From Inflation to Exchange Rate Targeting: Estimating the Stabilization Effects

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Abstract

This paper attempts to estimate possible losses in macroeconomic stabilization due to a move from inflation to exchange rate targeting on an example of the Czech Republic. The authors use an estimated New Keynesian policy model, general inflation and exchange rate targeting rules, and representative central bank loss functions to carry out such estimations. The authors find that for the Czech Republic moving from the historically applied inflation targeting to optimized exchange rate targeting should not involve any significant losses in macroeconomic stabilization. However, the Czech National Bank could improve its stabilization outcomes while remaining an inflation targeter. This requires the Czech National Bank to respond stronger to increasing expected future inflation and be less concerned about an opening output gap when adjusting its policy rate. Moving then from such optimized inflation targeting to optimized exchange rate targeting can result in significant losses in economic stabilization in the magnitude of 0.4 to 2 percentage points of GDP growth.

Keywords: Inflation Targeting, Exchange Rate Targeting, Optimized Simple Monetary Policy Rules, Loss in Macroeconomic Stabilization, Czech Republic

JEL Classification: E32, E52, E58.

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1 Introduction

Many small open economies around the world followed the positive experience of New Zealand with macroeconomic stabilization and currently apply inflation targeting as their monetary policy regime, including the Czech Republic. The on-going trade and monetary integration within Europe constitutes an example for possible future economic integration in other world's regions. By joining the European Union (EU), the European countries commit to further, monetary integration and eventual adoption of the euro sometime in the future. Those of the European countries that will be applying inflation targeting before taking the steps towards the euro adoption will have to, at some point, switch from inflation to exchange rate targeting. This can occur with the entry into the ERMII or later within the ERMII. In general, moving from inflation to exchange rate targeting decreases the autonomy of domestic monetary policy for a given country. This could exacerbate the country's macroeconomic stability and have negative implications for the country's financial stability and economic growth. However, the extent of the exacerbation is an empirical matter specific to each country and could, in some cases, prove to be negligible.

This paper outlines a possible methodology for estimating the effects of moving from inflation to exchange rate targeting on macroeconomic stabilization using the example of the Czech Republic. The methodology involves an estimated New Keynesian policy model for the Czech Republic using quarterly data from 1995 to 2007, typical specifications of inflation targeting and exchange rate targeting rules, and a representative loss function for the central bank. The estimated open-economy model for the Czech Republic has a domestic and an exogenous foreign block describing the macroeconomic dynamics in the euro area. The properties of the model are studied through the impulse response analysis. The accompanying variance decomposition reveals that despite the exchange rate shock having the largest estimated size its impact on the Czech output gap and inflation is smaller than the impact of any of the domestic shocks. The latter appear to be almost equally important with the domestic supply shock slightly dominating. The importance of external developments for the Czech economy is illustrated by the effects of a foreign demand shock which appears to be the most influential force behind variations in Czech inflation. Treating the estimated model as a set of constraints we optimize, in turn, the inflation targeting and exchange rate targeting rule using a representative central bank loss function. This analysis implies that, for the Czech Republic, moving from the current inflation targeting rule to an optimized exchange rate targeting rule would not induce any significant losses in macroeconomic stabilization. However, the Czech National Bank can further improve its macroeconomic stabilization efforts by increasing its response to expected future inflation and decreasing its response to the current output gap, while adhering to current interest rate smoothing. Moving from such optimized inflation targeting to optimized exchange rate targeting would involve losses in macroeconomic stabilization approximately in the range of 0.4 to 2 percentage points of GDP growth.

The literature has been extensively dealing with the appropriate choice between exchange rate and inflation targeting regimes for a given country, see e.g. Svensson (1997) for an early discussion on Norway. We, on the other hand, do not question or investigate the initial choice of inflation targeting and take it as given, and look ahead in the context of the European integration process. This is similar to Karam et al. (2008) who investigate the cost and benefits of adopting euro using a calibrated medium-size DSGE[1] model focusing on the Central and Eastern Europe. They find that although the monetary union has the benefit of eliminating nominal exchange rate shocks, the loss of the buffering role of the nominal exchange rate leads to greater volatility in domestic output and inflation. However, they point out that the costs are likely to decline over time, due to accelerated convergence as a result of the monetary union membership. The convergence process and challenges for monetary policy concerning the Czech Republic have been recently analyzed by Allard and Munoz (2008), and Bruha at al. (2007) using calibrated DSGE models. And, Benes et al. (2005) look into the desired properties of a forecasting DSGE model effectively describing the convergence process in the Czech Republic. Our paper's focus is thus different as we take the move to exchange rate targeting as the benchmark change for the currently applied inflation targeting regime of monetary policy as opposed to the rather irreversible adoption of the euro, and use an empirical DSGE model fitted to the Czech data rather than a calibrated model to investigate the aforementioned policy issue.

The remainder of the paper is organized as follows. Section two describes the employed structural model and outlines its microfoundations. Section three describes the data and chosen estimation method. Section four presents the estimations results and their discussion, and section five carries out the impulse response analysis. Section six strives to estimate the losses in macroeconomic stabilization due to a move from inflation to exchange rate targeting. Section seven concludes.

[1] Dynamic Stochastic General Equilibrium

2 Model

This section describes theoretical underpinnings of the open-economy model that we estimate for the Czech Republic. It consists of two blocks – a small open economy (the Czech Republic) and the rest of the world (approximated by the euro area economy). Let $E_t x_{t+1}$ denote the rational expectation forecast of x_{t+1} conditional on the information set available to the forecasting agent at time t. The equation describing inflation dynamics is modelled by the following "hybrid" Phillips curve[2]:

$$\pi_t = \rho_\pi E_t \pi_{t+1} + (1 - \rho_\pi)\, \pi_{t-1} + \lambda_y y_t + \lambda_{\Delta y} E_t \Delta y_{t+1} + \lambda_q \Delta q_{t-1} + \epsilon_{AS,t} \tag{1}$$

where π_t is CPI inflation, y_t is the output gap, q_t is the real exchange rate, and $\epsilon_{AS,t}$ is an autocorrelated aggregate supply (AS) shock. Although allowing for an inertial effect by giving a non-zero weight to π_{t-1} in Equation (1) was initially empirically motivated, the effect can be derived from a staggered price-setting mechanism, where a proportion of firms use a naïve, backward-looking rule to forecast inflation. The inertial effect also arises as a consequence of a Calvo-type price setting mechanism, with partial indexation to last period's inflation. For explicit derivation of the hybrid Phillips curve, see e.g. Christiano *et al.* (2001). The empirical usefulness of the hybrid specification has been advocated in e.g. Fuhrer and Moore (1995). Further, CPI inflation increases in response to a positive output gap and an increasing marginal cost of production. We also assume that inflationary pressures intensify if it is expected that opening of the output gap will accelerate in the next period, similarly as Svensson (2000). The effect of the exchange rate on CPI inflation is exercised directly through the domestic currency price of imported final goods, and the domestic currency price of the imported intermediate inputs. Eventually, the exchange rate will also affect nominal wages via the effect of CPI inflation on wage setting. In either case, the exchange rate will affect the cost of domestically produced goods and inflation in the prices of domestically produced goods (see e.g. Svensson, 2000). For empirical reasons we use the specification with the first difference in real exchange rate as in Giordani (2004), and work with an one-period lagged value to capture the exchange rate pass-through.

The output gap dynamics is described by the following aggregate demand (IS) equation:

$$y_t = \rho_y E_t y_{t+1} + (1 - \rho_y) y_{t-1} - \delta_r \left(r_{t-3} - E_{t-3} \pi_{t-2} \right) + \delta_q q_{t-2} + \delta_q y_t^* + \epsilon_{IS,t} \tag{2}$$

[2] The term hybrid relates to the fact that the Phillips curve is backwards, as well as forward-looking in inflation.

where r_t is the interest rate and $\epsilon_{IS,t}$ an autocorrelated aggregate demand shock. One can see from Equation (2) that the output gap depends on its expected value one period ahead and its lagged value, where the relative impact is determined by the size of ρ_y. The forward-looking term is due to households' inter-temporal optimizing behavior and the lagged term arises as a result of consumption habit formation, or a costly adjustment of the capital stock under inter-temporal optimization, see e.g. Clarida *et al.* (2002) and Christiano *et al.* (2001) for further details. When the interest rate increases, consumption today in terms of consumption tomorrow becomes more costly, leading to a reduction in current domestic demand. Moreover, the interest rate affects the user cost of capital, influencing investment demand. Aggregate demand is thus influenced through intertemporal substitution effects (by the real interest rate), and through intratemporal price effects (by changes in the real exchange rate). The presence of the real exchange rate and foreign output captures the changing export (and import) demand. More specifically, the net exports are assumed to increase with depreciating domestic currency (increase in q_t) and an increasing foreign output gap y_t^*. The motivation for the open-economy IS equation can be found in Monacelli (2005), Clarida *et al.* (2001), and Svensson (2000). The lag-length selection of variables is motivated empirically, and has been performed in an encompassing manner using the BIC criterion. Further, we have imposed the restriction that the impact of exchange rate changes is faster than the impact of real interest rate changes. The latter is a stylized fact which holds for most small open economies including that of the Czech Republic (see e.g. Buncic and Melecky, 2008).

For the specification of the monetary policy (MP) reaction function, we use a Taylor-type rule that considers only the domestic output gap and domestic inflation, which has been found empirically plausible[3] and reasonably robust to different model structures (see Svensson, 2000). In some circumstances, the Taylor rule can also be used to describe optimizing behavior (see Benigno and Benigno, 2003). A forward-looking version of the Taylor rule is employed to emphasize a central bank's focus on future inflation when adjusting its monetary policy instrument

$$r_t = \rho_r r_{t-1} + (1-\rho_r)\left(\psi_\pi E_t \pi_{t+1} + \psi_y y_t\right) + \epsilon_{MP,t} \tag{3}$$

where $\epsilon_{MP,t}$ is assumed to be a white-noise process.[4] The specification in (3) implies that the monetary

[3] Empirical validation of this can be sought in, for example, Giordani (2004), who includes r_t^*, π_t^* and y_t^*, but nevertheless finds that only r_t^* receives a non-zero weight in the monetary policy reaction function in his model for Canada. In the models estimated by Lubik and Schorfheide (2007) and Lubik (2005), changes in the nominal exchange rate were included in the monetary policy reaction function of the central bank, however, no statistical evidence was found to suggest that the monetary policy authority reacted to exchange rate fluctuations. We thus decided to exclude foreign variables from the monetary policy reaction function.

[4] An *i.i.d* specification of the monetary policy shock is a common assumption in the literature, see Smets and Wouters

authority responds to expected inflation one period ahead and the current output gap, while at the same time adhering to a certain degree of inertia in r_t.

Finally, the real exchange rate, q_t, needs to be described to close the model. The real exchange rate in logs is defined as $q_t \equiv s_t + p_t^* - p_t$, where s_t is the log of the nominal exchange rate, and p_t^* and p_t are the foreign and domestic price levels in logs. We adopt an assumption common in the literature of the exchange rate evolving according to real UIP. The UIP condition is generally stated as an identity over the log of the exchange rate and interest rates, with the exchange rate expressed as the ratio of domestic to foreign currency units. Since the model becomes stochastically singular if UIP is left as an identity in (4), it is necessary to either add a shock or evaluate the log-likelihood function excluding the exchange rate equation. We follow the former approach, similar to Justiniano and Preston (2004) and McCallum and Nelson (2001)

$$E_t \Delta q_{t+1} = (r_t - E_t \pi_{t+1}) - \left(r_t^* - E_t \pi_{t+1}^*\right) + \epsilon_{RER,t} \tag{4}$$

where $\epsilon_{RER,t}$ is an autocorrelated exchange rate shock. For more details regarding the empirical properties of UIP, see the studies by Ferreira and Leon-Ledesma (2007), Chinn and Meredith (2004), and Mark and Moh (2001).

The foreign (euro area) economy, which is used as a proxy for the world economy, is modelled according to the NKPM that was recently employed by Cho and Moreno (2006). This model consists of the following three equations:

$$\begin{aligned} \pi_t^* &= \rho_\pi^* E_t \pi_{t+1}^* + (1 - \rho_\pi^*)\, \pi_{t-1}^* + \lambda^* y_t^* + \epsilon_{AS,t}^* \\ y_t^* &= \rho_y^* E_t y_{t+1}^* + (1 - \rho_y^*) y_{t-1}^* - \delta^* (r_{t-6}^* - E_{t-6} \pi_{t-5}^*) + \epsilon_{IS,t}^* \\ r_t^* &= \rho_r^* r_{t-1}^* + (1 - \rho_r^*) \left(\psi_\pi^* E_t \pi_{t+1}^* + \psi_y^* y_t^*\right) + \epsilon_{MP,t}^* \end{aligned} \tag{5}$$

The specification of the closed economy model for the euro area is analogous to that for the domestic economy, with the impacts of foreign variables on domestic inflation and the output gap excluded. Notice that the lagged effect of the real interest rate on the output gap is empirically motivated using the BIC selection criterion. Having a structural model for the foreign economy enables a structural identification of foreign shocks rather than working with reduced-form shocks.

The model described by Equations (1) to (5) specifies the complete two-block structure that we

(2003) and Del Negro *et al.* (2005).

consider, with the foreign block being exogenous to the domestic one.

3 Data and Estimation Method

Given the data availability we use quarterly data series from 1995Q1-2007Q4 for the Czech Republic and from 1981Q1-2007Q4 for the euro area. The output gap is constructed as the deviation of the log of real GDP from its trend, estimated using the Hodrick-Prescott filter. The deviations are multiplied by 100 to scale up the variance of the series in accord with that of inflation and the interest rate (see also Buncic and Melecky, 2008; and Cho and Moreno, 2006). The real GDP series for the Czech Republic and the euro area were obtained from Datastream, where the real GDP for the euro area was extrapolated back to the first quarter of 1981 using the growth rates of the real GDP series from the Fagan *et al.* (2001) dataset. The inflation series are constructed as annualized percentage changes in the national CPI for the Czech Republic and the harmonized CPI for the euro area. Both CPI series were taken from Datastream. The interest rate series for the Czech Republic is the three-month PRIBOR taken from the Czech National Bank's statistic. For the euro area, the interest rate is the three-month EURIBOR obtained from Datastream and extrapolated from the first quarter of 1994 back to the first quarter of 1981 using the growth rates of the short-term interest rate from the Fagan *et al.* (2001) dataset. The real exchange rate between the Czech koruna and the euro (CZK/EUR) was constructed using the CZK/EUR exchange rate series, calculated as a cross-exchange rate between the synthetic EUR/USD rate and the CZK/USD rate obtained from Datastream, and the two CPI series described above. The real exchange rate series is expressed in logarithms and linearly detrended prior to the estimation. All data series were demeaned prior to the estimation. Giordani (2004) has recently argued that working with demeaned data avoids dealing with parameter instability and structural breaks which, he finds, largely affect the unconditional mean of the series being modeled.

There are several estimation methods used in the literature to fit New Keynesian models to the data. Recently, the most popular method has been the Bayesian estimation which overcomes some problems of the Full Information Maximum Likelihood method by imposing priors on the structural coefficients' distributions (see e.g. An and Schorfheide, 2005; or Buncic and Melecky, 2008). Given the relatively higher model uncertainly for transition economies, and the fact that system estimators can be inconsistent if one of the equations in the system is misspecified (see Johansen, 2005) our preferred estimation method is the Generalized Method of Moments (GMM) (see e.g. Gali and Gertler, 1999;

among others). We used up to three lags of the variables in the system as instruments if needed while determining the lag-length in an encompassing manner. The long-run heteroscedasticity and autocorrelation consistent (HAC) covariance matrix weighting the moment conditions in the GMM estimator is estimated using the Bartlett kernel with the variable New-West bandwidth selection. In addition, pre-whitening of the moment conditions was applied.

4 Discussion of Estimation Results

The estimates of the model parameters using GMM and the quarterly data for the Czech Republic and the euro area are shown in Table (1).

Parameter	Czech Republic		Parameter	Euro Area	
ρ_π	0.5961	$(0.0650)^{***}$	ρ^*_π	0.7606	$(0.1068)^{***}$
λ_y	0.0976	$(0.0366)^{***}$	λ^*_y	0.0316	$(0.0171)^{*}$
$\lambda_{\Delta y}$	0.1005	$(0.0382)^{**}$			
λ_q	0.1292	$(0.0634)^{**}$			
ρ_y	0.4895	$(0.0381)^{***}$	ρ^*_y	0.4721	$(0.0403)^{***}$
δ_r	0.0320	$(0.0085)^{***}$	δ^*_r	0.0257	$(0.0118)^{**}$
δ_q	0.0250	$(0.0133)^{*}$			
δ_{y^*}	0.0399	$(0.0157)^{**}$			
ρ_r	0.8259	$(0.0310)^{***}$	ρ^*_r	0.9215	$(0.0364)^{***}$
ψ_π	1.6880	$(0.1065)^{***}$	ψ^*_π	1.7352	$(0.3083)^{***}$
ψ_y	0.3964	$(0.1339)^{***}$	ψ^*_y	0.1264	$(0.0670)^{*}$
σ_{AS}	3.5273		σ^*_{AS}	0.9780	
σ_{IS}	1.5710		σ^*_{IS}	1.4720	
σ_{MP}	2.1926		σ^*_{MP}	0.4703	
σ_{RER}	5.8557		$\rho_{\epsilon_{RER}}$	0.4265	$(0.1314)^{***}$

Table 1: GMM Estimates of Model Parameter for the Czech Republic and the Euro Area

Consider first the parameter estimates of the Phillips curve for both the Czech Republic and the euro area. The estimate of ρ_π : 0.59 suggests that the inflation process in the Czech Republic has been more forward- than backward-looking. Also in the euro area, expected inflation appears to affect inflation dynamics more than past inflation, but even to a larger extent (ρ^*_π estimate of 0.76). This can be a result of relatively higher competition and associated price changes in the euro area. Or, perhaps the fact that there was higher uncertainty associated with future inflation in the Czech Republic over 1995-2007, so that the Czech agents were choosing to index more to past inflation. The sensitivity of inflation to demand pressures, as measured by the output gap, (λ_y) is estimated to be almost three times higher in the Czech Republic than the euro area (0.10 versus 0.03).[5] These estimates imply that an

[5] We acknowledge the fact that the specifications of the estimated equations for the Czech Republic and the euro area

equal increase in excess demand in the two countries will result in about three times higher an increase in the marginal cost of production in the Czech Republic compared with the euro area. This can be a result of Czech firms operating closer to full capacity or facing relatively higher constraints in expanding their production in the short term, e.g. due to higher credit constraints. In addition, the significantly positive estimate of $\lambda_{\Delta y}$ suggests that to the extent the Czech firms can expect (predict) the increase in excess demand for their production in the next period, they will add 10 percent of this increase into current prices. The open-economy Phillips curve estimated for the Czech Republic reveals a positive exchange rate pass-through at the 10 % significance level. Namely, the positive estimate of λ_q: 0.12, implies that a 10 percent increase in the exchange rate (CZK/EUR) will result in a 1.2 percent increase in Czech CPI inflation. This estimate could decline over time as the share of services in the sales of imports (especially to final consumers) will increase. However, the competition between importers can also intensify, or the share of tradeables in the CPI basket can increase as the small economy further specializes, both of which will boost the exchange rate pass-through. Due to a shorter span of available observations and the transition nature of the Czech economy, the data fit of the estimated Phillips curve for the Czech Republic is significantly lower, adjusted R squared of 0.25, than the fit for the euro area, adjusted R squared of 0.83. This is also reflected in magnitudes of the estimated standard deviations of AS shocks for the two countries, where the Czech Republic is estimated to face more than three times larger supply shocks than the euro area ($\sigma_{AS} = 3.53$ versus $\sigma^*_{AS} = 0.98$).

We now proceed with the IS-curve parameters' estimates. The weight on past output gap levels in the process driving output gap formation is larger in both countries than the weight on the future output gap (ρ_y : 0.49; ρ^*_y : 0.47) suggesting that in both economies consumption-habit formation and costly adjustments of the capital stock result in significant output gap persistence. The real interest rate's impact on output is fairly similar in magnitude for the two economies where δ_r is estimated 0.032 and 0.026 for the Czech Republic and the euro area, respectively. The maximum effect of the real interest rate on output is estimated, using the lag-length selection approach, to arrive with a *three*-period lag in the Czech Republic and a *six*-period lag in the euro area. The length of the interest rate transmission channel is thus longer in the euro area. The effect of changes in the real exchange rate on net exports and thus output is estimated to arrive with a *two*-period lag in the Czech Republic, so that the exchange rate transmission channel appears to be faster than the interest rate transmission channel, as it is commonly found for small open economies (see e.g. Buncic and Melecky, 2008). The

differ and thus the marginal effects were estimated using differing conditioning sets. Nevertheless, we still attempt to make some comparisons.

magnitude of the real exchange rate effect on output is, however, estimated to be somewhat smaller (δ_q : 0.025) than the magnitude of the interest rate effect, δ_r, which could be seen as a bit unusual for an small open economy. The impact of foreign demand, changes in foreign (the euro area's) output, δ_{y^*}, is contemporaneous and estimated to be 0.04. This implies that a 10 percent increase in euro area's output is estimated to result in a 4 percent increase of Czech output. As the real convergence of the Czech Republic to the EU and the euro area intensifies this effect is likely to increase due to higher trade integration of the two economies. The data fit of the open economy IS curve for the Czech Republic, adjusted R squared of 0.89, is slightly better than the data fit of the closed economy IS curve for the euro area, adjusted R squared of 0.83. Nevertheless, the standard deviation of the IS shock in the Czech Republic, σ_{IS}: 1.57, appears to be marginally higher than the standard deviation of the IS shock in the euro area, σ^*_{IS} : 1.47.

The estimated MP reaction functions of a Taylor rule type, show that both the Czech National Bank (CNB) and the ECB smooth their interest rates to a large extent, where the ECB policy rate, with ρ^*_r : 0.92, exhibits slightly more intertia than the CNB policy rate, with ρ_r : 0.83. The ECB reaction to expected inflation appears to be, on average, higher than that of the CNB, with ψ^*_π and ψ_π estimated at 1.74 and 1.69, respectively. On the other hand, the ECB appears to put less weigh on the output gap in its reaction function than the CNB where ψ^*_y and ψ_y are estimated at 0.13 and 0.40. In Svensson (2000) classification, the ECB thus appears to act as a more conservative central banker compared with the CNB. In addition, based on the estimates of the standard deviations of the MP shocks for the Czech Republic and the euro area, σ_{MP} : 2.19 and σ^*_{MP} : 0.47, the discretion, within the context of the assumed monetary policy rule, applied by the ECB seems to be much lower than the discretion applied by the CNB. Both the monetary policy reaction functions fit the data well with the adjusted R squared for the Czech Republic and the euro area being 0.84 and 0.98.

Finally, the uncovered interest parity condition implies that the standard deviation of the exchange rate shock, σ_{RER}, is 5.86. The exchange rate shock also appears to be significantly positively correlated over time, with the autocorrelation coefficient of 0.43.

5 Impulse Response Analysis

In the impulse response analysis, we look into how the domestic (Czech) economic variables respond to individual structural shocks, both domestic and external. We solve the system of equations with rational expectations into an VAR form using the QZ algorithm of Sims (2002). Once the reduced-form of the system is obtained, it can be readily used to generate the impulse responses of endogenous variables to selected shocks. We focus first on the responses of the Czech inflation, output gap , interest rate and CZK/EUR exchange rate to domestic shocks, plotted in Figure (1), and then to external shocks, plotted in Figure (2).

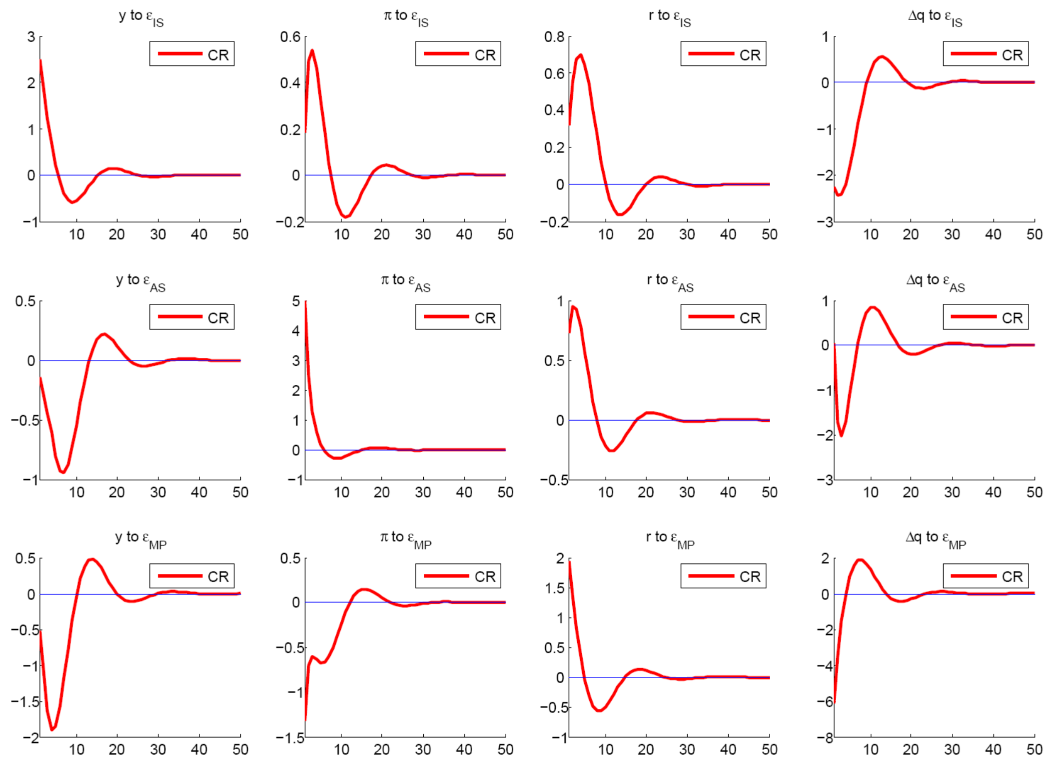

Figure 1: Responses of the Czech output gap, inflation, interest rate and CZK/EUR exchange rate to domestic demand, supply and monetary policy shocks

Consider the first row of Figure (1). Once the Czech economy is hit by the domestic IS shock the output gap increases at impact followed by an increase in inflation. As the Czech National Bank (CNB) reacts to increased inflation and output gap by raising its interest rate the real interest rate differential vis-a-vis the euro area becomes even more positive and the CZK appreciates against the euro as a result, in accord with the postulated real UIP. The interest rate hike and CZK appreciation help contain demand pressures and inflation so that the output gap and inflation adjust to their steady-state values in about 25 quarters.

In the second row of Figure (1) we see that as the economy is hit by an AS shock, inflation increases sharply at impact, the CNB reacts to this development by raising its interest rate more than one-to-one in accord with its MP rule, so that the CZK appreciates in real terms vis-a-vis the euro. The increased real interest rate and appreciating CZK make the output gap drop into significantly negative values. As the real domestic interest rate becomes negative during the adjustment of inflation, the interest rate and output gap to their steady states, the CZK depreciates in real terms against the euro, shortly before it settles around its steady-state value.

The third row of Figure (1) shows the IRFs of the domestic variables to a MP shock. An idiosyncratic increase in the CNB interest rate (a MP discretionary shock) causes by definition spike in the domestic interest rate at impact, making inflation decline into the negative territory. This results in a significantly positive real interest rate differential vis-a-vis the euro, and the CZK appreciates strongly in real terms against the euro. The sharp increase in the real interest rate and sharp real appreciation of the CZK make the output gap contract significantly due to declining domestic demand, and foreign demand for Czech merchandise as a result of lower external price competitiveness.

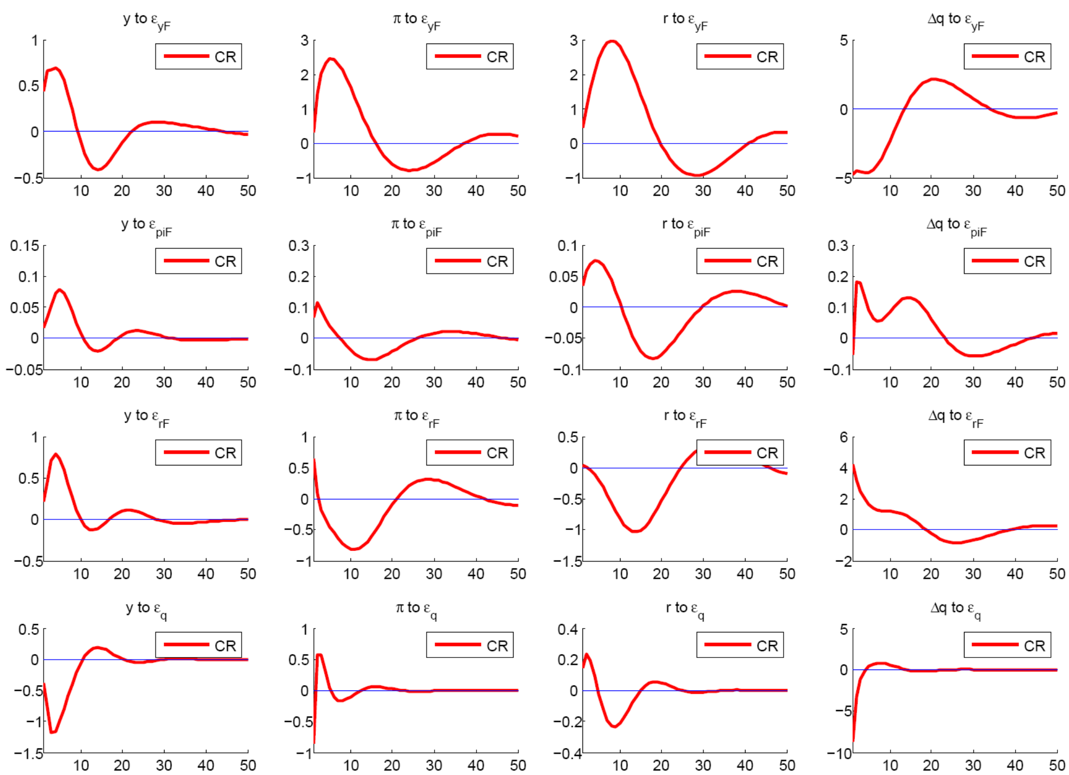

Figure 2: Responses of the Czech output gap, inflation, interest rate and CZK/EUR exchange rate to foreign demand, supply and monetary policy shocks, and the exchange rate shock.

Next, we inspect the responses to foreign shocks. Consider the first row of Figure (2). As the foreign IS shock hits the euro area economy, foreign demand increases and the Czech output gap opens in a positive direction. Consequently, inflation increases and the CNB reacts by raising its interest rate more than one-to-one with respect to inflation so that the real interest rate increases. Also the ECB raises its interest rate as the euro area IS shock results in higher euro area inflation. Nevertheless, a positive real interest rate differential emerges in favour of the Czech economy and the CZK appreciates relative to the euro in real terms. The positive real interest differential arises due to the fact that the CNB reacts relatively more to the output gap (see ψ_y and ψ_y^* in Table (1)) and that the credit channel of monetary policy in the euro area functions with a longer lag than the credit channel in the Czech Republic. Inflation thus starts declining faster in the Czech Republic and the real interest rate peaks sooner. As the full effect of the interest rate materializes in the euro area the real exchange rate swings to the opposite direction so that the euro appreciates vis-a-vis the koruna in real terms before the exchange rate settles at its steady-state value. The differing reactions of monetary policy and lengths of transmission mechanisms in the euro area and the Czech Republic cause larger swings in the IRFs of the Czech variables before they reach their steady states. We will get back to this property later in the paper.

The second row of Figure (2) shows the responses of Czech variables to the euro area AS shock. After the euro area AS shock hit the euro area economy, the ECB raises its interest rate inducing an increase in the real euro area interest rate and depreciation of the CZK relative to the EUR. This depreciation has a positive effect on Czech net exports and the Czech output gap increases. The positive Czech output gap and the pass-through of CZK depreciation into Czech CPI result in increased inflation. And, as the CNB reacts to positive inflation and the output gap, it increases its interest rate, lowers the real interest rate differential vis-a-vis the euro and the koruna's depreciation slows down. Again, the differing intensity of the reaction of the CNB and the ECB to inflation and positive output gap together with the differing length of the monetary transmission channels result in significant swings in the IRFs of the Czech variables to the euro area AS shock.

Consider now the third row of Figure (2). The discretionary MP shock in the euro increases real interest rate therein and results in a depreciation of the CZK with respect to the EUR in real terms. This depreciation fades out slowly in about 18 quarters. As the external price competitiveness of Czech exports increases and imports become more expensive, the net exports rise and the output gap opens in a positive direction in the Czech Republic. As a result of the positive output gap and CZK depreciation the domestic inflation increases initially. The positive impact of the koruna's depreciation on the domestic output gap peaks in about 4 quarters and then adjusts quickly back to its steady state.

The expectation of this rapid adjustment of the output gap downward causes a period of deflation (note the presence of $E_t \Delta y_{t+1}$ in Equation (1)) to which the CNB reacts by decreasing its interest rate to bring the inflation response back to its steady state.

The last row of Figure (2) shows the responses of Czech variables to a positive exchange rate shock. The positive exchange rate shock causes short appreciation of the CZK relative to the EUR which induces a negative Czech output gap and drop in inflation at impact. However, because of the observed, only short appreciation of the koruna, the Czech output gap is expected to adjust back fast and this expected positive output gap adjustment causes a short-lived increase in inflation after two quarters to which the CNB reacts by increasing its interest rate. After several quarters, the CNB decreases its interest rate in order to smooth out the exchange rate response which returns to zero in about 13 quarters.

Finally, Table (2) shows the results of an asymptotic variance decomposition for the domestic variables in percent. It appears that domestic discretionary MP shock has the largest impact on output gap fluctuations in the Czech Republic, followed by the domestic IS shock and the real exchange rate shock, while the remaining structural shocks contribute significantly as well. Inflation variations, on the other hand, are from about 50 percent attributable to the foreign IS shock, and from about 34 percent to the domestic AS shock whereas other shocks' influences are relatively small. The domestic interest rate is mostly influenced by the euro area IS shock as a result of its impact on inflation variations in the Czech Republic, where the CNB's discretionary shock and the domestic AS shock contribute significantly as well. The exchange rate variability is also most significantly influenced by the euro area IS shock, followed by the exchange rate shock, the CNB's discretionary shock, and the ECB's discretionary shock.

	$\epsilon_{IS,t}$	$\epsilon_{AS,t}$	$\epsilon_{MP,t}$	$\epsilon_{RER,t}$	$\epsilon^*_{IS,t}$	$\epsilon^*_{AS,t}$	$\epsilon^*_{MP,t}$
y_t	28.2	10.6	35.6	12.3	7.8	0.1	5.7
π_t	1.1	34.0	4.9	1.6	50.6	0.1	7.7
i_t	2.12	3.23	7.0	0.35	77.1	0.1	10.1
Δq_t	6.0	3.1	14.3	18.5	45.5	0.1	12.6

Table 2: Asymptotic variance decomposition for the Czech output gap, inflation, interest rate and the real exchange rate

6 From Inflation to Exchange Rate Targeting

In this section we attempt to investigate to what extent a possible move from inflation to exchange rate targeting affects the monetary policy ability to stabilize the economy. We will carry out this investigation on the example of the Czech Republic using the estimated New Keynesian policy model discussed above. We divide the investigation into the following steps. First, we assume a representative loss function for the monetary authority. To examine sensitivity of our findings to the assumed central bank's loss function we consider a range of alternatives which also help in generalization of our findings. Second, we compute the optimized simple rule within the context of the estimated model for the Czech Republic using the assumed CNB's loss function (a range of plausible loss functions). Third, we assume that as the Czech Republic proceeds with its integration into the European Monetary Union (EMU), and as a part of its strategy to adopt the euro in the future, the CNB will switch at some point from inflation to exchange rate targeting. This switch will result in the CNB using the exchange rate as its nominal anchor and will change the monetary policy reaction function into an interest rate rule for fixed exchange rate regimes. Using the estimated model for the Czech Republic and the assumed loss function, we optimize the type of an interest rate rule for fixed exchange rate regimes suggested by Benigno et al. (2006). Fourth, we evaluate the differences in the loss function values under the optimized inflation targeting rule and exchange rate targeting rule. We use results of growth regressions including inflation and output volatility as explanatory variables to loosely translate the possible losses in economic stabilization due to a move from inflation to exchange rate targeting into percentage points of GDP growth. This translation is not aiming to provide any rigorous quantification of the effect of economic stabilization on growth, but rather illustrate how relevant the effect is, in terms of economic growth, to substantiate policy relevance of the issue at hand.

We assume that the central bank aims to stabilize inflation, around the inflation target, the output gap and the interest rate by minimizing the following loss function

$$L = var\left(\overline{\pi}_t - \overline{\pi}^*\right) + \alpha_y var\left(y_t\right) + \alpha_i var\left(\bar{i}_t\right) \tag{6}$$

where $\overline{\pi}_t$, $\overline{\pi}_t^*$, and $\bar{i}_t$ measure inflation, the inflation target and the nominal interest rate in annualized terms. This objective function is consistent with the mandates of most central banks.[6] As the baseline,

[6] This objective function is not an approximation of the representative household's utility, as we do not attempt to carry out a full-fledged welfare analysis of a representative household in our economy (see Woodford, 2003) and concentrate on the mandate and preferences of the central bank. The objective function specification in (6) approaches more general

we assume that the central bank preference parameters are given by $\alpha_y = 0.5$ and $\alpha_i = 0.1$, so the central bank attaches a larger weight to inflation stability than to output gap stability, and a small weight to stability in the interest rate. The interest rate stabilization objective can be seen as a proxy of a preference for stability in financial markets. Tinsley (1999), for example, argues that interest rate volatility may increase term premia and therefore lead to higher long-term interest rates. From a theoretical perspective, Woodford (2003) shows that the welfare-maximizing policy should aim at reducing interest rate volatility when there are money transaction frictions or when the central bank wants to avoid the zero lower bound on nominal interest rates. To inspect the sensitivity of our results to different preferences (mandate) of the central bank, we consider three alternative parametrizations of the loss function. Namely, $L^y(\cdot, \alpha_y = 0.9)$ where the CB puts larger weight on stabilizing the output gap; $L^i(\cdot, \alpha_i = 0.4)$ where the CB puts larger weight on smoothing the interest rate; and $L^\pi(\cdot, \alpha_y = 0, \alpha_i = 0.4)$ where the central bank cares only about stabilizing inflation around the inflation target. We do not optimize over the σ_{MP} parameter of the monetary policy rule characterizing the degree of monetary policy discretion within the context of the assumed MP rule. This is because this problem is trivial as any $\sigma_{MP} > 0$ produces a suboptimal value of the central bank's loss function. Nevertheless, we consider two cases. First, when $\sigma_{MP} = \widehat{\sigma}_{MP} = 2.1926$ and the monetary policy retains the historical degree of discretion for the assumed MP rule (inflation targeting or exchange rate targeting rule). Second, when $\sigma_{MP} = 0$ and the MP sticks strictly to the assumed MP rule and no discretion is allowed, i.e. the interest rate becomes strictly endogenous in our framework.

Further, for the purpose of translating the losses or gains in economic stabilization due to a move from inflation to exchange rate targeting we use the following equation

$$\Delta g = \beta \left(\sqrt{L_{ERT}} - \sqrt{L_{IT}} \right) \tag{7}$$

where g is the GDP growth and β is the coefficient translating the change in the square root of the loss function value as a result of a move from inflation to exchange rate targeting into percentage points of GDP growth. We use the existing empirical growth literature to calibrate the β parameter. Since, we are not aware of any study that would estimate jointly the effects of inflation volatility, output gap volatility and interest rate volatility on growth, we use the estimation results of Judson and Orpahides

specification of

$$L_t = \left(1 - \widehat{\beta}\right) E_t \sum_{j-0}^{\infty} \widehat{\beta}_j \left[(\overline{\pi}_t - \overline{\pi}^*)^2 + \alpha_y y_t^2 + \alpha_i \overline{i}_t^2 \right]$$

as the central bank discount factor $\widehat{\beta}$ approaches one.

(1999) and Hnatkovska and Loaya (2003). Judson and Orpahides (1999) estimate the effect of inflation volatility on growth using various specification and different control variables. Our preferred estimates are those presented in Table 6 of their paper in which they control for investment as a percent of capital, the growth rate of per capita human capital, and inflation. Since they report a range of estimates for different country groups we use as the upper bound their estimate for the full sample of countries, $\beta : -0.551$, and as the lower bound their estimate for the OECD countries, $\beta : -0.135$. Hnatkovska and Loaya (2003), on the other hand, estimate the effect of output gap volatility on growth where our preferred estimates are those reported in Table 9 in which they control for the effect of the output gap volatility on growth in crisis periods, initial GDP per capita, secondary enrollment rates, and private domestic credit over GDP. We consider as the upper bound their IV estimate of $\beta : -0.536$, and as the lower bound their OLS estimate $\beta : -0.1251$. Despite the fact that the preferences on inflation volatility, output volatility and interest rate volatility change across our assumed loss functions, using unified β should not introduce an excessive bias as indicated by similar β estimates produced by Judson and Orpahides (1999) and Hnatkovska and Loaya (2003). From now on we report only the growth effect estimates due to changes in economic stabilization using Judson and Orpahides (1999) range of estimates $\beta = [-0.135; -0.551]$. This is for the sake of brevity and due to the fact that inflation volatility is always dominating in the assumed loss functions of the central bank.

6.1 Evaluating the central bank loss function under optimized, simple inflation-targeting rule

Table (3) shows the estimated coefficients of the forward-looking Taylor rule (see Equation (3)) estimated by GMM (see also Table(1)), and the optimized coefficients of the forward-looking Taylor rule under the assumed baseline loss function of the CNB, and some alternatives loss functions – columns with headings ψ_π, ψ_y, ρ_r. Note that other coefficients, such as those of the IS and Phillips curve, the real UIP equation and the euro area block are fixed when computing the optimized coefficients of the Taylor rule. Table (3) also shows the value of the assumed loss functions evaluated at the optimized Taylor rule coefficients in the column with the heading L_{IT}. The second last column of Table (3) shows the percentage change in the loss function should the CNB change the existing weights on the future inflation, output and lagged interest rate to the optimized weights. The last column of Table (3) attempts to translate the percentage change reported in the second last column into percentage points of GDP growth, a measure that could be more explicit and relevant for the purposes of policy makers.

Loss function	ψ_π	ψ_y	ρ_r	L_{IT}	$\frac{(L_{GMM}-L_{IT})}{L_{GMM}}$	in % GDP
			Historical Discretion, $\sigma_{MP} = 2.1926$			
GMM loss function	1.688	0.396	0.826	na	0	0
$L\,(\alpha_y = 0.5, \alpha_i = 0.1)$	4.963	0.298	0.856	72.114	-45.94%	[0.41; 1.68]
$L^y\,(\alpha_y = 0.9, \alpha_i = 0.1)$	3.345	0.205	0.807	99.195	-34.13%	[0.31; 1.27]
$L^i\,(\alpha_y = 0.5, \alpha_i = 0.4)$	6.1695	-0.240	0.890	92.000	-44.77%	[0.45; 1.83]
$L^\pi\,(\alpha_y = 0, \alpha_i = 0)$	24.415	-1.557	0.193	2.240	-97.72%	[1.14; 4.64]
			No Discretion, $\sigma_{MP} = 0$			
GMM loss function	1.688	0.396	0.826	na	0	0
$L\,(\alpha_y = 0.5, \alpha_i = 0.1)$	7.623	0.434	0.939	60.256	-49.37%	[0.42; 1.73]
$L^y\,(\alpha_y = 0.9, \alpha_i = 0.1)$	3.519	0.230	0.863	84.097	-36.03%	[0.31; 1.26]
$L^i\,(\alpha_y = 0.5, \alpha_i = 0.4)$	4.045	-0.103	0.893	80.894	-47.15%	[0.46; 1.86]
$L^\pi\,(\alpha_y = 0, \alpha_i = 0)$	9.232	-0.197	0.218	6.133	-93.54%	[0.98; 4.01]

Table 3: Central bank loss function evaluation under optimized, simple inflation-targeting rule

6.1.1 The Case with Historical Discretion

Under the baseline loss function $L\,(\alpha_y = 0.5, \alpha_i = 0.1)$ and the assumption that the CNB retains the historical degree of discretion, the optimized weight on expected future inflation, ψ_π^*: 4.963, is significantly higher than the estimated historical weight, $\widehat{\psi}_\pi$: 1.688, which the CNB appears to be putting on expected future inflation when adjusting its interest rate. On the other hand, the optimized weight on the output gap, ψ_y^*: 0.298, appears to be lower than the estimated historical weight, $\widehat{\psi}_y$. The estimated degree of interest rate smoothing historically applied by the CNB, $\widehat{\rho}_r$: 0.826, is similar to the optimized degree of interest rate smoothing, ρ_r^*: 0.856, under the assumed baseline loss function. The loss function value at the optimized Taylor rule coefficients, i.e. ψ_π^*, ψ_y^* and ρ_r^* is 72.114 which is about 45.9 percent lower than the loss function value at the GMM coefficients. If the baseline loss function, $L\,(\alpha_y = 0.5, \alpha_i = 0.1)$, is representative of CNB's preferences then the CNB can better fulfill its objectives by increasing its response to expected future inflation, and somewhat decreasing its response to the current output gap when adjusting its interest rate. This is estimated to generate an increase in GDP growth of between 0.41 and 1.68 percentage points.

Nevertheless, the CNB preferences about inflation stabilization versus output gap and interest rate stabilization can differ. Therefore, we consider some alternative loss function to examine the differences in the optimized Taylor rule coefficients and the potential CNB losses under these alternatives. If the CNB were to put relatively more weight on output gap stabilization, assuming $L^y\,(\alpha_y = 0.9, \alpha_i = 0.1)$, the optimized weight on inflation in the forward-looking Taylor rule would decrease compared with the baseline loss function to ψ_π^*: 3.345. On the other hand, should the CNB be putting more weight on interest rate smoothing, under L^i, or be purely concerned about inflation stabilization, under L^π, the optimized response of CNB to expected future inflation would increase even further compared with the baseline loss function to 6.170 and 24.415.[7] The optimized weight on the output gap in the forward-looking Taylor rule appears to be lower under all three alternative loss functions L^y, L^i and L^π, i.e. even if the CNB was more emphasizing output gap stabilization in its preferences. Note that the negative optimized weights on the output gap under L^i and L^π arise because a positive supply shock increases inflation and decreases the output gap, and supply shocks are the second largest shocks in the system after the exchange rate shock. Changing the assumed CNB's loss function does not seem to have any significant impact on the optimized weight on interest rate smoothing as long as $\alpha_i > 0$. Once α_i is set to zero the optimized degree of interest rate smoothing drops significantly and to the value inconsistent with the historical estimates obtained from the data.

After examining the optimized weights ψ_π^*, ψ_y^* and ρ_r^* across the baseline and alternative loss functions, L and L^y, L^i and L^π, it appears that the GMM estimates of the forward-looking Taylor rule, and thus the weights the CNB have been placing on its components, could be most consistent with the assumed baseline loss function L with possibly higher preference for output gap stability in the direction of L^y. The values of the loss functions L^y, L^i and L^π at the respective optimized Taylor rule coefficients are 99.195, 92.000 and 2.240, where the differences with respect to the loss functions evaluated at the GMM coefficient estimates are 34.13, 44.77 and 97.72 percent. This means that if the CNB's preferences were characterized by L^y, L^i or L^π, moving from the historical weights $\widehat{\psi}_\pi, \widehat{\psi}_y$ and $\widehat{\rho}_r$ to the respective optimized ones would decrease the loss function values by 34.13, 44.77 and 97.72 percent, respectively. The resulting growth effects could amount to 0.31 to 1.27 percent of GDP under L^y, 0.45 to 1.83 percent of GDP under L^i, and 1.14 to 4.64 percent of GDP under L^π.

6.1.2 The Case with No Discretion

Considering the baseline loss function $L\,(\alpha_y = 0.5, \alpha_i = 0.1)$ and assuming that the CNB will not apply any discretion and stick strictly to the forward-looking Taylor rule, when setting its interest rate, produces an optimized response to expected future inflation of ψ_π^*: 7.623. This is significantly higher than the estimated historical CNB response and also higher than the optimized response in the case when the CNB retains its historical degree of monetary policy discretion. Also, the optimized weights

[7] Optimized policy rules are commonly more aggressive than estimated rules where this result is often attributed to the fact that the optimized rules do not take into account different sources of uncertainty that could cause more cautious policy responses see, for instance, Melecky et al. (2008), Cateau (2005), or Rudebusch (2001).

on the output gap and interest rate are somewhat higher than their estimated counterparts. While this was the case for the interest rate weight in the optimized rule with historical discretion as well, the optimized weight on the output gap is notably higher in the no-discretion case compared with the historical discretion case. The value of the loss function at the optimized coefficients is 60.256, i.e. lower than in the case with historical discretion (72.114). If CNB were to adjust its response from the estimated historical weights to the optimized ones, under L and no MP discretion, the resulting decrease in the loss function value would be 49.37 percent. This could translate to increased GDP growth by about 0.42 to 1.73 percentage points.

When we consider the three alternative loss functions and allow no MP discretion, the optimized weight on expected future inflation decreases in cases where the CNB is assumed to have more preference for output and interest rate stabilization, while it increases in the case of pure preference for inflation stabilization. Overall, the optimized weights on inflation tend to be lower than those under historical MP discretion. This could be due to the fact that there is one less shock in the system (the MP shock) and thus lower variables volatility overall. The optimized weights on the output gap are generally higher than in the historical-discretion case, however, the negative signs on the optimized output gap weights under L^i or L^π prevail. Also, the optimized weights on the past interest rate are generally higher than in the historical discretion case and thus further from the estimate based on the data, except for L^i. Due to the absence of the interest rate shock in the system, the values of the alternative loss functions $(84.097, 80.894$ and $6.133)$ tend to be lower than in the analogous cases with historical discretion. And, only the L^π value at the optimized coefficients is lower than the baseline no-discretion case. If the CNB were to move from the estimated weights to the ones optimized under L^y, L^i or L^π, the resulting decrease in the loss function values would be $36.03, 47.15$ and 93.54 percent, respectively. The use of the optimized weights is estimated to increase GDP growth by 0.31 to 1.26 percentage points under L^y, 0.46 to 1.86 percentage points under L^i, and 0.98 to 4.01 percentage points under L^π.

6.2 Evaluating the central bank loss function under optimized, simple exchange rate-targeting rule

While the Czech Republic progresses in its accession to the European Monetary Union (EMU), the CNB will have to change its nominal anchor at some point in the future and adopt exchange rate targeting before the ultimate adoption of the euro. Although it is not certain when in the ERMII this will occur, we are not concerned with the timing of this change but take it as a milestone at which we measure the possible loss in macroeconomic stabilization due to the move from the inflation to exchange rate targeting regime of monetary policy. The change of the nominal anchor of monetary policy will result in the CNB adjusting its interest rate according to a new interest rate rule for exchange rate targeting. For the purpose of our exercise we consider an interest rate rule for exchange rate targeting of the following form

$$i_t = i_t^* + \psi_S E_t \Delta s_{t+1} + \epsilon_{MP,t} \tag{8}$$

consistent with the type of interest rate rules for exchange rate targeting proposed by Benigno et al. (2006). The CNB is thus assumed to adjust its interest rate one-to-one with respect to the euro area interest rate, i_t^*, and respond to the expected changes in the nominal CZK/EUR exchange rate, s_t, while possibly applying some degree of discretion to this rule – represented by $\epsilon_{MP,t}$. The coefficient ψ_S is constrained to be positive, and Benigno et al. (2006) argue that for the purpose of a model's stability ψ_S should be around two or higher.

Table (4) shows the baseline and the alternative loss functions for the historical discretion case, i.e. when the CNB is assumed to retain the same degree of discretion as measured by σ_{MP} in the context of the interest rate rule for exchange rate targeting, and for the no discretion case, i.e. when the CNB sticks strictly to the systematic part of Equation (8), i.e. $\epsilon_{MP,t}$ drops out, and the interest rate becomes purely endogenous within our model. The column with the heading ψ_S shows the optimized weight on the expected future change in the CZK/EUR exchange rate under the relevant loss function. The column with heading L_{ERT} shows the loss functions evaluated at ψ_S^* and Equation (8) used as the MP reaction function in the simulation of inflation, output gap and interest rate volatility. The column with the heading $\frac{(L_{ERT}-L_{IT})}{L_{IT}}$ shows the computed percentage change in the loss function values if the CNB were to move from the optimized inflation targeting rule to the optimized exchange rate targeting rule. The fifth column then strives to translate this change into percentage points of GDP growth. Analogously, the column with the heading $\frac{(L_{ERT}-L_{GMM})}{L_{GMM}}$ shows the computed percentage change in the loss function values if the CNB were to shift from the estimated inflation targeting rule based on historical data to the optimized exchange rate targeting rule, for each type of the loss function. The last column strives to translate this change in the loss function value into GDP growth figures.

Loss function	ψ_S	L_{ERT}	$\frac{(L_{ERT}-L_{IT})}{L_{IT}}$	in % GDP	$\frac{(L_{ERT}-L_{GMM})}{L_{GMM}}$	in % GDP
Historical Discretion, $\sigma_{MP} = 2.1926$						
$L\,(\alpha_y = 0.5, \alpha_i = 0.1)$	2.325	129.489	79.56%	$[-0.39; -1.59]$	-2.93%	$[0.02; 0.09]$
$L^y\,(\alpha_y = 0.9, \alpha_i = 0.1)$	2.325	137.651	38.77%	$[-0.24; -0.98]$	-8.59%	$[0.07; 0.30]$
$L^i\,(\alpha_y = 0.5, \alpha_i = 0.4)$	2.756	213.135	131.67%	$[-0.68; -2.76]$	27.92%	$[-0.23; -0.93]$
$L^\pi\,(\alpha_y = 0, \alpha_i = 0)$	2.025	85.629	3723.13%	$[-1.05; -4.27]$	-13.04%	$[0.09; 0.37]$
No Discretion, $\sigma_{MP} = 0$						
$L\,(\alpha_y = 0.5, \alpha_i = 0.1)$	2.429	129.328	114.63%	$[-0.49; -1.99]$	8.67%	$[-0.06; -0.26]$
$L^y\,(\alpha_y = 0.9, \alpha_i = 0.1)$	2.395	137.565	63.57%	$[-0.35; -1.41]$	4.64%	$[-0.04; -0.14]$
$L^i\,(\alpha_y = 0.5, \alpha_i = 0.4)$	2.400	211.877	161.91%	$[-0.75; -3.06]$	38.41%	$[-0.29; -1.20]$
$L^\pi\,(\alpha_y = 0, \alpha_i = 0)$	2.100	86.621	1312.16%	$[-0.92; -3.76]$	-8.82%	$[0.06; 0.24]$

Table 4: Central bank loss function evaluation under optimized, simple exchange rate-targeting rule

6.2.1 The Case with Historical Discretion

Considering the assumed baseline loss function and a retained historical degree of MP discretion, the optimized coefficient on the expected future change of the exchange rate in Equation (8), ψ_S^*, is 2.325. Evaluating the loss function at this coefficient value produces value L_{ERT}: 129.489 which constitutes a 79.56 percent increase in the loss compared with the case when CNB uses the optimized inflation targeting rule for adjusting its interest rate, i.e. L_{IT}. This could translate into a 0.39 to 1.59 percentage point decrease in GDP growth. On the other hand, when one considers the estimated inflation targeting rule as the basis for computation of the possible loss in macroeconomic stabilization, a move to the optimized exchange rate targeting rule does not involve any significant loss and, on contrary, appears to produce mild gain. This improvement in economic stabilization is estimated to increase GDP growth by 0.02 to 0.09 percentage points.

Employing alternative loss functions and assuming the degree of historical discretion produces different results in terms of estimated losses in macroeconomic stabilization. Under the loss function L^y with a greater emphasis on output, ψ_S^* is 2.325, the same as if using L. The loss in macroeconomic stabilization due to a move from the optimized inflation targeting rule to an optimized exchange rate targeting rule is 38.77, about half that in the baseline case, and could translate into a 0.24 to 0.98 percentage point decrease in GDP growth. However, if the estimated inflation targeting rule is considered as the basis, the move to optimized exchange rate targeting rule produces a mild gain in economic stabilization of 8.59 percent, which could translate into a 0.07 to 0.30 percentage point increase in GDP growth.

When greater preference for interest rate smoothing is reflected in the loss function, ψ_S^* becomes 2.756, i.e. higher than in the baseline case and so does the estimated loss when moving from the optimized inflation targeting rule to the optimized exchange rate targeting rule, namely 131.67 percent, or a likely decrease in GDP growth of 0.68 to 2.76 percentage points. Moving from the estimated inflation targeting rule to the optimized targeting rule, in this case, produces estimated loss in macroeconomic stabilization of 27.92 percent, likely translating into a 0.23 to 0.93 percentage point decrease in GDP growth.

If the CNB is assumed to be concerned only about inflation stabilization, i.e. under L^{π}, the loss in macroeconomic stabilization, when moving from the optimized inflation targeting rule to the optimized exchange rate targeting rule, becomes enormous of about 1.05 to 4.27 percentage points of GDP growth. In contrast, moving from the estimated inflation targeting rule to the optimized exchange rate targeting rule produces a gain in macroeconomic stabilization of 13.04 percent, roughly equivalent to a 0.09 to 0.37 percentage point increase in GDP growth.

6.2.2 The Case with No Discretion

Consider now the baseline loss function and no discretion by the CNB to the exchange rate targeting rule. In this case ψ_S^* is 2.429, somewhat higher than in the case when the CNB retains its historical degree of MP discretion, and higher uncertainty makes the CNB respond less aggressively when smoothing the CZK/EUR exchange rate. When the baseline loss function L is evaluated at ψ_S^*, it takes the value of 129.328 which indicates 114.63 percent loss with respect to the case when the CNB would be using the optimized inflation targeting rule. This is estimated to translate into a 0.49 to 1.99 percentage point decrease in GDP growth. Also, when compared with the loss under the estimated inflation targeting rule, the indicated loss remains positive at 8.67 percent, roughly equivalent to a 0.06 to 0.26 percentage point decrease in GDP growth.

When we assume the three alternative loss functions and no discretion by the CNB, the optimized exchange rate coefficients under L^y and L^i are similar to the baseline case, only under L^{π} the optimized exchange rate response, ψ_S^*, decreases noticeably. The estimated loss in macroeconomic stabilization tends to fall if the CNB preferences on output gap stabilization are increased, and rise if the CNB preferences emphasize interest rate smoothing or are purely focused on inflation stabilization. Namely, under L^y the computed loss in macroeconomic stabilization due to a move from the optimized inflation targeting to optimized exchange rate targeting is a 63.57 percent, translating into about a 0.35 to 1.41 percentage point decrease in GDP growth. Similarly, under L^i moving from the optimized inflation targeting rule to optimized exchange rate targeting rule is estimated to result in a 161.91 percent loss in macroeconomic stabilization, roughly equivalent to a 0.75 to 3.06 percentage point decline in GDP growth. Analogous move under L^{π} indicates huge losses as it was the case with historical discretion, estimated to translate into a 0.92 to 3.76 percentage point decline in GDP growth. If we consider the CNB moving from the current estimated inflation targeting rule to the optimized exchange rate targeting rule under L^{y}, L^{i} and L^{π}, the losses remain positive of 4.64 and 38.41 percent in the first two cases, roughly equivalent to 0.04 to 0.14 percentage point decline and a 0.29 to 1.20 percentage point decline in GDP growth, respectively. But, a gain in macroeconomic stabilization is estimated, should CNB preferences be focused entirely on inflation stabilization, roughly equivalent to a 0.06 to 0.24 increase in GDP growth.

To sum up, under the assumed baseline loss function, the CNB can improve macroeconomic stabilization of the Czech economy, by about 46 to 49 percent[8], achieving roughly a 0.41 to 1.73 percentage point increase in GDP growth, if it increases its responses to expected future inflation from the estimated 1.69 to about 4.96, and by decreasing its response to the current output gap from the estimated 0.40 to about 0.30, while adhering to roughly a similar degree of inertia in interest rate setting as currently estimated. Should at some point the CNB consider moving from the current inflation targeting rule estimated from the data to an optimized exchange rate targeting rule, the estimated loss in macroeconomic stabilization appears to be negligible. However, if an optimized inflation targeting rule is used as the basis for calculating the loss in macroeconomic stabilization due to a move to an optimized exchange rate targeting rule, the loss can be as high as 80 to 115 percent. This would translate into about a 0.39 to 1.99 percentage point decline in GDP growth. In another words, it is estimated that the CNB can, in current circumstances, adopt exchange rate targeting without incurring significant losses in macroeconomic stabilization. But, the CNB can also stick to the currently applied inflation targeting and further optimize its responses to inflation and the output gap to significantly increase its success in macroeconomic stabilization.

7 Conclusion

In this paper we have estimated a structural model comprising the Czech Republic and the euro area. We have investigated the model dynamics and transmission mechanism through the impulse response analysis, and used variance decomposition to estimate most influential shocks for the Czech economy.

[8] This range relates to the degree of discretion the CNB would prefer to keep where the bounds are zero and the estimated historical discretion.

We have found that a foreign demand shock induces relatively more variance in the Czech output and inflation than the real exchange rate shock or any of the domestic structural shocks. Out of the domestic shocks, the supply shock appears to be the most influential regarding domestic output and inflation variations. Assuming a representative central bank loss function we have estimated an optimized, simple inflation targeting rule for the Czech Republic which suggests that the Czech National Bank can improve macroeconomic stabilization by increasing its responses to expected future inflation and lowering its concern about the current output gap. The resulting improvement in macroeconomic stabilization is estimated to be in the range of 0.41 to 1.73 percentage points of GDP growth. Assuming that the Czech Republic will at some point switch to exchange rate targeting, we have estimated an optimized, simple exchange rate targeting rule for the monetary policy rate, and found that moving from the *current* inflation targeting rule to an optimized exchange rate targeting rule should not involve any significant losses in macroeconomic stabilization. However, if we considered the *optimized* inflation targeting rule as the initial stage for the move to exchange rate targeting the implied loss in macroeconomic stabilization appeared to be significant in the rage of 0.4 to 2 percentage points of GDP growth.

Future research could investigate the causes of deteriorating macroeconomic stabilization under the latter scenario. This would essentially involve examination of the degree of convergence between the Czech and the euro area economies. In the presented framework, such an examination could then focus on differences in the sizes of corresponding structural shocks in the Czech Republic and the euro area, their correlations, and transmission. Regarding the shocks transmission, a statistical comparison of the corresponding structural coefficients estimated for the Czech Republic and the euro area could be undertaken. The aim would be to find microeconomic evidence supporting the potential differences in the corresponding coefficients and suggesting areas where structural policies could help increase convergence of the Czech economy towards the euro area.

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