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Inflation Target and its Impact on Macroeconomy in the Zero Lower Bound Environment: the case of the Czech economy

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Abstract: This paper uses a stochastic simulation of a DSGE model of the Czech economy to study the macroeconomic consequences of inflation target setting when interest rates are constrained by the zero lower bound. The distortions of this constraint depend non-linearly on the inflation target. For an inflation target of two percent the costs are negligible, but they increase steeply with lower target values. The largest impact is on the average values of output, consumption and investment; inflation is only slightly influenced. The volatility of all the variables considered increases significantly, but only for inflation targets that are close to zero. An inflation target of four percent does not bring additional benefits either in terms of lower volatility or in terms of higher average values.

Key words: zero lower bound on interest rate, inflation target, DSGE model

JEL Classification: E37

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Introduction

Many central banks set their target inflation rate at two percent. These include the Federal Reserve, the European Central Bank and the Czech National Bank. This two percent target has recently been criticised by some economists (e.g. Ball, 2013) as being too low, on the grounds that it then restricts the monetary policy options for combating recession, because of the zero lower bound (ZLB) on the interest rate. Many economies have recently experienced such situations.[2] The USA and many EU countries are slowly recovering from the recent recession, but their nominal interest rates are close to zero and could not be further lowered to boost the economy, due to the zero lower bound. The zero lower bound on the interest rate thus limits the possibilities of monetary policy. There is a solution to this: a higher inflation target will raise the long-run nominal interest rate and induce more space for monetary policy to decrease interest rates in reaction to adverse shocks. Therefore the goal of this paper is to explore how inflation target values influence the probability of the interest rate hitting the zero lower bound, and,

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[2] Japan is an example of an economy that has had near zero interest rates since the 1990s.

more importantly, what the consequences of this are for macroeconomic variables. This issue is studied in a New Keynesian framework, more specifically using an open economy DSGE model from Kolasa (2009), which is estimated on Czech economy data from 2001:Q2 – 2014:Q1. The model is simulated in reaction to shocks similar to those that the Czech economy experienced during the estimated period. The results show that for an inflation target of two percent the probability of hitting the ZLB is sixteen percent, and that this probability steadily decreases with higher inflation target values. The costs of choosing a two percent target over a four percent target are negligible. The difference in the statistical distribution of the simulated variables is virtually nil. However, for inflation targets below two percent the costs rise dramatically, especially for the real variables. Output, investment and consumption are lower by 1.5 – 2 percent on average due to the ZLB constraint. Average annual inflation is only slightly higher, but its volatility increases by 10 percentage points. These results suggest that the inflation target of two percent pursued by the Czech National Bank provides a sufficient buffer against the threats connected with the zero lower bound. Lower target values are highly undesirable. In any case, recent experience from the Czech economy has shown that the central bank can use an alternative instrument – exchange rate interventions, if interest rates are too low (see Franta et al., 2014).

Literature review

A detailed discussion of the possible costs and benefits of increasing the inflation target from 2 to 4 percent is provided by Ball (2013). He argues that the risks of hitting the zero lower bound are too high at 2 percent, and that a higher inflation target is desirable. He documents this using data from U.S. history. Our paper is model-based and closely follows Coenen et al. (2003), who carry out similar analysis using U.S. data from the 1980s and 1990s. They find that the ZLB constraint has negative consequences for output and partly for inflation, but only for inflation targets between zero and one. The distortions are negligible for a target value of two percent. These low costs could be caused by the analysed period, which was a relatively calm period in U.S. history. Williams (2009) analyses a longer time period, including the recent recession, and finds that the zero lower bound imposed significant welfare costs on the U.S. economy during that period. These costs did not come from a sharp decline at the beginning of the recession but from a slow recovery. He argues that an inflation target of two percent is insufficient and that alternative macroeconomic policy instruments should be employed. Gust, Lopez-Salido and Smith (2012) explore how the ZLB constraint contributed to the severity of the Great Recession. They find that in a hypothetical situation in which monetary policy were not constrained, the GDP would be one percent higher on average.

A few papers examine the implications of the ZLB for the Czech economy, but their research questions are different. Hloušek (2014) uses a simulation of a small open economy model estimated by Bayesian techniques to point out that the most dangerous shocks that can take the economy to the ZLB are domestic cost-push shock and foreign preference shock. This has implications for consumption and output behaviour, but those implications are quantitatively small. Malovaná (2015) examines the effects of various shocks when the economy is at ZLB and under various regimes of monetary policy. She finds that when the economy is at the ZLB, the volatility of the real and nominal variables is amplified in reaction to domestic demand shocks, foreign demand and financial shocks and terms of trade shocks. The reaction of the variables is stronger the higher the persistence of the shocks and the longer the period during which the interest rate constraint is binding. A fixed exchange rate regime proved an efficient way to mitigate deflationary pressures and to recover economic activity.

Model economy

The model applied in this paper is borrowed from Kolasa (2009). The structure of the model is described only verbally here, while a log-linearized version of the model can be found in online Appendix or in the original paper. It is a model of two open economies, which are treated identically and differ only by their size, which is determined by the calibrated parameter *n*. The domestic economy represents the Czech economy, and the foreign economy is the Euro area.

There are two types of firm in every economy: producers of tradable goods and producers of non-tradable goods. The production function is Cobb-Douglas using capital and labour, and the capital accumulation is subject to adjustment cost. The output is divided into consumption and investment goods. The tradable consumption and investment goods are combined with imports to make composite goods, a proportion of which are exported. There is assumed price rigidity at three stages of the production process. The rigidity is modelled in Calvo (1983) style and results in three price Phillips curves (for home tradable goods, non-tradable goods and composite consumption goods). Households consume a bundle of tradable and non-tradable goods, and decide about labour supply and bond purchases. There is an assumption of habit formation in consumption. Households have different labour skills, which gives them the power to influence wages. The wage setting is subject to rigidity, which is again modelled according to Calvo (1983).

The government collects lump-sum taxes to finance its expenditures and always have a balanced budget. The government expenditures consist of domestic non-tradable goods and are modelled as an AR(1) process. Monetary policy follows the Taylor rule with interest rate smoothing and attention to inflation and the output gap.

The model consists of forty structural equations and its dynamic is driven by seven exogenous shocks in each economy. Six of them follow AR(1): these are a productivity shock in the tradable sector and the non-tradable sector, a labour supply shock, an investment efficiency shock, a consumption preference shock and a government spending shock. Monetary policy shock is assumed *iid.*

Data and Methods

The model is estimated using data for fourteen variables – GDP, consumption, investment, inflation, real wages, nominal interest rate and internal exchange rate,[3] each for

[3] Calculated as price of tradable goods divided by price of non-tradable goods.

both the domestic and foreign economies. The data series have quarterly frequency, are obtained from the Eurostat database and cover the time period 2000:Q2 – 2014:Q1. The time span is determined by the availability of data for the calculation of the internal exchange rate. The time series enter as growth rates and are demeaned before estimation.[4] The nominal interest rate and price inflation are already stationary and so are only demeaned.[5]

The model parameters are estimated using Bayesian techniques. A posterior distribution of the parameters is obtained by the Random Walk Chain Metropolis-Hastings algorithm. It generates 2,000,000 draws in two chains with 1,000,000 replications each; 90% of the replications are discarded so as to avoid any influence from initial conditions. MCMC diagnostics are used to verify the convergence. All computations are carried out using the Dynare toolbox (Adjemian et al., 2000) in Matlab software.

The estimated model is then simulated using the *Occbin toolbox* developed by Guerrieri and Iacoviello (2015), who use a piecewise linear perturbation method that is able to solve dynamic models with an occasionally binding constraint. This method provides a very good approximation of a dynamic programming solution and is simple to implement. It can capture nonlinearities that arise in models with two regimes – with and without a binding constraint. Therefore, this algorithm is suitable for studying the effects of attaining the zero lower bound on the nominal interest rate.

Calibration and Estimation

Several structural parameters are calibrated according to the data. The key calibrated parameters are discount factors. They are set to β=0.9994 for the Czech economy and β^*=0.9988 for Euro area, which correspond to the means of the real interest rates calculated from the data, 0.24 % and 0.48 % respectively.[6] The rest of the calibrated parameters are listed in Table 2 in the Appendix. The priors of the estimated parameters are set according to Kolasa (2009) and Slanicay (2013). These are quoted in Table 3 and 4 in the Appendix.

Ten structural parameters, seven standard deviations of shocks and six autoregressive parameters are estimated for each economy. The domestic and foreign shocks are allowed to correlate and the correlation coefficient is also estimated.

The results of the estimation are quoted in Tables 3 and 4 in the Appendix. Here, only the most relevant estimated parameters are commented on. Let us begin with the parameters of monetary policy rule. The posterior means of the interest rate smoothing parameters are quite similar in both economies at $\rho = 0.85$ $\rho^* = 0.84$, and the weights to inflation are quite comparable, $\psi_\pi = 1.37$ and $\psi_\pi^* = 1.41$; however, the European Cen-

[4] The growth rates are calculated as first difference of logarithms of the time series.

[5] Inflation is calculated as the log difference of HCPI, nominal interest rates are represented by three months Pribor and Euribor.

[6] Parameters with an asterisk refer to the Euro area economy.

tral Bank pays greater attention to the output gap $\psi_y^* = 0.13$ than the Czech National Bank does, $\psi_y = 0.07$. The persistence of shocks and their volatility is reported in Table 4 and is key to our analysis. The most persistent shock is domestic productivity shock in the tradable goods sector, while the least persistent is domestic productivity shock in the non-tradable goods sector. The most volatile shock is domestic labour supply shock, with standard deviation $\sigma_l = 0.345$, while the least volatile is domestic monetary policy shock, $\sigma_m = 0.002$. Generally, the shocks in the Czech economy are more volatile than the shocks in the Euro area. The confidential bands of correlation coefficients of four shocks are zero; two shocks (productivity shock in the non-tradable goods sector and preference shocks) are partly correlated between the economies, and a very high correlation was found for monetary policy shocks.

Simulation

To illustrate the importance of inflation target setting, let r^* denote the long-term level of the real interest rate and π^* denote the inflation target set by the central bank. The long-term level of the nominal interest rate is then $r^* + \pi^*$. Let us assume that the real interest rate is $r^* = 1$ % and the inflation target is $\pi^* = 1$ %. The nominal interest rate is thus two percent. Now suppose that there is an adverse shock that pushes the economy into recession. The central bank can respond by lowering the interest rate, but only by up to two percent. On the other hand, a higher inflation target provides a larger buffer for monetary policy reaction. In the context of the research question we examine how the inflation target influences the probability of hitting the zero bound, and what the consequences are for output, consumption, investment and inflation behaviour. This issue is examined by a simulation of the estimated model. First, five thousand samples of shocks are generated. Their magnitude and persistence represent the average shocks that affected the economy during the estimated period.[7] Concretely, for every shock an innovation is generated using a random number generator and this innovation is multiplied by the estimated standard deviation. Every shock follows the AR(1) process with the persistence parameter obtained from the estimation. The model is simulated in reaction to all fourteen shocks.

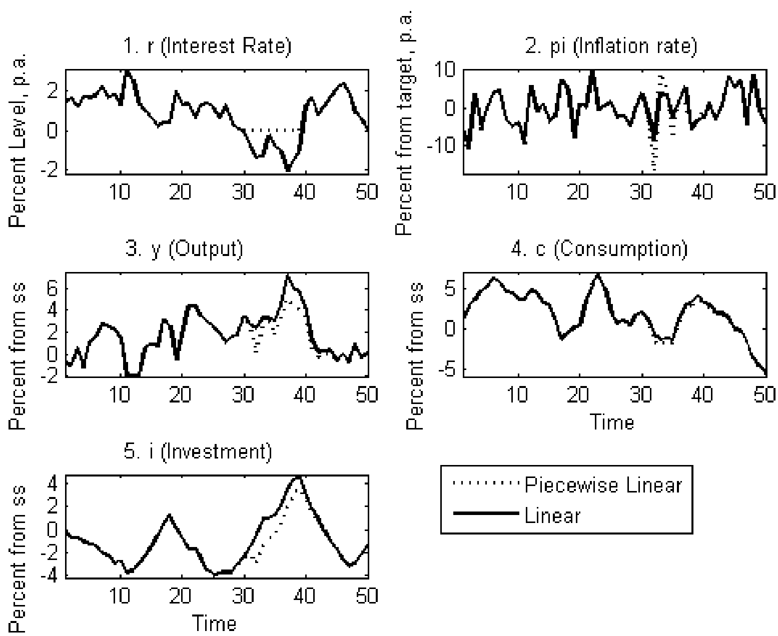
Figure 1 shows the behaviour of the simulated model variables for fifty selected periods. The inflation target is set to one percent. The solid line represents cases when the interest rate can be negative, the dashed line is the version with a zero lower bound constraint on the interest rate. The series of shocks takes the nominal interest rate to zero in period thirty and it remains there until period thirty-nine. The outcome of this restriction is that output, investment and to some extent consumption are lower compared to the results when interest rates are allowed to be negative. The inflation rate is more volatile

[7] Most shocks follow the AR(1) process, e.g. $\epsilon_{g,t} = \rho_g \epsilon_{g,t-1} + \mu_{g,t}$. The term “shock” is used for the variable $\epsilon_{g,t}$ and “innovation” for $\mu_{g,t}$, which has properties $\mu_{g,t} \sim N(0, \sigma_g)$.

during the period of restriction. Thus it is evident that the zero lower bound induces welfare losses in terms of lower real variable trajectories and higher inflation volatility.

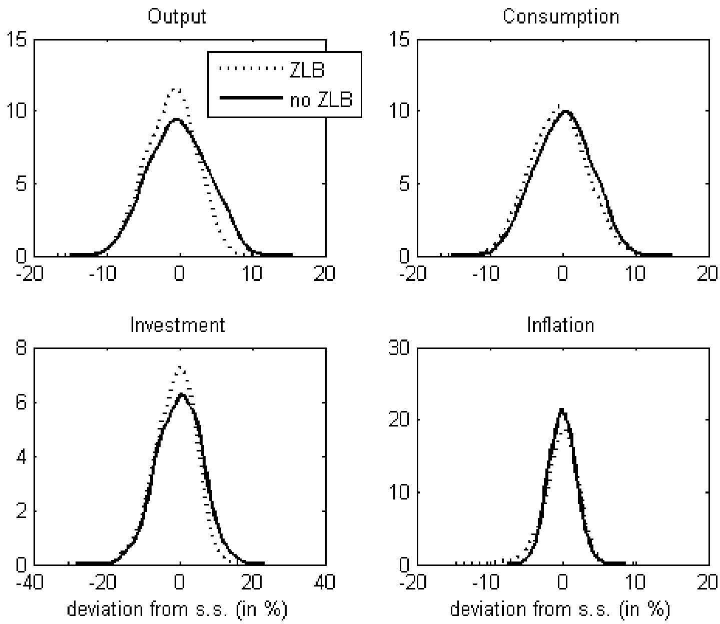
Figure 2 shows the stationary distribution from the simulation of model variables (five thousand replications) at an inflation target of half a percent. It is evident that the distribution for the ZLB case is different, and usually shifted into negative values. This confirms our conclusion from the previous figure that restrictions on the interest rate negatively influence the average outcome of the economy. Descriptive statistics expressed as the difference in median and standard deviation between the ZLB and noZLB cases are quoted in Table 1. The zero lower bound causes lower average values of the real variables and slightly higher inflation. Paradoxically, the volatility of the real variables is lower in the ZLB case and the volatility of inflation increases. However, this simulation is only carried out for an inflation target of half a percent. The impact of different inflation target values on the economy is described in the following section.

Figure 1 Simulation of selected variables (inflation target of 1 percent)



Source: Author's calculations

Figure 2 Distribution of selected variables (inflation target of 0.5 percent)



Source: Author's calculations

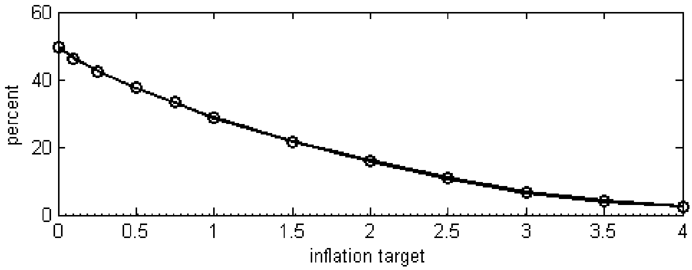
Table 1 Difference of descriptive statistics ZLB – noZLB (inflation target set to 0.5 percent)

	output	consumption	investment	inflation (p.a.)
Difference of median (in %)	-0.86	-0.78	-0.85	0.14
Difference of std (in %)	-0.64	-0.07	-0.55	2.08

Source: Author's calculations

First, we look at the probability of hitting the zero lower bound. Figure 3 shows the relationship between the inflation target value and the frequency with which the interest rates reaches the zero lower bound. For an inflation target of two percent the interest rate binds in sixteen percent of cases. In the case of a four percent inflation target that value is only 2.5 percent. For inflation targets below two percent, the zero lower bound is hit substantially more frequently, in up to 50 percent of cases.

Figure 3 Frequency of binding interest rate



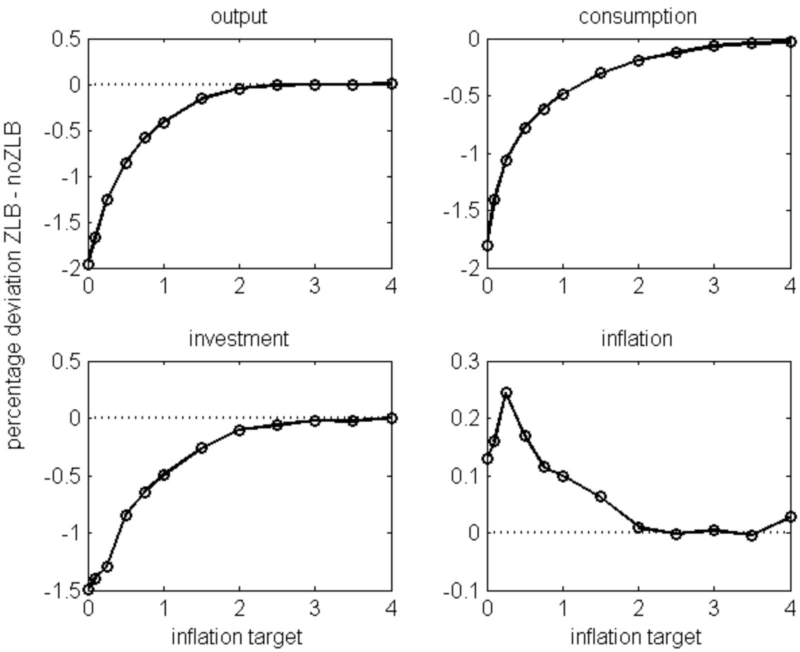
Source: Author's calculations

Figure 4 depicts the differences in median between ZLB and noZLB distributions for different inflation target values. There are nearly no distortions for any variable for inflation targets between two and four percent, with some exceptions. In the ZLB case, consumption is lower by 0.2 percent for an inflation target of two percent, and inflation is slightly higher for an inflation target of four percent. These differences can be considered negligible. Much larger biases are observed for targets below two percent. In the case of zero targeted inflation, output would be 2 percent below its usual value, and consumption and investment lower by 1.8 and 1.5 percent, respectively. Inflation would be higher by only 0.13 percentage points annually. Average inflation is slightly higher for targets between zero and one; the maximal bias reaches a value of 0.25 percentage points. This non-linear behaviour is quite surprising, although this result is also robust for a larger sample of replications. The differences are, in any case, very small.

Finally, the volatility of the variables for different inflation target values is studied in Figure 5. This figure shows the differences in the variables' standard deviation between the ZLB and noZLB cases. The volatility of the real variables (output, consumption and investment) reveals an interesting pattern. From an inflation target of four percent, the volatility decreases with lower target values, down to a target of half a percent. This would indicate that an inflation target below two percent is beneficial for the economy in terms of the lower volatility of the real variables as the economy gets to the zero lower bound. However, this benefit is disputable because the reduction of volatility is rather small[8] and would be offset by the lower average values of the variables, as explained above. Nevertheless, below an inflation target value of 0.1, the volatility sharply increases.

[8] 0.6 percentage points for output, 0.06 p.p. for consumption and 0.5 p.p. for investment

Figure 4 Distribution of the variables: differences of median

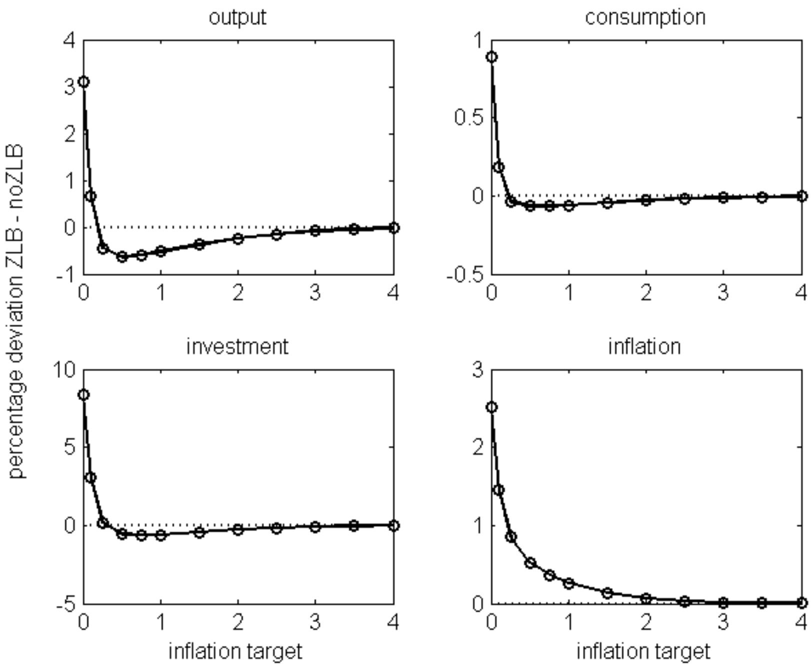


Source: Author's calculations

The standard deviations of output, consumption and investment in the ZLB case are larger by three, one and eight percentage points, respectively, when the inflation target is zero. The volatility of inflation increases steadily as the inflation target decreases, and the bias of standard deviation reaches 10 percentage points of annualized inflation at the zero target value.

When it comes to comparison, unfortunately no similar studies have been carried out on Czech data. Our results are in line with Coenen et al. (2003), who used a similar methodology but on a small-scale model and using US data from the 1980s and 1990s. They also argue that the macroeconomic consequences of the zero lower bound are negligible for an inflation target of two percent. Lower values of the target (between zero and one) result in significant deterioration in the economy's performance, especially in terms of output. However, we obtained much larger biases compared to their results, e.g. the bias of the average value of output at a zero inflation target is twenty five times larger for the Czech economy than they found for the US. The main reason for this difference is probably the equilibrium value of the real interest rate, which is currently quite low in the Czech economy, and the size of the shocks, because the analysed period for the Czech economy included the recent financial crisis.

Figure 5 Distribution of the variables: differences of standard deviation



Source: Author's calculations

To support the results, several sensitivity analysis checks were performed. Here, only the main results are commented on; for a full comparison see the online Appendix. First, the model was estimated on a shorter period, excluding the financial crisis (2000Q2 - 2008Q1). The results for target inflation between 2 and 4 percent are almost the same. Some slight differences are obtained for lower inflation target values, concretely less distortion of the real variables and a slightly higher inflation rate. Nevertheless, the distortions are still significant. A second sensitivity analysis check focused on different values of structural parameters within the simulation. Again, the differences for inflation targets between 2 and 4 percent are negligible. Higher wage and price rigidities (a higher Calvo parameter) reduce the distortions compared to the benchmark. On the other hand, a higher investment adjustment cost increases the distortions for consumption and output, but only slightly. Altogether, the distortions remain substantial and the paper's main message remains valid.

Conclusion

This paper has explored the influence of inflation target setting on the behaviour of macroeconomic variables in the Czech economy when monetary policy faces a zero lower bound constraint on the interest rate. The results show that an inflation target of two percent, as set by the Czech National Bank, provides a sufficient buffer for monetary policy. The costs connected with the ZLB at a two percent target are negligible compared to a target of four percent. However, the distortions would be substantial for inflation targets between zero and one, in particular resulting in lower average values for the real variables. The volatility of the variables induced by ZLB is only higher for inflation targets close to zero. In any case, recent experience has shown that the Czech National Bank can use alternative monetary policy tools, such as exchange rate interventions, to address inflation issues.

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Appendix

Table 2 Calibrated parameters

Parameter	Interpretation	Value
β	discount factor CZ	0.9994
β^*	discount factor EA	0.9988
$\frac{C}{Y}$	consumption output ratio CZ	0.4929
$\frac{C^*}{Y^*}$	consumption output ratio EA	0.5681
$\frac{I}{Y}$	investment output ratio CZ	0.2590
$\frac{I^*}{Y^*}$	investment output ratio EA	0.1999
γ_c	share of final tradable C goods CZ	0.5384
γ_c^*	share of final tradable C goods EA	0.4953
γ_i	share of final tradable I goods CZ	0.5006
γ_i^*	share of final tradable I goods EA	0.4257
η	capital share CZ	0.4160
η^*	capital share EA	0.3618
n	relative size of the Czech Republic in the EA	0.0138

Table 3 Estimated parameters

Parameter	Density	Prior distribution Mean	S.D.	Posterior distribution Mean	2.5 %	97.5 %
Habit formation						
h	beta	0.7	0.1	0.65	0.50	0.81
h^*	beta	0.7	0.1	0.73	0.60	0.86
Elasticity of intertemporal subst.						
σ	gamma	1	0.7	1.28	0.50	2.01
σ^*	gamma	1	0.7	2.52	1.24	3.76
Frisch elasticity of labour supply						
ϕ	gamma	1	0.7	0.37	0.01	0.78
ϕ^*	gamma	1	0.7	0.97	0.23	1.71
Investment adjustment cost						
S'	norm	4	1.5	3.40	1.25	5.51
S'^*	norm	4	1.5	4.73	2.69	6.59
Calvo parameters						
θ_H	beta	0.7	0.05	0.75	0.69	0.81
θ_F^*	beta	0.7	0.05	0.73	0.67	0.78
θ_N	beta	0.7	0.05	0.77	0.72	0.82
θ_N^*	beta	0.7	0.05	0.63	0.57	0.69
θ_W	beta	0.7	0.05	0.73	0.65	0.80
θ_W^*	beta	0.7	0.05	0.78	0.73	0.84
Monetary policy rule						
ρ	beta	0.7	0.15	0.85	0.82	0.88
ρ^*	beta	0.7	0.15	0.84	0.81	0.88
ψ_y	gamma	0.25	0.1	0.07	0.05	0.09
ψ_y^*	gamma	0.25	0.1	0.13	0.07	0.18
ψ_π	gamma	1.3	0.15	1.37	1.18	1.55
ψ_π^*	gamma	1.3	0.15	1.41	1.21	1.62

Table 4 Estimated shocks

Param.	Density	Prior distribution Mean	S.D.	Posterior distribution Mean	2.5 %	97.5 %
Volatility						
σ_{a^H}	invg	0.01	Inf	0.049	0.032	0.065
$\sigma^*_{a^F}$	invg	0.01	Inf	0.023	0.014	0.033
σ_{a^N}	invg	0.01	Inf	0.083	0.044	0.119
$\sigma^*_{a^N}$	invg	0.01	Inf	0.022	0.014	0.029
σ_d	invg	0.01	Inf	0.038	0.015	0.060
σ^*_d	invg	0.01	Inf	0.040	0.018	0.061
σ_l	invg	0.01	Inf	0.349	0.085	0.653
σ^*_l	invg	0.01	Inf	0.168	0.044	0.298
σ_g	invg	0.01	Inf	0.032	0.027	0.037
σ^*_g	invg	0.01	Inf	0.013	0.011	0.015
σ_i	invg	0.01	Inf	0.073	0.026	0.116
σ^*_i	invg	0.01	Inf	0.033	0.020	0.044
σ_m	invg	0.01	Inf	0.002	0.001	0.002
σ^*_m	invg	0.01	Inf	0.002	0.002	0.002
Persistence of shocks						
ρ_{a^H}	beta	0.7	0.1	0.91	0.82	0.93
$\rho^*_{a^F}$	beta	0.7	0.1	0.63	0.62	0.96
ρ_{a^N}	beta	0.7	0.1	0.45	0.89	0.97
$\rho^*_{a^N}$	beta	0.7	0.1	0.57	0.91	0.98
ρ_d	beta	0.7	0.1	0.77	0.63	0.88
ρ^*_d	beta	0.7	0.1	0.73	0.63	0.86
ρ_l	beta	0.7	0.1	0.45	0.28	0.67
ρ^*_l	beta	0.7	0.1	0.49	0.56	0.88
ρ_g	beta	0.7	0.1	0.78	0.69	0.85
ρ^*_g	beta	0.7	0.1	0.81	0.73	0.89
ρ_i	beta	0.7	0.1	0.66	0.48	0.82
ρ^*_i	beta	0.7	0.1	0.74	0.68	0.88
Correlation of shocks						
$corr_{a_H,a^*_F}$	norm	0	0.4	-0.02	-0.23	0.18
$corr_{a_N,a^*_N}$	norm	0	0.4	0.24	0.05	0.44
$corr_{d,d^*}$	norm	0	0.4	0.23	0.02	0.45
$corr_{l,l^*}$	norm	0	0.4	0.12	-0.08	0.33
$corr_{g,g^*}$	norm	0	0.4	0.12	-0.07	0.33
$corr_{i,i^*}$	norm	0	0.4	0.18	-0.01	0.39
$corr_{m,m^*}$	norm	0	0.4	0.92	0.88	0.96