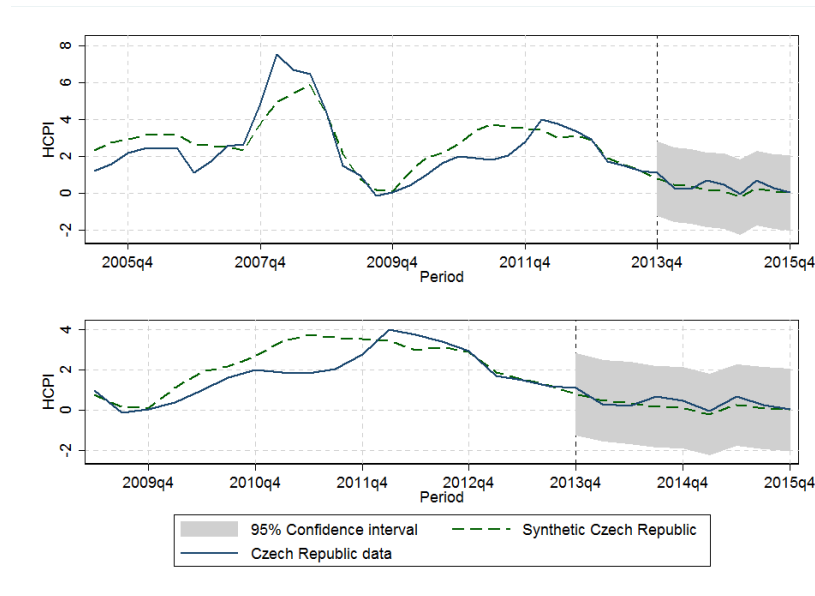
In conclusion, figures 6, 7, and 8 show that there is an effect of the intervention on the unemployment rate in the Czech Republic. Moreover, compared to the GDP per capita in section 4.1, the effect is relatively large. This could be

due to the fact that the unemployment rate is less dependant on the idiosyncratic events mentioned in the end of section 4.1.1. For instance, in contrast with GDP per capita, increasing the indirect tax on tobacco products and intensified pumping of structural funds from the EU did not have direct impacts on the unemployment rate.

4.3 Harmonized Consumer Price Index

In this section, we provide the results of the impact of the intervention on HCPI. In figure 10, the reader can see the estimation of the HCPI synthetic counterpart during the period Q1 2005–Q4 2015. Additionally, we show the estimation for the period Q4 2007–Q4 2015 in figure 11.²⁰ Keep in consideration that all tables below are related to the period Q1 2005–Q4 2015.

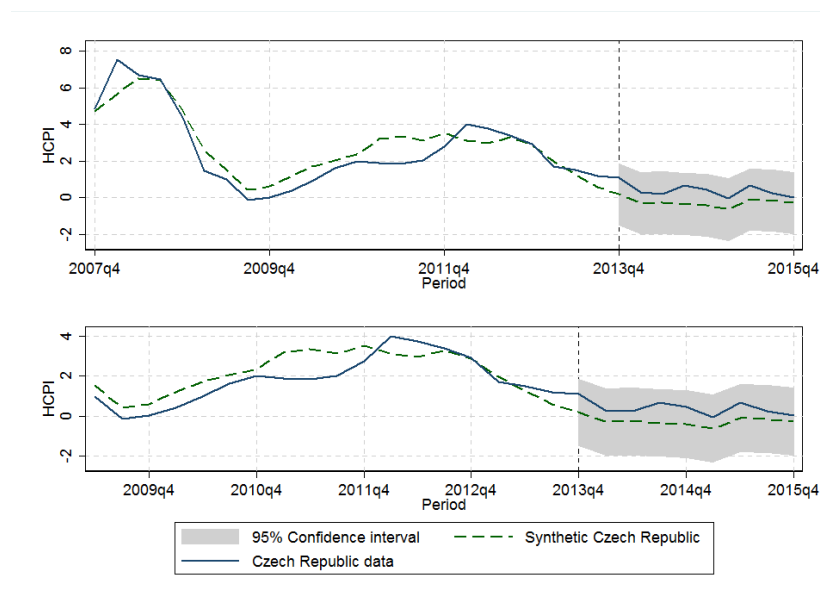
Figure 10: Harmonized Consumer Price Index Q1 2005–Q4 2015



Source: Synthetic control method computation.

²⁰Appendix A provides related tables with weights of countries and predictors.

Figure 11: Harmonized Consumer Price Index Q4 2007–Q4 2015



Source: Synthetic control method computation.

Both figures indicate that the Czech Republic's synthetic counterpart would touch level zero of the HCPI from the negative side of y-axis. Furthermore, it remains below the real Czech Republic's HCPI after the intervention, which suggests the positive effect of the intervention on the HCPI in the Czech Republic. On the other hand, the real Czech data does not exceeds the 95% confidence interval of its synthetic counterpart, which should be considered when interpreting the result.

Table 7 displays weights of predictors. The prediction power of the predictors decrease in following order: Seasonally Adjusted GDP per capita, Real Exchange Rate, HCPI, Index of Weight in Industry Sector, Final Consumption per Capita, and unemployment rate.

Table 7: Predictor Weights

Country	Synthetic Control predictor weight
Seasonally Adjusted GDP per capita	0.743
Final Consumption per Capita	0.001
Real Exchange Rate	0.256
Index of Wage in Industry Sector	0.001
HCPI	0.001
Unemployment rate	0.001

Source: Synthetic control method computations.

In table 8, the reader can see the difference between the predictor means of a treated unit and a synthetic one. As explained in Section 3, we use the nested optimization process to calculate the weight of predictors. The table 7 shows that unemployment rate, Final Consumption per Capita, HCPI, and Index of Wage in Industry Sector obtain very small prediction weights. As Abadie *et al.* (2012) say, a small prediction power explains the discrepancy between the variables.

Table 8: Predictor Means Before the Intervention

Country	Treated Unit	Synthetic Unit
Seasonally Adjusted GDP per capita	2.214	2.214
Final Consumption per Capita	0.840	1.490
Real Exchange Rate	113.451	113.445
Index of Wage in Industry Sector	88.060	90.263
HCPI	2.455	2.763
unemployment rate	6.590	8.294

Source: Synthetic control method computations.

In the next table, 9, we can see the weights of countries computed by the synthetic control method. The weights reported in the table indicate that the HCPI in the Czech Republic is best reproduced by a combination of Denmark, Slovakia, Estonia, and Luxembourg with weights decreasing in this order. Note that Ireland is excluded from control units, because of its missing values for Seasonally Adjusted GDP per capita during the whole period Q1 2005–Q4 2015.

Table 9: Countries Weights

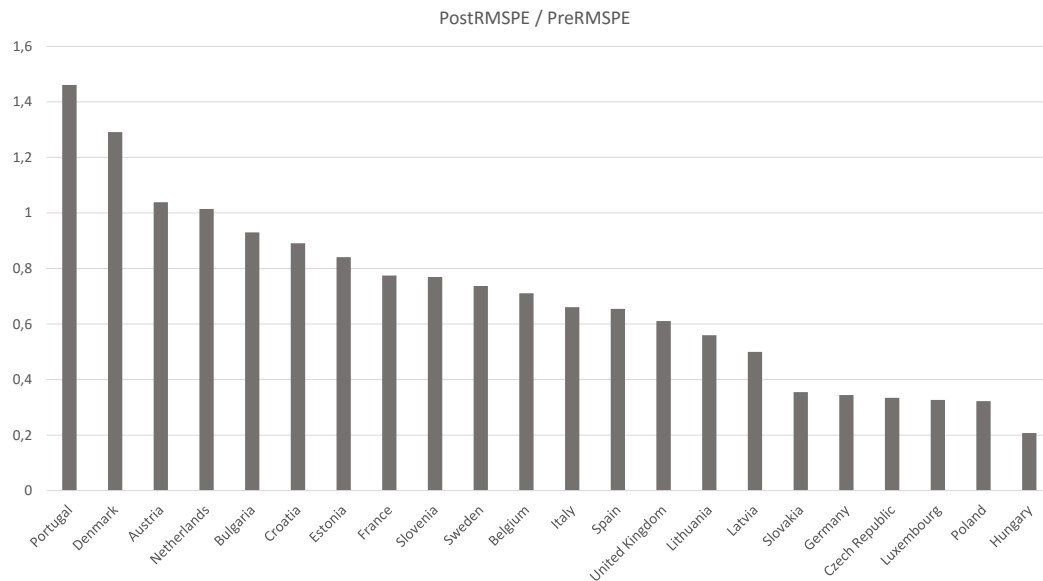
<i>Country</i>	<i>Synthetic Control Weight</i>
Austria	0
Belgium	0
Bulgaria	0
Croatia	0
Denmark	0.487
Estonia	0.200
France	0
Germany	0
Hungary	0
Italy	0
Latvia	0
Lithuania	0
Luxembourg	0.061
Netherlands	0
Poland	0
Portugal	0
Slovakia	0.252
Slovenia	0
Spain	0
Sweden	0
United Kingdom	0

Source: Synthetic control method computations.

4.3.1 Robustness tests

In this subsection we provide robustness tests of results related to the HCPI. As can be seen in figure 12, the Czech Republic stands fourth to last. This indicates that the magnitude of the intervention's effect on the HCPI is not large in comparison to other countries in the control unit. At the end of this subsection, we provide discussion about possible factors that might make the detection of the effect more difficult.

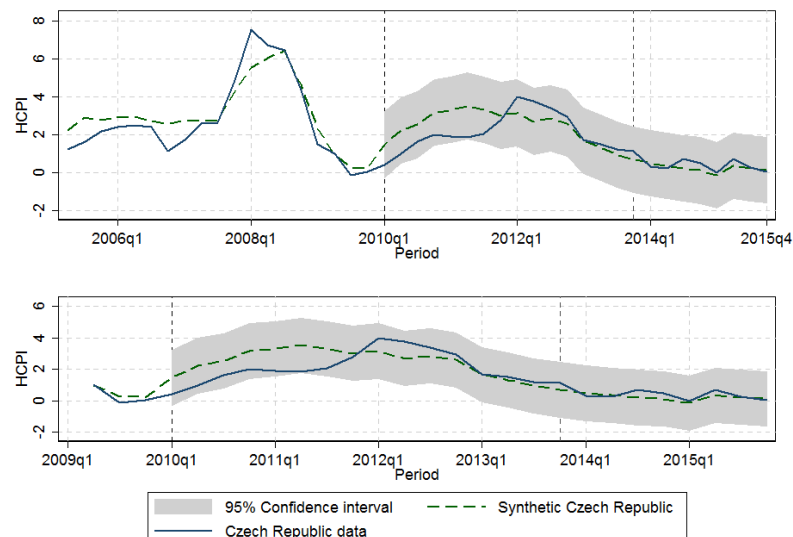
Figure 12: Ratio of Post-intervention RMSPE and Pre-intervention RMSPE Related to the HCPI



Source: Synthetic control method computation.

Figure 13 shows the result of the synthetic Czech Republic when the intervention period is reassigned to the period Q1 2010.

Figure 13: HCPI Reassigned to the Period Q1 2010.



Source: Synthetic control method computation.

Trajectories of real the output and its synthetic counterpart during the

period Q1 2010–Q3 2013 do not differ substantially compare to figure 10. This indicates that reassignment of the intervention has no significant effect on the output. Moreover, the output after the intervention is very similar to the one in figure 10.

When evaluating the effect of the intervention on the HCPI, we should consider several idiosyncratic events that affected both the Czech economy, and also other economies in the control unit. Some of the events that influenced the performance of the Czech economy were mentioned in section 4.1.1, such as an accelerated pumping of EU funds in the year 2014 and increasing indirect tax on tobacco products. On the other hand, the non-standard steps taken by the European Central Bank (ECB) during the crisis had an impact on the economies of the countries in the control unit.

As Mersch (2013) pp. 2 said in his speech at the UniCredit Business Dialogue, Hamburg, 17 June, 2013, the ECB introduced non-standard steps to support economies in the synthetic control unit:

One of these non-standard measures is the policy of full allotment in our refinancing operations against appropriate collateral. We have also extended the maturities of our refinancing operations up to three years and have expanded the collateral framework. These measures are geared towards bank's refinancing conditions, which in turn make it easier for credit institutions to provide sufficient credit to the economy at favourable terms.

Last summer we decided on more far-reaching measures - notably the announcement of the Outright Monetary Transactions. Prior to this announcement, we had to observe that market financing conditions were increasingly characterised by the fears among market participants that Member States would revert back to their national currencies. The markets hence priced in a conversion risk premium. Owing in part to this premium, the refinancing conditions of many commercial banks - and thereby the real economy - deteriorated dramatically.

The monetary policy of ECB is committed to maintaining price stability in the euro area as a whole. So we had to take measures that would ensure that our single monetary policy would take effect in all Member States.

All mentioned idiosyncratic events should be considered when interpreting the results of this paper related to the Harmonized Consumer Price Index.

5 Conclusion

In this paper we examine the impact of the Exchange Rate Commitment introduced by the CNB in the period Q4 2013. By using the synthetic control

method developed by Abadie & Gardeazabal (2003), we estimate an effect of the intervention on the Seasonally Adjusted GDP per capita, unemployment rate, and Harmonized Consumer Price Index. The procedure involves identifying the effect by comparing the real path of the outcome of interest with its synthetic counterpart computed by the SCM.

Our estimates show a positive significant effect of the intervention on the unemployment rate, which created around 100,000 working positions by the end of the year 2015. We also demonstrate a slight positive significant effect on the GDP per capita and an insignificant effect on the Harmonized Consumer Price Index. However, in the case of GDP per capita and HCPI, there are several idiosyncratic events that might make the visibility of the magnitude of the effect more difficult. The accelerated pumping of EU structural funds in the year of 2014 and increasing an indirect tax on tobacco products might overestimate the results. On the other hand, the restrictive fiscal policy at the beginning of the intervention, the decreasing of the nominal wage in the year 2013, and the deflation expectation might underestimate the effect of the intervention. Moreover, the introduction of the non-standard steps of the ECB during the crisis in order to fight the falling economies of the Eurozone plays a negative role in discovering the effect of the exchange rate commitment.

Overall, the estimated effects of the Czech National Bank's Exchange Rate Commitment are positive to neutral for selected macroeconomic predictors. However, the decisiveness of the results related to GDP per capita and HCPI are negatively affected by idiosyncratic events influencing the Czech economy before and after the intervention of the Czech Nation Bank. The long term effects are subject to be observed.

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