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2017

CZECH NATIONAL BANK

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4/2017

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# An Exchange Rate Floor as an Instrument of Monetary Policy: An Ex-post Assessment of the Czech Experience

Jan Brůha and Jaromír Tonner *

## Abstract

In November 2013 the Czech National Bank introduced a floor for the Czech koruna exchange rate as its monetary policy instrument. The rationale for this action was to prevent the risk of deflation in a zero-lower-bound environment where policy rates could not be lowered any further. The goal of this paper is to assess ex post the effect of the exchange rate floor on the Czech economy – inflation and the main real aggregates. The paper uses two different approaches. First, the official DSGE forecasting model is used to simulate the counterfactual macroeconomic dynamics of no introduction of a floor. Second, the paper applies an empirical approach: the synthetic control method and its generalised variant are used to estimate these counterfactual trajectories. Both approaches show that the floor prevented inflation from turning negative. Moreover, both methods indicate likely positive effects on macro variables and on various measures of inflation, although strongly statistically significant effects are only obtained for core inflation. The statistical significance for other variables is weaker or zero. We conclude that the introduction of the exchange rate floor was a correct policy action that has retrospectively been successful.

## Abstrakt

Česká národní banka v listopadu 2013 zavedla kurzový závazek s dolní hranicí pro kurz české koruny jako nástroj své měnové politiky. Důvodem tohoto opatření bylo odvrácení rizika deflace v prostředí nulových úrokových sazeb, v němž měnověpolitická sazba nemohla být dále snížena. Cílem tohoto článku je zpětně vyhodnotit dopady zavedení kurzového závazku na českou ekonomiku – inflaci a hlavní makroekonomické agregáty. V článku používáme dva rozdílné přístupy. Za prvé používáme oficiální makroekonomický model DSGE k simulacím kontrafaktuálních trajektorií pro případ, že by závazek zaveden nebyl. Za druhé k odhadu těchto kontrafaktuálních trajektorií používáme empirické metody: metodu syntetické proměnné a její zobecněnou variantu. Oba přístupy ukazují, že zavedení závazku zabránilo pádu inflace do záporných hodnot. Navíc oba přístupy nachází pravděpodobné pozitivní dopady na makroekonomické proměnné a na různé míry inflace. Statisticky signifikantní výsledky jsou nicméně dosaženy pouze pro jádrovou inflaci. Statistická signifikance pro ostatní veličiny je slabá nebo žádná. Uzavíráme tedy, že zavedení kurzového závazku lze ze zpětného pohledu hodnotit jako správné a úspěšné měnověpolitické opatření.

**JEL Codes:** C21, E58, F47.
**Keywords:** DSGE modelling, exchange rate policy, monetary policy in a zero interest rate environment, synthetic control method.

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We thank Vít Bárta, Francesca Caselli, Michal Franta, Tibor Hlédik, Tomáš Holub, Petr Král, Jan Vlček and Yinquig Xu for helpful comments. The authors are solely responsible for all errors and omissions. The views expressed herein are those of the authors and should not be attributed to the Czech National Bank.

## Nontechnical Summary

After the outbreak of the Great Recession in 2008, the Czech National Bank gradually eased the monetary conditions by lowering its policy rate. The rate hit "technical zero" in autumn 2012, and thereafter the CNB used forward guidance to further ease the monetary conditions. This, however, was not sufficient, as the 2013 inflation forecasts were predicting that inflation would turn negative in 2014. On 7 November 2013, therefore, the CNB introduced a floor (i.e. a one-sided commitment) for the Czech koruna exchange rate as its instrument: it committed to keeping the Czech koruna/euro exchange rate weaker than the floor of 27 Czech koruna/euro.

The main rationale for this action was to prevent the risk of deflation in a zero-lower-bound environment where policy rates could not be lowered any further. Now, some 30 months later, it is time to assess the effect of the introduction of the exchange rate floor on the Czech economy – inflation and the main real aggregates.

Two different approaches are applied in the paper. First, we use simulations with structural macroeconomic models to obtain the trajectories of the main macroeconomic variables under the counterfactual of no floor. As a benchmark, we use the official g3 DSGE forecasting model. As a robustness check, we use also the DSGE model by Tonner et al. (2015), which has the advantage of having a detailed labour market block. The second approach is empirical: the synthetic control method and its generalised variant are used to estimate these counterfactual trajectories.

Both the model-based simulations and the two empirical methods show that the floor prevented inflation from turning negative. Also, all the methods indicate positive effects on macro variables and on various measures of inflation. The effect on core inflation is strongly significant both statistically and economically. Without the floor, core inflation would have been negative. The statistical significance for the rest of the variables (headline inflation and real variables) is weaker. We interpret these findings as follows. First, the exchange rate floor affected inflation in the intended way. Second, the effects on the real economy were most likely positive. We at least find no evidence that the exchange rate floor hurt the real economy.

It should be mentioned the methods employed – since they are linear in nature – cannot capture the possible benefits of preventing the economy from falling into a vicious deflationary spiral. The extent and magnitude of the risks and costs of deflationary spirals are currently being discussed a great deal by both academics and policymakers. This paper is salient to this issue. If one believes that the risks are real and the costs are sizeable, then the benefits of preventing deflation are much larger than indicated in this paper.

All in all, given the strong evidence for positive effects on core inflation, and given that there is no evidence that the floor hurt the real economy, we conclude that the introduction of the exchange rate floor was a correct policy action that has retrospectively been successful.

# 1. Introduction

After the outbreak of the Great Recession in 2008, the Czech National Bank gradually eased the monetary conditions by lowering its policy rate. The rate hit "technical zero"[1] in autumn 2012, and thereafter the CNB used forward guidance to further ease the monetary conditions. This, however, was not sufficient, as the 2013 inflation forecasts were predicting that inflation would turn negative in 2014. On 7 November 2013, therefore, the CNB introduced a floor (i.e. a one-sided commitment) for the Czech koruna exchange rate as its instrument: it committed to keeping the Czech koruna/euro exchange rate weaker than the floor of 27 Czech koruna/euro. The introduction of the floor caused the Czech koruna to depreciate from 25.8 to 27 CZK/EUR in just a few hours after the floor was announced. From then on, the exchange rate was weaker than, or close to, the floor. The study by Franta et al. (2014) describes in detail the economic environment at that time, the rationale for introducing the floor and the subsequent public debate, and evaluates the initial experience with applying this tool.

Now, 36 months later, it is time to assess the effects of the introduction of the exchange rate floor on the Czech economy. As noted above, the main rationale was a forecast of negative inflation. Nevertheless, positive effects on the real economy have also been mentioned in the public debate on the introduction of this policy instrument.[2] What would the inflation rate have been if the floor had not been introduced? Did the positive effects on the real economy materialise?

After the floor was introduced, the Czech economy enjoyed positive growth during 2014 and 2015 (of 2.7% and 5.4% respectively). The factors said to be behind the positive growth (other than the possible effects of the weaker koruna) were a recovery in growth in the euro area, domestic fiscal policy and a fall in oil prices. The November 2013 GDP forecast was almost fulfilled in 2014, and in 2015 the actual growth was higher than predicted. On the other hand, inflation remained very low and well below the inflation target during this period. This was attributed to strong deflationary tendencies in the euro area and to a fall in food and energy commodity prices. These factors outweighed the effects of the weakening of the nominal exchange rate as well as the demand effects of the growing economy on inflation. Because of the low, below-target inflation and the threat that a sustained period of low inflation might affect inflation expectations, the duration of the exchange rate floor was prolonged several times. To sum up, the dynamics of inflation were disappointing, as it remained low and below the target in the period 2014–2015, while the positive outlook for real variables materialised.

It is certainly not enough to do a plain comparison of what happened to inflation and the real economy after November 2013 (even relative to the then forecast). Although inflation did not hit the target, this does not mean that the floor did not increase it: without the floor, inflation may have been even lower. Similarly, the growing economy in 2014 and 2015 is not proof that the floor

[1] There are restrictions on zero or negative central bank interest rates, as some legal rules define penalty interest as a multiple of the CNB discount rate. Given the strictly legalistic Czech system, a negative discount rate would imply that creditors would have to start paying money to debtors in arrears, which would be at odds with the purpose of the penalty.

[2] Various effects on the real economy have been mentioned. First, from the perspective of New Keynesian economics, the direct effects on the real economy stem from re-consideration of the intertemporal plans of consumers, who increase their consumption due to the fall in the real interest rate. This was supposed to help overcome the recession at the time. Second, as the Czech economy is an open economy, a nominal depreciation could have temporary positive side effects on exports, effects which could spill over to the rest of economy, increasing wages and reducing unemployment and therefore further boosting output and private consumption. Finally, the risk of deflation was seen as a serious menace that could trigger a deflationary spiral, i.e. a vicious circle of ever-falling prices, wages and real activity.

helped the economy, as positive growth may have been achieved even without (or despite) it. We therefore need to ask what would have happened had the exchange rate floor not been introduced. In other words, we need to conduct a counterfactual analysis.

The goal of this paper is therefore to perform a counterfactual analysis of the introduction of the FX floor. To do so, we employ two different approaches. First, ex-post simulations with the official g3 structural macroeconomic forecasting model (Andrle et al., 2009) are used. The advantage of employing the structural model is that it allows for model-consistent filtration of structural shocks: the filtered shocks can be used for counterfactual simulations using a model without any constraint on the exchange rate. To achieve more robustness and to allow for the possibility of evaluating more variables, we repeat the exercise with another DSGE model, the one by Tonner et al. (2015). This alternative DSGE model has the advantage that it contains a detailed labour market block, so the effects on unemployment can also be simulated.

Second, we apply an empirical approach: the synthetic control method (Abadie et al., 2010) and its generalised variant (Xu, 2015). The synthetic control method involves constructing the counterfactual as a (convex) combination of control units, i.e. countries not affected by the policy action. The weights of the combination of control countries are determined based on the pre-treatment outcomes (i.e. the outcomes before the introduction of the exchange rate floor). We consider several sets of control countries and the results seem to be pretty robust across the choice of control countries. Finally, we compare our results with those of other studies that have addressed this issue.

Our results are the following. Both the model-based simulations and the point estimates of both the synthetic control method (SCM) and the generalised synthetic control method (GSCM) yield positive effects of the floor on real variables and inflation. This is in line with the results of other studies. Although the SCM estimates for real macroeconomic variables are positive, no real variable passes the placebo test, which is a reality check for the SCM: only core inflation passes the placebo test. Hence, the SCM cannot prove that the effects were indeed positive for the real economy, but the floor worked for inflation in the intended way. The results for the GSCM are more encouraging: not only does it find both a statistically and economically positive effect on inflation, but also the effects on real variables are statistically significant.

Our interpretation of these results is as follows. First, it is almost certain that the floor prevented core inflation from turning negative.[3] The insignificant results for headline inflation are probably due the high volatility of this indicator. Second, we can be pretty confident that the exchange rate floor did not hurt the real economy. The empirical methods – in line with the simulations with structural models – suggest that the floor helped the real economy. All in all, given that there is a strong evidence for positive effects on core inflation and there is no evidence that the floor hurt the real economy, we can conclude that this policy action was successful.

The rest of the paper is organised as follows. The next section 2 contains the model-based assessment. In Section 3 we describe the application and results of the synthetic control method, which is the empirical technique used for the counterfactual analysis. Section 4 compares our results with the results of other studies. The last section 5 concludes. Appendices contain additional material.

[3] This means that the menace of a deflationary spiral was averted. Standard sticky price models with intertemporally optimising consumers predict that deflation at the zero lower bound results in economic disaster: a deflationary spiral with non-fundamental fluctuations (Benhabib et al., 2002). On the other hand, there are economists who doubt the reality of this deflation trap concept; e.g. Cochrane (2017). We do not want to enter these discussions in this paper. That is why we stick to a weaker statement about negative numbers and leave the assessment of the reality of deflation traps to the reader. We are grateful to Vít Bárta for discussions on this issue.

## 2. Model-based Assessment

The Czech National Bank uses a DSGE model called g3 as its main tool for creating its official forecasts and also for conducting ex-post evaluations of its past forecasts. The model is described by Andrle et al. (2009) and the experience with the forecasting process using the g3 model since 2008 is discussed in detail by Brůha et al. (2013). It is therefore natural to do our ex-post analysis using this model to evaluate whether the bright prospects associated with the introduction of the floor materialised.

In normal times, the evaluation exercise for a monetary policy action would be quite straightforward: first, structural shocks would be filtered and then the economy would be simulated under the shocks identified and without the policy action. In our case, however, the policy action took place when the lower bound on policy rates was binding. It is well known that it is not trivial to impose inequality constraints such as a zero lower bound or an exchange rate floor in a linear forward-looking model. Fortunately, recent advances in computational economics offer methods of overcoming these technical difficulties. In the case of the g3 model, it was decided to model the zero-lower-bound constraint (which was binding in November 2013) in the standard way by means of shadow shocks to the monetary policy rule.[4] The exchange rate floor is a one-sided commitment which, in the case of the CNB, states that the central bank will not allow the nominal exchange rate to appreciate below some threshold (27 CZK/euro). This commitment can be indefinitely defended by "printing money", so it is natural to present it in the DSGE framework by means of shadow UIP shocks.[5]

The g3 model was used for generating the November 2013 forecast, the discussion of which by the Board led to the decision to introduce the floor. One can therefore argue that there is a danger of circular reasoning: if the model used to generate the then forecast was biased, the ex-post analysis could be biased as well. To address this potential criticism, we repeat the exercise with another DSGE model, the one by Tonner et al. (2015), which is also calibrated for the Czech economy. Moreover, the labour market block in the g3 model is very stylised and unemployment is not among the observable variables of the model, while Tonner et al. (2015) contains detailed labour market blocks and the effects on unemployment can be simulated.

The results of the counterfactual exercise are shown in Figure 2. The effect of the floor on real GDP growth is 1.2 pp in 2014 and 0.6 pp in 2015 according to the g3 model, while it is 0.8 pp and 1.2 pp respectively according to the alternative model by Tonner et al. (2015). The latter model evaluates the floor's contribution to the fall in unemployment at 0.3 pp in 2014 and 1.2 pp in 2015. A reduction of the unemployment rate of 0.25 pp means about 10,000 jobs more (provided that the labour force was unaffected). Hence, both models indicate positive – although not huge – effects on the real economy.

According to the g3 model, the floor increased CPI inflation by 1.2 pp in 2014 and 1.8 pp in 2015 compared to the counterfactual. The alternative model gives similar numbers: 1.2 pp and 1.5 pp

[4] The idea behind the "shadow shock" approach is to add artificial expected shocks to the structural equations so that the inequality constraints are satisfied (details on how these shocks are set can be found in Appendix A). The advantage of the shadow shocks approach is not only that it can be used for generating forecasts subject to inequality constraints, but also that the shocks can be filtered historically; see, for example, Appendix B in Lindé et al. (2016) for an algorithm of how this can be done.

[5] Modelling the opposite commitment would be much harder, as it would have to take into the account the size of the central bank's reserves.

respectively. The effects on net inflation are even higher:[6] 1.4 pp and 2.1 pp according to the g3 model and 1.4 pp and 1.8 pp according to the alternative model. More importantly, according to both models, both CPI inflation and net inflation would have been negative in 2014 and 2015 if the floor had not been introduced. Both models therefore indicate that the floor prevented inflation from turning negative, which could have triggered a dangerous deflationary spiral.

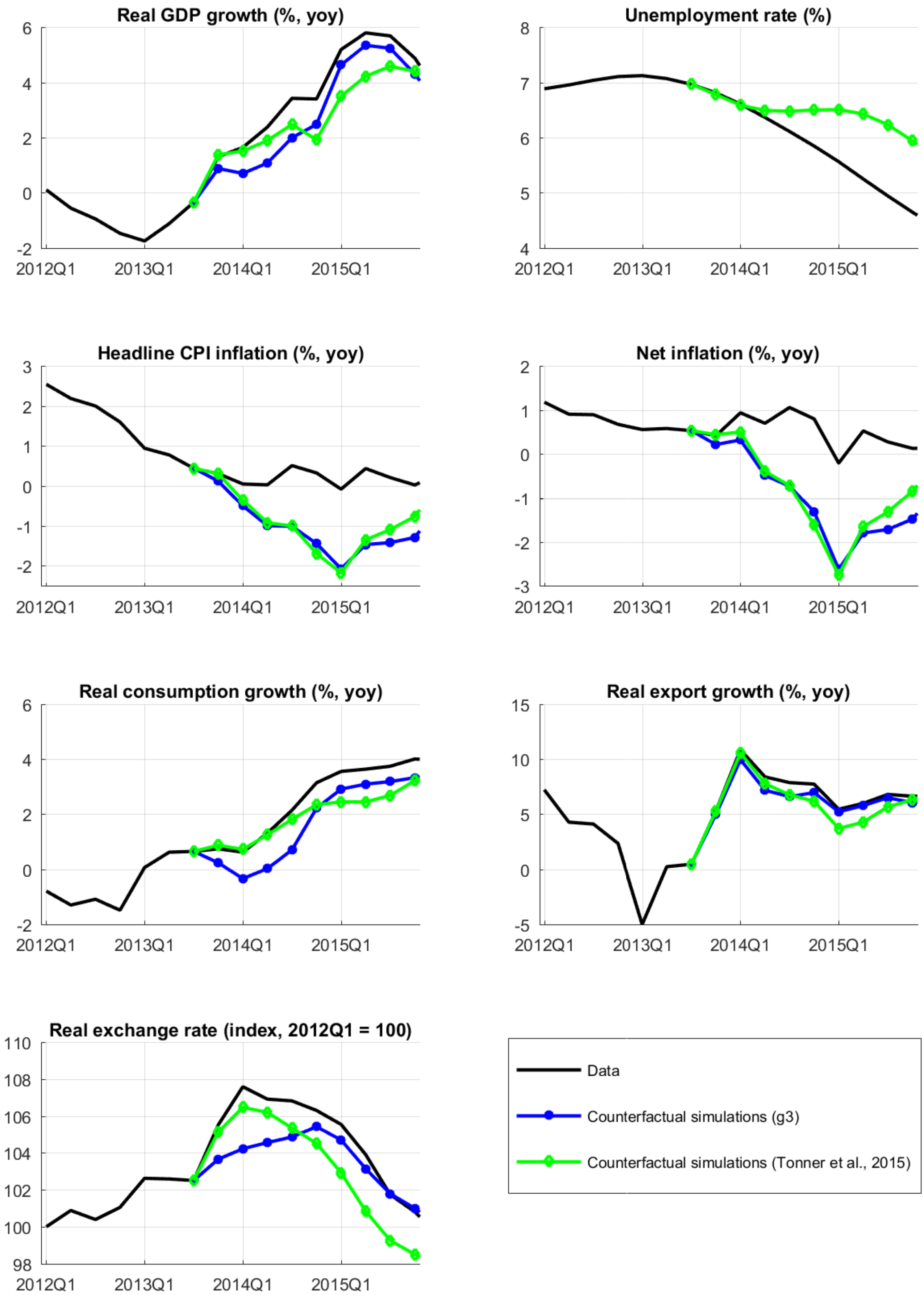
The floor increased real consumption. The main channel in the New Keynesian framework is the re-optimisation of intertemporal consumption plans, as an increase in inflation causes a drop in the real interest rate when nominal rates are stuck at zero. Other channels can be identified, too. In particular, growth in exports boosts employment and wages. This shifts households' real income up, which translates to a rise in real household consumption. These two effects outweigh the inflation effect, which *ceteris paribus* would negatively affect real household income and consumption. To sum up, real consumption growth was 1.4 pp higher in 2014 and 0.9 pp higher in 2015 than the counterfactual according to the g3 model. The alternative model evaluates the effect on real consumption growth at 0.3 pp in 2014 and 1.0 pp in 2015.

The effects on real export growth are generated mainly through the temporarily weaker real exchange rate and are estimated to be 1.0 pp in 2014 and 0.4 pp in 2015 according to the g3 model. The export effects according to the alternative model are somewhat larger: 0.9 pp in 2014 and 1.2 pp in 2015.

Finally, we compare the actual and counterfactual paths of the real exchange rate (see the last chart in Figure 2: an increase means depreciation). In the counterfactual simulations, the real exchange rate is clearly stronger by 2.1 % in 2014. Nevertheless, it is worth noting that by the second half of 2015, the actual and counterfactual real exchange rates have converged. This reflects the lower domestic inflation in the counterfactual, which balances the stronger nominal exchange rate. This result nicely illustrates the fact that monetary policy is only able to influence relative prices in the short to medium run, while in the long run it can only influence nominal variables. This explains why the real economy effects in the model-based simulations are strongest after the introduction of the floor and why they weaken over time.

[6] The larger effect on net inflation is to be expected, as net inflation excludes administrative prices, which are less affected by exchange rate appreciation than standard market prices.

***Figure 1: Model-based Assessment of the Effect on Macro Variables***



## 3. Empirical Assessment

In this part of the paper, we apply the empirical approach – the synthetic control method (SCM) and its generalised variants (GSCM). These methods assess the effects of an intervention as the difference between the actual outcome of the treated unit (i.e. the Czech Republic) and its counterfactual "synthetic" counterpart. The counterfactual counterpart is called *synthetic* because it is synthetised from control (i.e. non-treated) units. In practice, this means that the counterfactual outcome for Czech macro variables is given as a linear (and often convex) combination of the outcomes of the control countries. Formally, let $Y_t^{CZ}$ be the actual (and hence observed) outcome of interest for the Czech Republic at time $t$. Then, the estimated effect of the policy action is given as follows:

$$\text{effect}_t = Y_t^{CZ} - Y_t^{\text{syn}},$$

where $Y_t^{\text{syn}}$ is the counterfactual outcome estimated as a linear combination of the observed outcomes of the control countries:

$$Y_t^{\text{syn}} = \sum w_i Y_t^i + \mu. \tag{1}$$

Various variants of the synthetic control method differ in how the weights $w_i$ of the linear combinations and possibly the intercept $\mu$ are determined. Doudchenko and Imbens (2016) provide an overview of the various possible methods and put them into a broader context.[7]

As the benchmark set of control countries, we consider the union of the new accession countries,[8] the remaining non-euro EU countries[9] plus Germany and Austria as important trade partners of the Czech Republic. We also consider three alternative sets of control countries: (i) all EU countries, (ii) new accession countries, (iii) non-euro area EU countries.[10] It should be noted that some of countries in the control group underwent some kind of treatment (such as the quantitative easing policy of the European Central Bank), so the SCM is likely to slightly underestimate the effect of the floor on the Czech economy.

For all variants of the synthetic control methods, we consider the following variables: real GDP growth, the unemployment rate, headline CPI inflation, a measure of core inflation, real consumption growth, real export growth and the real exchange rate. The source for all data is Eurostat. For real GDP, consumption and export growth, we consider seasonally and working-day adjusted data.[11] Headline CPI inflation is measured by the overall HICP index. As a measure of core inflation, we take the non-energy industrial goods sub-index of the HICP.[12]

[7] It is worth noting in particular that the well known difference-in-difference estimator can be obtained by using uniform weights $w_i = 1/N$.
[8] The set of new accession countries (along with the Czech Republic) consists of Bulgaria, Estonia, Hungary, Lithuania, Latvia, Poland, Romania, Slovakia and Slovenia.
[9] i.e. Denmark, Sweden and the United Kingdom.
[10] These are Bulgaria, Denmark, Hungary, Poland, Romania, Sweden and the United Kingdom.
[11] A few countries do not report seasonally and working-day adjusted data. For them, we consider just seasonally adjusted data.
[12] The motivation is the following: this index should be minimally influenced by commodity prices and we expect that it reflects demand pressures. Ideally, we would want to use median inflation as our measure of demand-driven inflation (Andrle et al. (2013) show that median inflation in the euro area is well aligned with business cycles, while Andrle et al. (2016) show that median inflation is aligned with business cycle fluctuations for a large set of advanced countries). Unfortunately, we are not aware of any officially available data on median inflation for European countries. Therefore, we take the non-energy industrial goods index as a substitute.

We apply two variants of the synthetic control method: the recent formulation by Doudchenko and Imbens (2016) and the generalised variant by Xu (2015). The original formulation of the SCM by Abadie et al. (2010) has already been applied to this question by Caselli (2017) and Opatrny (2016).

### 3.1 Empirical Assessment using the Synthetic Control Method

As noted above, the synthetic control method depends on the appropriate choice of control country weights $w_i$ for the construction of the synthetised control unit $Y_t^{\text{syn}}$ in (1). Abadie et al. (2010) in their original paper suggest determining the weights based on the similarity of the characteristics of the treated unit to the control units in the pre-treatment period. This approach has already been applied to investigate the effects of the floor by Opatrny (2016) and Caselli (2017).

As an alternative, we opt for the approach suggested by Doudchenko and Imbens (2016). They recommend using the elastic net approach to determine the weights.[13] The weights are set as a solution to:

$$\min_{w_i} \sum_{t \in \mathscr{T}_0} (Y_t^{cz} - \sum_i w_i Y_t^i)^2 + \lambda_1 \sum_i |w_i| + \lambda_2 \sum_i w_i^2, \tag{2}$$

where $\mathscr{T}_0$ denotes the set of pre-treatment periods. This approach sets the weight simply as a regression of the Czech outcomes on the outcomes of the control countries during the pre-treatment periods. While plain-vanilla OLS regression is likely to have poor finite sample properties (as the macroeconomic variables of the control countries tend to be highly correlated), elastic net regression is more robust. The coefficients $\lambda_1$ and $\lambda_2$ control the degree of regularisation (i.e. they guard against overfitting). The values of these coefficients are crucial for the reliability of the results, and Doudchenko and Imbens (2016) recommend leave-one-out cross-validation as the way to determine them. We follow their recommendation.

Doudchenko and Imbens (2016) further recommend determining the confidence intervals for the counterfactual trajectory (1) using the cross-validated variances. That is, one can estimate weights $w_i^j$ as a solution to (2) where the Czech Republic is replaced by a control country $j$ (and the dimension of the set of control countries is therefore diminished by 1). For such weights, one can compute the estimates:

$$\ddot{Y}_t^j = \sum_{i \neq j} w_i^j Y_t^i,$$

for all $t \in \mathscr{T}_1$. The variance of the estimated policy effect at time $t$ in the post-intervention period is naturally estimated as:

$$\hat{\sigma}_t^2 = \frac{1}{I} \sum_i (\ddot{Y}_t^i - Y_t^i)^2, \tag{3}$$

which is feasible since $Y_t^i$ are observed. $\hat{\sigma}_t^2$ can be then used to construct the confidence intervals around $Y_t^{\text{synth}}$.

Moreover, $\ddot{Y}_t^i$ can be used to construct the placebo test. If the estimated "effects" $\ddot{Y}_t^i$ for non-treated countries are large, it is apparent that the results are not reliable.

[13] In addition to the recommendation of Doudchenko and Imbens (2016), the elastic net approach has been chosen because it is a flexible regression technique that can guard against overfitting. The results should therefore be more reliable compared to the standard LS regression.

Table 1 summarises the results of the synthetic control method based on specification (2). The estimates and the results for the placebo test are displayed graphically in Figures 2 and 3. The country weights for the benchmark set of control countries can be found in Table B2 in the Appendix.

***Table 1: Results of the Synthetic Control Method for Various Sets of Control Countries***

| | Benchmark set | | New accession countries | | Non-euro EU countries | | All EU countries | |
|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| GDP growth | $0.30^{+}$ | $1.68^{*}$ | 0.57 | 2.18 | -0.05 | 1.00 | 0.40 | 1.79 |
| Unemployment rate | -0.23 | -0.61 | -0.17 | -0.42 | -0.45 | -0.90 | -0.36 | -0.75 |
| CPI inflation | $0.10^{+}$ | $0.58^{+}$ | $0.10^{+}$ | $0.68^{+}$ | $0.48^{+}$ | $0.36^{+}$ | 0.10 | $0.61^{+}$ |
| Core inflation | $2.18^{+}$ | $2.16^{**}$ | $1.15^{*}$ | $0.78^{**}$ | $0.58^{*}$ | $0.43^{+}$ | $0.86^{+}$ | $0.89^{+}$ |
| Consumption growth | 0.36 | 1.47 | 0.50 | 1.51 | 0.14 | 0.96 | 0.42 | 1.51 |
| Export growth | $2.89^{+}$ | $1.70^{+}$ | $4.64^{+}$ | $4.04^{+}$ | $3.49^{+}$ | $1.00^{+}$ | $3.70^{+}$ | $2.79^{+}$ |
| Real exchange rate | $8.1^{+}$ | $7.5^{+}$ | $8.9^{+}$ | $7.4^{+}$ | $9.1^{+}$ | $6.7^{+}$ | $9.0^{+}$ | $8.1^{+}$ |

***Note:*** $^{+}$ denotes significance at 32%, $^{*}$ denotes significance at 10% and $^{**}$ denotes significance at 5%.

Apparently, in contrast to the model-based assessment, the point estimates of real economy effects tend to be larger and higher in 2015 than in 2014. While the model-based evaluation of the effects for real GDP growth for 2014 is roughly similar to the SCM, the empirical method tends to see much higher effects for 2015. For real consumption and real export growth, the method yields much higher effects, and for consumption the effects are higher in 2015. The same applies to the unemployment rate.

Both the model-based assessment and the SCM find a positive effect on inflation, and in both cases the effect on net (or core) inflation is higher than the effect on the CPI. Again, the SCM evaluates the effect for 2015 as higher than that for 2014.

The point estimate of the effect on the real exchange rate attains about 8% in 2014 (again, a positive number means depreciation) and is only slightly lower for 2015. This is in contrast to the structural models: according to the model-based assessment, the difference between the actual and counterfactual real exchange rates almost disappeared at the end of 2015. This is a general difference between the two approaches. The model-based approaches suggest a quicker effect that dies out in about two years. The empirical approach suggests that the effects appear more slowly but persist longer.

Turning to inferential issues, the only significant effect at the conventional 5% is attained for core inflation. From Figure 3 it is clear that only this variable passes the placebo test. That is, based on the SCM results, we can be confident that the floor increased inflation and prevented it from turning negative. On the other hand, the effects on real variables may be positive, but the SCM does not provide strong evidence for this.

***Figure 2: Synthetic Control Method Estimates of the Effect on Macro Variables***

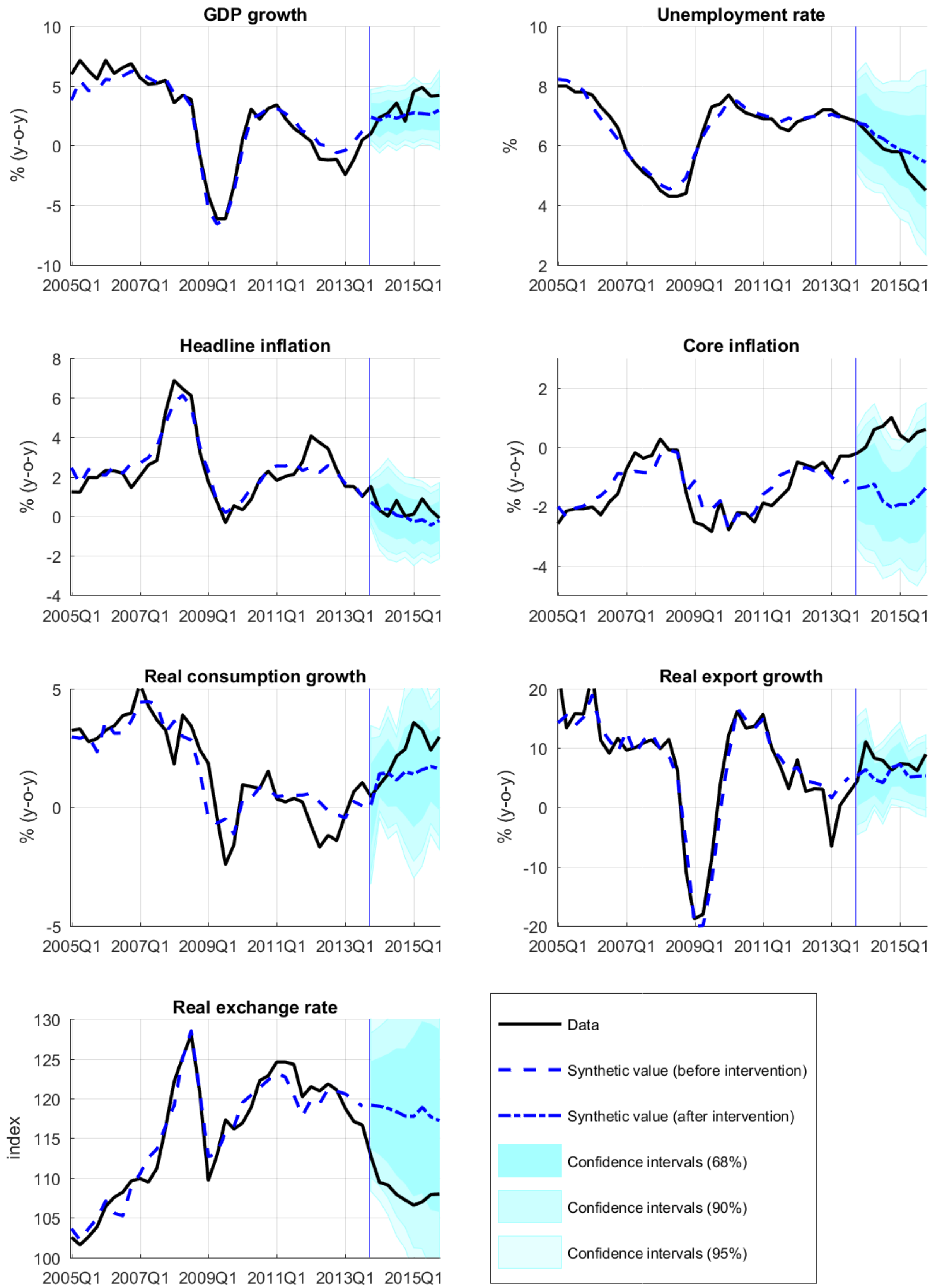
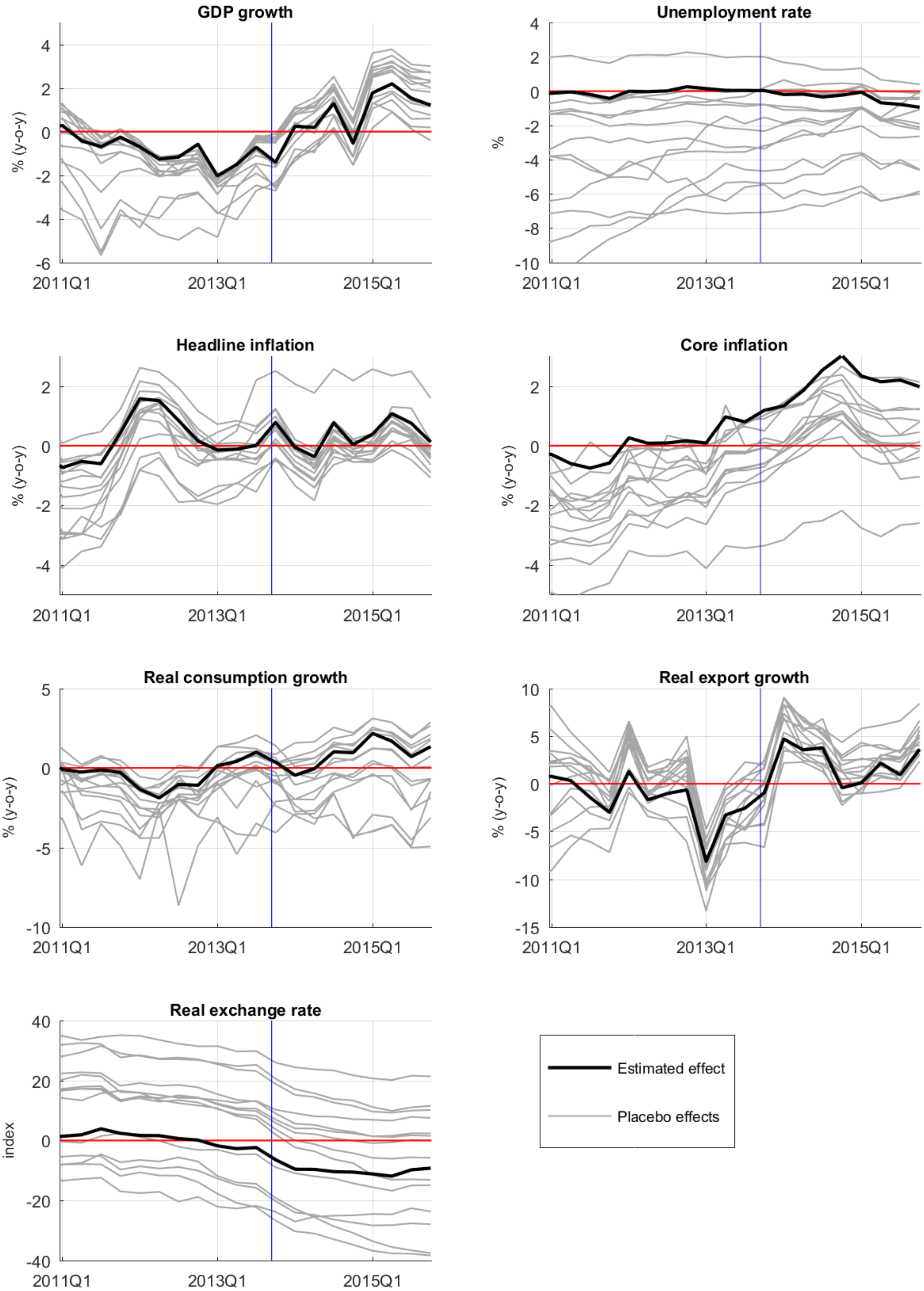


*Figure 3: The Placebo Test for the Synthetic Control Method*



### 3.2 Empirical Assessment using the Generalised Synthetic Control Method

Next, we apply the generalised synthetic control method introduced by Xu (2015). This model assumes the following functional form:

$$Y_{it} = \delta_{it} D_{it} + x_{it}\beta + \lambda_i f_t + \varepsilon_{it}, \tag{4}$$

where $Y_{it}$ is the outcome of interest for country $i$, $D_{it}$ is the dummy for the treatment indicator (i.e. $D_{it} = 1$ if country $i$ was exposed to the treatment prior to time $t$), $\delta_{it}$ is the treatment effect to be estimated, $x_{it}$ is the vector of covariates, $\beta$ is the vector of unknown regressors, $f_t$ is the vector of unobserved factors, $\lambda_i$ are unknown factor loadings and finally $\varepsilon_{it}$ are the idiosyncratic error terms.

For the purposes of this paper, the model has been extended to:

$$Y_{it} = \delta_{it} D_{it} + x_{it}\beta + z_t \gamma_i + \lambda_i f_t + \varepsilon_{it}, \tag{5}$$

where $z_t$ are covariates that are constant across countries (say, commodity prices) and $\gamma_i$ are country-specific regressors.[14]

The benefit of this method is that it can explicitly take into account the effects of variables that may affect the outcome of interest in a systematic and important way. This is important for the purposes of this paper: the Czech economy witnessed an increase in government spending (mainly due to inflows of EU structural funds). Not accounting for this effect may bias the estimates upwards. Low commodity prices (especially low oil prices) in 2014 and 2015 affected inflation and represented a positive supply-side factor that may have boosted the real economy. While this factor is common to all the control countries, its effects may be different across countries due to different production structures and different compositions of consumer baskets.

Therefore, we included the ratio of government spending to GDP among the country-specific controls $x_{it}$, while we included oil, metal and food prices among the common controls $z_t$. Only oil prices turn out to be significant; the inclusion of food or metal prices does not affect the results significantly.

To estimate the treatment effect, Xu (2015) proposes a three-step approach. First, Model (4) is estimated for the control countries. This estimation can be done using the method by Bai (2013).[15] Second, given the estimation of $\hat{\beta}$ and $\hat{f}_t$, the loading for the treated country $\hat{\lambda}_{CZ}$ can be estimated from (4) using OLS for the pre-treatment periods. Finally, the counterfactual values for the periods after the treatment are estimated as:

$$\hat{Y}^{\text{cfact}}_{CZ,t} = x_{CZ,t}\hat{\beta} + z_t \hat{\gamma} + \hat{\lambda}_{CZ} \hat{f}_t. \tag{6}$$

The effect of the intervention is then given as the difference between the estimated counterfactual values $\hat{Y}^{\text{cfact}}_{CZ,t}$ and the actual observed values $Y_{CZ,t}$. Xu (2015) then describes the bootstrap approach to constructing the confidence intervals for $\hat{Y}^{\text{cfact}}_{CZ,t}$.

[14] One may argue that the explicit inclusion of covariates $z_t$ is not necessary, as they are captured by the unobserved factors $f_t$. This is true in infinite samples. In finite samples, the explicit inclusion of $z_t$ may improve the inference by reducing the number of factors $f_t$. Moreover, it can increase the interpretability of the results.

[15] This estimation method can be straightforwardly extended to model (5). As this extension is trivial, we omit the details.

The GSCM suggests a large and significant effect on core inflation. The effect on headline inflation is lower and less statistically significant. Despite the statistical significance, the point estimates of the effects of the floor on inflation using both the SCM and the GSCM are lower than the model-based estimates.

Contrary to the SCM, we also find weakly statistically significant effects for real GDP, real consumption and real exports. The effects on unemployment are quantitatively similar to the effects estimated using the model (Tonner et al., 2015), but are not significant. Similarly to the SCM results (and contrary to the model-based estimates), the positive effects on real variables are higher in 2015 than in 2014. Also, the effects on the real exchange rate are similar to those found by the SCM and are more persistent than those obtained from the structural models.

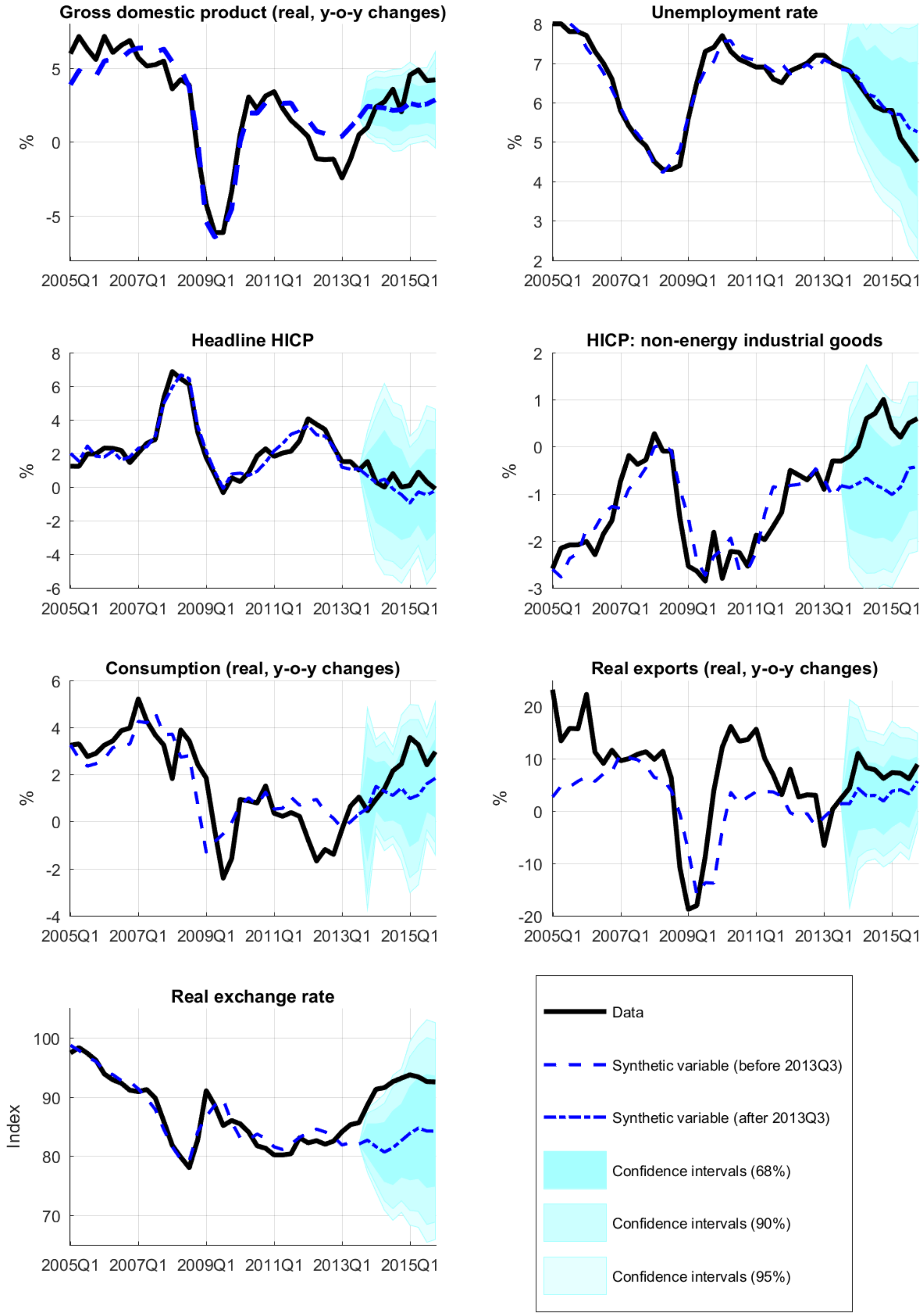
Hence, the GSCM, which controls for confounders such as fiscal expansion and commodity prices, does not overturn the results of the SCM: the point estimates of the two empirical methods are similar.

***Table 2: Results Based on the Generalised Synthetic Control Method***

| | Benchmark set | | New accession countries | | Non-euro EU countries | | All EU countries | |
|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| GDP growth | 0.43 | 1.81* | 0.37+ | 1.88* | 0.25* | 1.51* | 0.28* | 1.27* |
| Unemployment rate | -0.12 | -0.46+ | -0.31+ | -0.87* | -0.25* | -0.86** | -0.61+ | -1.02* |
| CPI inflation | 0.22 | 0.77+ | 1.90+ | 2.50+ | 0.97+ | 0.35 | 0.52+ | 0.79* |
| Core inflation | 1.36+ | 1.11* | 1.86* | 1.04* | 2.09+ | 1.66* | 2.53* | 1.74** |
| Consumption growth | 0.40* | 1.66* | 0.76* | 2.04* | -0.17 | 0.78* | 0.14 | 1.17* |
| Export growth | 5.32* | 3.20* | 5.56* | 3.20* | 1.76 | 2.71* | 6.09 | -0.31 |
| Real exchange rate | 9.73+ | 8.81** | 7.17+ | 5.4* | 10.7+ | 9.5* | 8.14+ | 8.45* |

***Note:*** + denotes significance at 32%, * denotes significance at 10% and ** denotes significance at 5%.

***Figure 4: Generalized Synthetic Control Method Estimates of the Effect on Macro Variables***



## 4. Comparison with Other Studies

In this paper, we assessed the macroeconomic effects of the introduction of the exchange rate floor using two different approaches: a model-based approach using the CNB's official g3 DSGE forecasting model, and an empirical atheoretical method – the generalised synthetic control method.

Nevertheless, other independent macroeconomic assessments have been done. Some of them use model-based approaches, while others use empirical methods.

There is a model-based assessment by Svačina (2015), who uses an estimated DSGE model to assess the effects of the floor. He finds that the floor increased GDP growth by as much as 0.8 pp and saved the economy from negative inflation in the following quarters. He also finds that the main channel was an improvement in the trade balance and an increase in import prices. His findings on GDP are very similar to ours, and his interpretation of the inflation effect is also the same as ours.

On the empirical side, Timko (2015) uses a VARX model to estimate the Czech economy. Using a counterfactual experiment, he analyses the effects of the FX floor and finds that the effect on GDP is small and statistically insignificant, while the effect on inflation in 2015 is both large and statistically significant. His study confirms our conclusion that the floor prevented inflation from turning negative.

Opatrny (2016) applied the synthetic control method using the original formulation by Abadie et al. (2010). He did not find a significant effect on inflation. However, he only looked at headline CPI inflation, for which we too did not find a significant result. Unlike us, he found a significant effect on GDP, but the effect is concentrated in 2015, while for 2014 it is zero (judging from his graphs). His findings on the unemployment rate are much larger than our results.

Finally, Caselli (2017) presented the effects of the FX floor on Czech inflation using several empirical approaches. Using an estimated reduced-form Phillips curve, she finds that in 2015, the effect on inflation was about 1 pp. Various specifications of the difference-in-difference method yielded inflation effects ranging from zero to 1 pp, and finally, she applies the synthetic control method to find the effect to be 0.5 pp. Overall, Caselli (2017) concludes that although the absolute effect is small, there is evidence that the FX floor prevented Czech inflation from turning negative. This is in line with our results, both model-based and empirical.

Table 3 compares our results with those of other researchers and analysts.

***Table 3: Comparison of Various Approaches***

| | Our approaches | | | | Independent approaches | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | g3 | Tonner et al. (2015) | SCM | GSCM | Svacina (2015) | Opatrny (2016) | Timko (2015) | Caselli (2016) (SCM) | Caselli (2016) (DiD) |
| CPI inflation (2014) | 1.2 | 1.2 | 0.1 | 0.2 | 0.5 | ±0 | 1.5 | ±0 | 0.5–1.0 |
| CPI inflation (2015) | 1.8 | 1.5 | 0.6 | 0.8 | | ±0 | 1.5 | 0.5 | |
| GDP growth (2014) | 1.2 | 0.8 | 0.3 | 0.4 | 0.8 | +0 | ±0 | | |
| GDP growth (2015) | 0.6 | 1.2 | 1.7 | 1.8 | | 2.0 | ±0 | | |
| Consumption growth (2014) | 1.4 | 0.3 | 0.4 | 0.4 | | | | | |
| Consumption growth (2015) | 0.9 | 1.0 | 1.5 | 1.7 | | | | | |
| Unemployment rate (2014) | | -0.3 | -0.2 | -0.1 | | -1.0 | | | |
| Unemployment rate (2015) | | -1.2 | -0.6 | -0.5 | | -1.8 | | | |

***Notes:*** g3 is the simulation with the g3 model; Caselli (SCM) is the result from Caselli (2017) using the synthetic control method; Caselli (DiD) is the result from Caselli (2017) using the difference-in-difference method.
Blank spaces mean that the study does not address the variable of interest; ±0 means that the study implies that the effect is both economically and statistically insignificant. Some results are not found in the tables or texts but were read from the graphs in the papers.

## 5. Conclusion

In this paper, we applied a set of methods to quantitatively evaluate the introduction of the Czech koruna/euro exchange rate floor on the Czech economy. We use both simulations with structural macroeconomic models and variants of the synthetic control method to estimate the counterfactual of what would have happened without the floor.

Both the model-based simulations and the two empirical methods show that the floor prevented inflation from turning negative. Also, all the methods indicate positive effects on macro variables and on various measures of inflation; nevertheless, statistically significant effects can only be found for core inflation. We interpret these findings as follows. First, the exchange rate floor affected inflation in the intended way. Second, there were probably, but not definitely, some positive effects on the real economy, effects that are hard to detect using statistical methods. It can at least be said that there is no evidence that the exchange rate floor hurt the real economy to any significant degree. All in all, given the strong evidence for positive effects on core inflation, and given that there is no evidence that the floor hurt the real economy, we conclude that the introduction of the exchange rate floor was a correct policy action that has retrospectively been successful.

To end the paper, we note that because of the linearity of the methods employed, the possible benefits of preventing the economy from falling into a vicious deflationary spiral cannot be assessed. The extent and magnitude of the risks and costs of deflationary spirals are currently being discussed a great deal in academia. This paper is salient to this issue. If one believes that the risks are real and the costs are sizeable, then the benefits of preventing deflation are much larger than indicated in this paper.

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## Appendix A: Simulations under the Lower Bound on the Policy Rate and/or under the Exchange Rate Floor

To obtain counterfactual simulations with structural models, i.e. with the g3 model (Andrle et al., 2009) and with its extension (Tonner et al., 2015), these models have to be simulated under the lower bound on policy rates and/or under the exchange rate floor. As stated in the main text, we used the shadow shock approach, and in this appendix we provide additional details.

The simulated trajectories under the lower bound (i.e. in the period between the decline of policy rates to technical zero in autumn 2012 and the introduction of the floor in November 2013) are obtained as follows. Let $\widetilde{x}_t$ denote a simulation outcome without the lower bound (LB) constraint. The simulation under the lower bound is obtained as follows:

$$x_t^{LB} = \widetilde{x}_t + \sum_{i=0}^{I} \Xi_i^{MP} \varepsilon_{t+i|i}^{MP},$$

where $\varepsilon_{t+i|i}^{MP}$ are expected monetary policy shocks that hit the economy at time $t+i$ but are anticipated already at time $t$, and $\Xi_i^{MP}$ is the matrix of impulse responses of such shocks to the variable $x_t$. The magnitudes of these shadow shocks $\varepsilon_{t+i|i}^{MP}$ are determined so that the LB constraint holds, i.e.:

$$i_t^{LB} = \begin{cases} \widetilde{i}_t & \text{if } \widetilde{i}_t \geq \text{ LB} \\ \text{LB} & \text{otherwise} \end{cases}, \tag{A1}$$

where $\widetilde{i}_t$ is the endogenous policy rate in a simulation without the LB constraint and $i_t^{LB}$ is the rate respecting the LB. It is well known that shadow shocks can be treated as a quadratic programming problem.

Similarly, after November 2013, the simulation respecting both the LB and the exchange rate floor is obtained as follows:

$$x_t^{LB,floor} = \widetilde{x}_t + \sum_{i=0}^{I} \Xi_i^{MP} \varepsilon_{t+i|i}^{MP} + \sum_{i=0}^{I} \Xi_i^{UIP} \varepsilon_{t+i|i}^{UIP},$$

where $\varepsilon_{t+i|i}^{UIP}$ are anticipated UIP shocks and $\Xi_i^{UIP}$ are corresponding impulse responses.

Again, the shadow shocks $\varepsilon_{t+i|i}^{MP}$ and $\varepsilon_{t+i|i}^{UIP}$ are set so that the simulation outcome respects both the LB constraint (A1) **and** the exchange rate floor, which reads as:

$$\eta_t^{LB,floor} = \begin{cases} \widetilde{\eta}_t & \text{if } \widetilde{\eta}_t \geq \text{ floor} \\ \text{floor} & \text{otherwise} \end{cases}, \tag{A2}$$

Again, the shadow shocks $\varepsilon_{t+i|i}^{MP}$ and $\varepsilon_{t+i|i}^{UIP}$ can be jointly determined as a solution to a straightforward quadratic programming problem.

# Appendix B: Additional Tables

***Table B1: Summary Statistics***

| Variable | 2012–2013 | | | 2014–2015 | | |
|---|---|---|---|---|---|---|
| | CZ | EA | EU | CZ | EA | EU |
| GDP growth | -0.61 | -0.14 | 0.16 | 3.96 | 2.68 | 2.74 |
| Real consumption growth | -0.33 | -0.42 | -0.14 | 2.72 | 1.91 | 2.16 |
| Real export growth | 2.27 | 3.23 | 3.25 | 7.17 | 4.88 | 5.03 |
| Unemployment rate | 6.85 | 11.60 | 10.92 | 6.55 | 10.88 | 9.96 |
| Headline inflation | 2.39 | 1.95 | 1.99 | 0.29 | 0.10 | 0.07 |
| Core inflation | -0.50 | 0.38 | 0.35 | 0.50 | -0.14 | -0.17 |

***Note:*** Column CZ contains the average values for the Czech Republic during the given period. Columns EA and EU contain the average values for euro area and EU countries for the given period. GDP, consumption and export growth are in y-o-y growth rates (%), the unemployment rate is in % and the inflation measures are yearly changes of the index (also in %).

***Table B2: Country Weights (SCM) for the Benchmark Set of Countries***

| Country | GDP growth | Unemployment rate | Headline inflation | Net inflation | Consumption growth | Export growth | Real exchange rate |
|---|---|---|---|---|---|---|---|
| Bulgaria | 0.341 | 0.160 | 0.000 | 0.000 | 0.000 | 0.000 | 0.023 |
| Denmark | 0.174 | 0.000 | 0.095 | 0.000 | 0.001 | 0.000 | 0.000 |
| Germany | 0.000 | 0.385 | 0.042 | 0.000 | 0.001 | 0.000 | 0.000 |
| Estonia | 0.014 | 0.000 | 0.178 | 0.054 | 0.001 | 0.000 | 0.000 |
| Latvia | 0.000 | 0.000 | 0.000 | 0.131 | 0.030 | 0.433 | 0.000 |
| Lithuania | 0.000 | 0.000 | 0.155 | 0.209 | 0.001 | 0.000 | 0.030 |
| Hungary | 0.189 | 0.136 | 0.000 | 0.000 | 0.071 | 0.357 | 0.000 |
| Austria | 0.000 | 0.146 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 |
| Poland | 0.193 | 0.000 | 0.052 | 0.000 | 0.179 | 0.042 | 0.322 |
| Romania | 0.000 | 0.329 | 0.000 | 0.000 | 0.001 | 0.033 | 0.000 |
| Slovenia | 0.182 | 0.061 | 0.209 | 0.153 | 0.002 | 0.000 | 0.232 |
| Slovakia | 0.056 | 0.000 | 0.080 | 0.136 | 0.363 | 0.000 | 0.467 |
| Sweden | 0.013 | 0.495 | 0.000 | 0.000 | 0.001 | 0.060 | 0.167 |
| United Kingdom | 0.000 | 0.025 | 0.000 | 0.250 | 0.001 | 0.150 | 0.000 |

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ISSN 1803-7070