Stockholm School of Economics
Department of Economics
5350 Master's Thesis in Economics
Academic Year 2015 - 2016

The Effectiveness of Exchange Rate Targeting as a Monetary Policy Tool at the Zero Lower Bound

The Case of the Czech Republic

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In November 2013, the Czech economy faced significant deflationary pressure as a consequence of a recessionary European environment. In response, the Czech National Bank decided to depreciate its exchange rate artificially and defend a one-sided exchange rate target of 27 CZK/EUR. The goal is to guide inflation back to target. It is the first central bank to do so and thus provides an example for studying the effectiveness of the policy. We employ a two-stage empirical strategy using a vector autoregressive model: first, we determine the role of the exchange rate for economic easing in the Czech Republic and find that a depreciation supports easing after a shock. At the zero lower bound, this automatic depreciation is constrained. Second, we simulate the development of the Czech economy in the absence of the policy. We find that the policy was effective in averting deflation and raising economic growth. The policy should thus be considered for the monetary policy toolkit of other central banks.

Keywords: Unconventional Monetary Policy, Exchange Rate Targeting, Czech Republic, Vector Autoregressive Models, Policy Evaluation

JEL classification: E65, E58, E52, E47, C32

Supervisor:	Jesper Lindé
Date submitted:	16^{th} May, 2016
Date examined:	23^{rd} May, 2016
Discussants:	Piotr Rozwalka, Simon Vinge
Examiner:	Federica Romei

Acknowledgements

We would like to express our gratitude to our supervisor Jesper Lindé who supported us with excellent mentoring throughout the project. He continuously provided insightful advice and valuable feedback as well as a genuine interest in the topic. We were able to profit greatly from his experience in monetary policy research.

We thank Christian Siebert, Martin Rassl and Lukas Killinger for their insightful feedback and careful proofreading of our work.

We thank our examiner Federica Romei for interesting feedback, as well as our discussants Piotr Rozwalka and Simon Vinge for a vivid and constructive discussion.

We are thankful to our families for their continued support throughout our studies.

Last but not least, a special "thank you" goes to Arvid and Martin.

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List of Abbreviations

AIC	Aikaike Information Criterion.
BIC	Bayesian Information Criterion.
BoJ	Bank of Japan.
CEE	Central and Eastern Europe.
CHF	Swiss Franc.
CI	Confidence Interval.
CNB	Czech National Bank.
CPI	Consumer Price Index.
CZK	Czech Koruna.
DSGE	Dynamic Stochastic General Equilibrium.
EA19	Euro Area 19; setup since January 2015; including Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Greece, Slovenia, Cyprus, Malta, Slovakia, Estonia, Latvia, Lithuania.
EC	European Commission.
ECB	European Central Bank.
ESA	European System of National and Regional Accounts.
EU	European Union.
EUR	Euro.
FEVD	Forecast Error Variance Decomposition.
GDP	Gross Domestic Product.
HICP	Harmonized Index of Consumer Prices.
IMF	International Monetary Fund.
LIBOR	London Interbank Offered Rate.
LM	Lagrangian Multiplier.
LSAP	Large Scale Asset Purchases.
MRO	Main Refinancing Operation.
NBER	National Bureau of Economic Research.
NER	Nominal Exchange Rate.

OECD	Organisation for Economic Co-Operation and Development.
OLS	Ordinary Least Squares.
repo	Sale and Repurchase Agreement.
SNB	Swiss National Bank.
UIP	Uncovered Interest Parity.
US Fed	Federal Reserve System of the United States of America.
VAR	Vector Autoregressive (Model).
VAT	Value Added Tax.
ZLB	Zero Lower Bound.

1. Introduction

After the global financial and economic turmoil in recent years and the continuous decline in inflation rates, interest rates of many economies have been gradually lowered. Central banks reached the zero lower bound on interest rates and saw themselves forced to start employing unconventional monetary policy tools in order to ease economic conditions and guide inflation back to target.

The Czech National Bank reached its zero lower bound in fall 2012. Since deflationary pressure and the need for further monetary easing remained, in November 2013, the CNB announced an unprecedented step: implementing a policy proposal that Svensson (2001) suggests for economies at the zero lower bound, it started to use the exchange rate as an instrument within its inflation targeting regime. The exchange rate takes the form of a publicly declared, one-sided exchange rate commitment to the euro. The CNB depreciated the Czech koruna by about four percent to 27 CZK/EUR with the aim of averting deflation. The Czech Republic, a small open economy with an independent currency, has closely woven trade relations with the rest of Europe, especially with euro countries such as Germany and Slovakia. Being highly reliant on exports, the exchange rate is a crucial factor for its economy.

The use of exchange rate targeting as an instrument at the zero lower bound was first described in economic literature around the year 2000 in response to the Japanese experience with lasting low interest rates. Svensson (2001) proposes a "foolproof way of escaping the liquidity trap" for open economies. About 12 years later, the CNB is the first central bank to employ his framework. Thus, the case of the Czech Republic represents a good basis for an analysis of the policy's effectiveness as well as a valuable example to derive insights for other economies that struggle with the liquidity trap.

Today, a lot of academic focus is drawn towards both the evaluation of newly employed unconventional policies and the design of additional tools. The fact that the experience with such policies remains relatively new while their significance for central banks is high makes this a research field of considerable importance. Due to the fact that many central banks are in need of additional means of easing economic conditions at the zero lower bound, the conclusions from the Czech case might entail important lessons for other countries.

In our study we determine the policy's effectiveness in spurring inflation and GDP growth. While the CNB itself draws highly positive conclusions regarding its policy, an independent quantitative analysis of the effectiveness has not yet been published. Our study fills this academic void. We discuss if exchange rate targeting is a policy tool worth adding to the unconventional monetary policy toolbox. Particularly, our findings are of interest for policy makers in economies of a similar structure as the Czech Republic.

In order to arrive at the described results, we employ a two-stage empirical strategy using a vector autoregressive model: first, we analyse the role of the exchange rate for economic easing in the Czech Republic and find that in normal times, it depreciates and thus supports easing after a shock. At the zero lower bound, this automatic depreciation is constrained, which underlines the need for unconventional tools. Second, we simulate the development of the Czech economy in the absence of the policy. We find that the policy was effective in averting deflation. Also, GDP grew 0.44 percentage points faster in the period under

discussion than it would have without the policy. Thus, the policy approach appears effective in fulfilling the central bank's goals. From here, we can draw some insightful lessons for central banks of other countries that are in need of additional means of easing economic conditions at the zero lower bound.

2. Research Context

In the following sections, we provide an overview of the research field this study adds to: First, we describe how the zero lower bound evolved and why it creates the need for alternative monetary policy tools. After that, we give a brief overview of the unconventional monetary policy tools that have been used and discussed by researchers and policy makers as a response.

2.1 Zero Lower Bound and the Liquidity Trap

Recent events such as the 2008/2009 financial crisis lead to economic developments that confronted central banks around the world with a situation in which they can no longer decrease short term interest rates in order to ease monetary conditions: the *zero lower bound*. The reason for the existence of such a zero lower bound, the so-called liquidity trap, was first discussed by Keynes (1936) and Hicks (1937). The situation leaves a central bank helpless to provide macroeconomic stimulus and therefore, it finds itself "trapped": at lower levels of interest rate a significant preference for cash emerges.

Over decades the academic discussion on a zero lower bound to policy rates and the implications for central bank policies was primarily a theoretical concern. In the late 1990s, Japan was the first economy to find itself in a situation where it could no longer use its short-term interest rate as an instrument to respond to decreasing inflation. After having been at below 1 percent interest rates for years, the Japanese economy had still not reached a phase of economic recovery or target inflation. The Japanese experience sparked a general discussion about the effectiveness of monetary policy in this specific situation (see e.g. Krugman, Dominquez and Rogoff 1998). In order to counteract low inflation and economic downturn in response to the global financial crisis of 2008 and the European sovereign debt crisis, more central banks, especially in Europe, were forced to gradually lower interest rates.

Determinants of this lower bound are for example legal constraints or the preference for cash of economic agents. These factors vary across countries and thus define varying levels of the lower bound on interest rates. The European Central Bank (ECB), for example, reduced its interest rate on main refinancing operations to 0.00 percent in March 2016 (ECB 2016a). The Czech National Bank, however, defines 0.05 percent as a binding lower bound. While conventional wisdom for many years had been that zero percent would be the explicit minimum to interest rates, some central banks have started to experiment with slightly negative rates in the past years. The Swedish Riksbank established a negative repo rate of -0.5 percent in February 2016 (Swedish Riksbank 2016d). The Swiss National Bank (SNB) similarly lowered their three-month LIBOR target band to a range of -0.25 to -1.25 in January 2015 (SNB 2016). It currently appears as if the room for manoeuvre in monetary

policy is larger than previously assumed.

In addition to a lowering of interest rates as result of recent recessionary trends, several structural factors cause a reduction of equilibrium real interest rates over the last decades. The ECB defines two factors causing a long-term decline in natural real interest rates: first, productivity growth has been declining since the 1970s and second, population growth is falling (ECB 2004). In addition, Summers (2014) notes that changes in the distribution of income have increased the propensity to save, which cause an additional decrease in real interest rates. The downward pressure in the equilibrium real interest rate mentioned above, will arguably lead to less room for adjustments through the short-term interest rate in the future. For central banks of small open economies, the zero lower bound represents an additional threat: when monetary policy is unconstrained, it can dampen the impact of foreign disturbances. In a liquidity trap, however, the possibility to respond to foreign shocks is constrained (Bodenstein, Erceg and Guerrieri 2010).

Against this background, a set of unconventional monetary policies has been set up and applied in order to provide additional stimulus at the zero lower bound and to avoid the liquidity trap.

2.2 Overview of Unconventional Monetary Policy Tools

In the following, we give an overview[1] of policies that have to date been employed to support inflation targeting economies in the case of the zero lower bound. These include negative interest rate policies, increased signalling (e.g. in the form of forward guidance), and balance sheet policies.[2] Most central banks choose a set of multiple different policies that they design according to their specific needs.

Negative interest rates are, strictly speaking, not an unconventional monetary policy tool: negative interest rate regimes, like the one in Sweden, Denmark or Switzerland, use the conventional tool (interest rate) at unconventionally low (negative) levels. And even the central banks of larger economies, for example the Bank of Japan or the ECB, are tentatively entering the negative territory. It is feared that they erode bank profitability through lowering the margin between bank lending and deposit rate, which sparks vivid criticism (e.g. by Steenis 2016).

Communication and signalling can be highly effective for central banks. The importance of expectations in the context of monetary policy is widely acknowledged (e.g. Clouse et al. 2000; Eggertsson and Woodford 2003; Rudebusch and Williams 2008; Walsh 2009; or Bernanke, Reinhart and Sack 2004).[3] Signalling is used to lower market expectations for interest rates in the future through different forms of communicated commitment. Standard New Keynesian models imply that a higher level of expected real income or inflation in the

1. For a comprehensive overview and classification of policies see for example Bernanke, Reinhart, and Sack (2004); Borio and Disyatat (2010), Stone, Fujita and Ishi (2011); or Woodford (2012).

2. In recent years, classic Keynesian approaches of active fiscal policy and pro-active counter-cyclical government spending have experienced a revival (e.g. Erceg and Lindé 2014 or Cook and Devereux 2011). However, a discussion of this research field is left out in the following since it is, strictly speaking, not a form of monetary policy.

3. For a further description of the functioning of the expectations channel on monetary policy, see Section 3.2.

future creates incentives for greater real expenditure and consequently larger price increases now (Eggertsson and Woodford 2003). A very common format of signalling of a central bank is *forward guidance*, explicit statements by a central bank about the outlook for future policy, that it publishes in addition to its announcements on policy changes (as discussed e.g. in Campbell et al. 2012). During the financial crisis of 2008/2009, for example, the US Fed communicated that it would keep interest rates low for an "extended period" (US Fed 2009). While such communication strategies were already widely used prior to the arrival at the zero lower bound, they became more common afterwards. Woodford (2012) argues that the most effective form of forward guidance involves advance commitment to definite criteria for future policy decisions.

Much of the discussion about expansionary policy in the major central banks has always been about the use of changes in the central bank's balance sheet, mainly *quantitative and qualitative easing*. While the former focuses on the size of the central bank's balance sheet through building up liabilities, the latter changes its composition and thus its risk profile. In both cases, the central bank uses its balance sheet to affect asset prices and financial conditions beyond the short-term interest rate (Borio and Disyatat 2010). While being one of the most controversly discussed, *quantitative easing* is also one of the most widely applied policies: the central bank purchases financial assets from financial institutions and thereby raises the price and lowers the yield of these assets. Hence, it increases the money supply and enhances the market's liquidity. The Bank of Japan was the first to adopt it in March 2001 (BoJ 2001). Starting in late 2008, the US Fed, the ECB, the Swedish Riksbank, the Bank of England and many others have launched quantitative easing packages.

The belief that the composition of the central bank's balance sheet matters and thus the central bank should accept a wider range of collateral is addressed by *qualitative easing*. Qualitative easing involves operations of the central bank intended to change the composition of its balance sheet away from relatively safe securities towards riskier and less liquid assets, holding constant the size of its balance sheet (e.g. Buiter 2008). The private sector banks can transfer risky and illiquid assets to the central bank and thereby obtain more liquid and less risky instruments to cover their needs. If the central bank holds less of certain assets and more of others, then the private sector is forced, also through changes in relative prices, to hold more of the former and less of the latter. This is intended to provide support to particular markets that were not operating efficiently and thus restore the functioning of the market and reduce risk premia. Consequently, it spurs economic activity and inflation.

Several sub- and mix-forms of quantitative and qualitative easing exist. *Credit easing*, for example, represents a mixture of the two. The central bank expands its balance sheet so that average liquidity decreases and/or the riskiness of its assets increases. This activity is aimed at affecting the cost and availability of loans and was mainly initiated in the later stages of the financial crisis. A prominent example of this approach is the US Fed's Large-Scale Asset Purchases Program (LSAP): it purchased agency debt securities, mortgage-backed securities and government bonds, which became part of its portfolio.

Exchange rate policies are another form of unconventional monetary policy that affect the balance sheet: using purchases of foreign reserves, countries attempt to influence their

currency's exchange rate (Borio and Disyatat 2010). Being the policy in focus of this study, exchange rate targeting is discussed in detail in the upcoming Section.

To conclude, many central banks have moved away from the relative simplicity and well-rehearsed routine of their interest rate policy. They now face much trickier calibration and communication issues that have to be well-managed (Borio and Disyatat 2010). And these changes might be longer lasting than initially anticipated if the structural changes in real interest rates hold. Overall, the measure of unconventional monetary policy a country's central bank employs depends mainly on specific legal and economic conditions in each country as well as the size of the economy. The effectiveness of many of these policies is still up for debate. Also, unconventional policies are not cost and risk free, but side effects have not been fully investigated. Thus, the topic of unconventional monetary policies is a highly interesting and vivid research field.

3. Current State of Knowledge on Exchange Rate Targeting

The idea that exchange rate targeting can be used as a monetary policy tool within inflation targeting frameworks is not new: New Zealand and Canada, for example, have in the 1990s periodically de facto targeted specific exchange rate levels along with adjusting interest rates in order to stir inflation (see e.g. Ball 1999 or Gerlach and Smets 1996). However, they did so without having reached the zero lower bound.

The concept of exchange rate targeting as policy option at the zero lower bound was advanced within the first wave of literature on unconventional monetary policy in the early 2000s, in the debate on Japan's experience with low interest rates. Most notably were contributions by McCallum (2000) and Svensson (2001, 2003, 2004) that describe two different approaches. Within exchange rate targeting frameworks, foreign exchange interventions are used limitless in order to reach a specific and potentially communicated level of exchange rate. While the intended effect on the exchange rate is defined, the level of interventions remains unclear in advance as it depends on market conditions.[4]

In the following, we give an overview of the current state of knowledge on exchange rate targeting policies. We first look at the core literature defining the theoretical basis and practical approaches of exchange rate targeting. Then, we discuss the transmission channels of monetary policy in the context of exchange rate targeting policies and the effectiveness of the pass-through to prices. Finally, we discuss the experience of Switzerland and Japan with exchange rate based policies at the zero lower bound.

4. This definition will be the focus in the in the remainder of this discussion. Contrary to that are approaches that try to influence the exchange rate through fixed amounts of foreign exchange interventions without a fixed target for the exchange rate.

3.1 Core Literature on Exchange Rate Targeting

With his publication "Theoretical Analysis Regarding a Zero Lower Bound on Nominal Interest Rates", Bennett McCallum (2000) provides a seminal paper on the utilisation of the exchange rate as an alternative monetary policy tool at the zero lower bound. The core insight of his work is that even in the liquidity trap an open economy has scope for additional stabilisation policy. McCallum shows that at the zero lower bound, a central bank in a trade-open economy can apply a policy rule that adjusts the rate of depreciation of the domestic currency to stabilise inflation and to ease economic conditions. In his approach, he uses a monetary policy rule similar to the one derived by John B. Taylor (1993). However, instead of the interest rate the exchange rate is adjusted. The exchange rate becomes the operating target of monetary policy:

$$s_t - s_{t-1} = \mu_0 - \mu_1(\Delta p_t - \pi^*) - \mu_2 E_{t-1}\tilde{y}_t + e_t \tag{1}$$

where $\mu_1, \mu_2 > 0$ and μ_0 is set equal to the average rate of interest. $\tilde{y}_t = y_t - \bar{y}_t$ represents the deviation of output from its (log) natural rate. π^* is the inflation target and thus $\Delta p_t - \pi^*$ represents the period's deviation from inflation target. $s_t - s_{t-1} = \Delta s_t$ is the rate of depreciation of the exchange rate[5] and e_t is the unsystematic monetary policy shock component that is assumed to be white noise.

A periodical depreciation of the exchange rate is reached through central bank purchases of foreign assets. It is designed to stabilise the inflation rate Δp_t toward its target value and output gap $\tilde{y}_t$ toward zero. In McCallum's model, the exchange rate s_t is less an instrument variable than the conventional policy rate as it can only be influenced via foreign exchange interventions. While the central bank can unambiguously determine the interest rate, it does not have this direct influence on the exchange rate. It is rather an indicator variable. The actual "tool" that the central bank has at hand are open market purchases of foreign exchange. This tool has no economic limit since purchases of foreign reserves and thus the depreciation can be made theoretically limitless.[6] After an empirical simulation of his model based on US quarterly data, McCallum concludes that the exchange rate is indeed effective in achieving monetary policy objectives and that the extent of stabilisation is substantial. Iwata and Wu (2006), however, find for Japan in the 1990s that McCallum's approach would not have been very effective in achieving the ultimate policy goal of lifting inflation.

The other seminal academic contribution to the topic of exchange rate targeting is that by Svensson (2001). He suggests a "foolproof way of escaping from a liquidity trap" through the temporary use of exchange rate targeting in an open economy.[7] It includes an initial depreciation of the currency through unsterilised foreign exchange interventions, the temporary pegging of the exchange rate at this depreciated level and a temporary regime change from inflation to price level targeting to jump-start the economy.

5. In accordance with our currency notation $\Delta s_t > 0$ equals a depreciation of the currency.

6. In order for this approach to be applicable, the analysis must presume that strict uncovered interest parity (UIP; see Appendix A.2 for further discussion of the concept of UIP) does not prevail on a period by period basis.

7. In this study, he advances first thoughts on this topic that he had published earlier (Svensson 1999a) and provides a simplified but complete exchange rate targeting framework for a country in the liquidity trap.

He defines the steps as follows: First, the central bank should define an upward sloping price-level target path $\{\hat{p}_t\}_{t=t_0}^{\infty}$. Second, the central bank should announce the fact that the currency will be devalued and the exchange rate pegged at an exchange rate target of:

$$\bar{s}_t = \bar{s}_{t_0} + (\hat{\pi} - \pi^*)(t - t_0), \quad t \geq t_0 \tag{2}$$

where $\bar{s}_t$ is the nominal exchange rate target, $\hat{\pi}$ is the inflation and π^* is the inflation target. This exchange rate peg needs to be defended by unlimited foreign-exchange interventions in order to create expectations of higher future inflation and thereby lower real interest rates to consequently increase aggregate demand and inflation. Svensson suggests that the peg should be abandoned as soon as the price level target path has been reached either in favour of flexible price level or inflation targeting.

He concludes that this "will jump-start the economy and escape deflation by a real depreciation of the domestic currency, a lower long real interest rate, and increased inflation expectations" (Svensson 2001 p.277). Crucial for his approach is the role of expectations as well as a high level of credibility of the respective central bank. Ideally, the policy would increase short-term inflation expectations without de-anchoring long-term expectations. Also, the initial devaluation of the currency, supported by foreign exchange interventions, is of central importance. It supports the credibility of the central bank and enhances the effect on inflation expectations of the public.[8] Also, he advocates the switch from inflation to price level targeting for rapidly achieving price growth: as price level targeting implies a temporary overshooting of the initial inflation target, it creates higher inflation expectations.[9] The abandonment of the exchange rate peg in favour of the standard policy tool once the price level target is reached shall maintain the anchor for long-term inflation expectations.

Despite both policy frameworks describing approaches to exchange rate targeting, Svensson and McCallum developed significantly different methods. While McCallum proposes the use of the exchange rate as a monetary policy tool in the form of periodic depreciation, Svensson proposes an initial depreciation and a peg in the following periods until the inflation target is reached. Svensson (2001) highlights a clear difference between his and McCallum's (2000) proposal: his "foolproof way" does not rely on the magnitude of the portfolio balance channel (see Section 3.2) of foreign exchange interventions, which he considers a controversial aspect of McCallum's work since the channel has not been found to hold empirically.

Also, Svensson's (2001) approach bases more on the high relevance of the signalling channel: with an explicit exchange rate commitment it supports the credibility of such a policy even better than McCallum's (2000) approach that periodically adjusts the exchange rate. The effect of this channel is supposed to be even stronger if, as Svensson suggests, the central bank switches to temporary price level targeting since that should increase inflation expectations to an even larger extent.

8. In his 2004 publication, Svensson extends his "foolproof way" to the "optimal foolproof way" and describes how it can be applied for larger open economies as well.

9. Svensson advocates the advantages of price level- over inflation targeting in detail in his previous work (1999b).

3.2 Transmission Channels of Exchange Rate Targeting Policies to Prices

The transmission of an exchange rate targeting policy under inflation targeting regimes like the ones described by Svensson (2001) and McCallum (2000) can be broken down into two different stages (see Figure 1 below). First, the interventions on the foreign exchange market affect the exchange rate. In the second stage, modifications in the exchange rate pass on to inflation.

The first stage, the transmission of foreign exchange interventions to the exchange rate, generally (in non-ZLB times) involves three different channels: the interest rate channel, the portfolio balance channel and the expectations channel (see e.g. Cavusoglu 2011 or Iwata and Wu 2006). These channels are intertwined and work hand in hand in normal times.

The *interest rate channel* describes the fact that growing liquidity from foreign exchange purchases (that are not matched by open market sales of government bonds; i.e. are unsterilised) lowers money market rates. According to the Uncovered Interest Parity (UIP), this lower interest rate should be associated with an expected future appreciation of the currency, which leads to an immediate depreciation. At the zero lower bound, however, growth in the money supply does not lead to a significant decrease in money market rates (Iwata and Wu 2012). Therefore, this channel can be considered ineffective, hence irrelevant, for the case under discussion. Other channels grow in relevance.

The *portfolio balance channel* implies that foreign exchange interventions will affect the exchange rate by altering the relative supply of foreign and domestic assets based on imperfect substitutability of domestic and foreign assets: individuals maximise their expected return by diversifying their portfolio (e.g. Cavusoglu 2011). The portfolio balance channel has to be regarded with caution for two reasons. First, empirical studies (e.g. Frankel 1982 or Dooley and Isard 1983) fail to find support. Second, as international capital markets have become increasingly integrated, the degree of substitutability of financial assets, especially in the major currencies, increased, leading to a diminishing of the channel over time (Taylor and Sarno 2001). While some more recent studies, like Blanchard, Adler and Cavalho Filho (2015), do find an effect derived from the portfolio balance, the channel remains controversial in its effectiveness.

The third transmission mechanism between foreign exchange interventions and the exchange rate is the *expectations or signalling channel*, a channel that is supposedly maximised in the case of fixed interest rates and thus the most crucial one for exchange rate targeting policies at the zero lower bound (Franta, Holub et al. 2014). In this channel, interventions as well as accompanying communication about future policy (incl. forward guidance) affect expectation about exchange rates and thus the current rate. Credibility of the central bank's willingness and ability to intervene on the exchange rate is central for this channel (e.g. Cavusoglu 2011). If the central bank has a high level of credibility and appreciating pressure is at moderate levels, the central bank might be able to keep the exchange rate at a set target without intervening regularly.

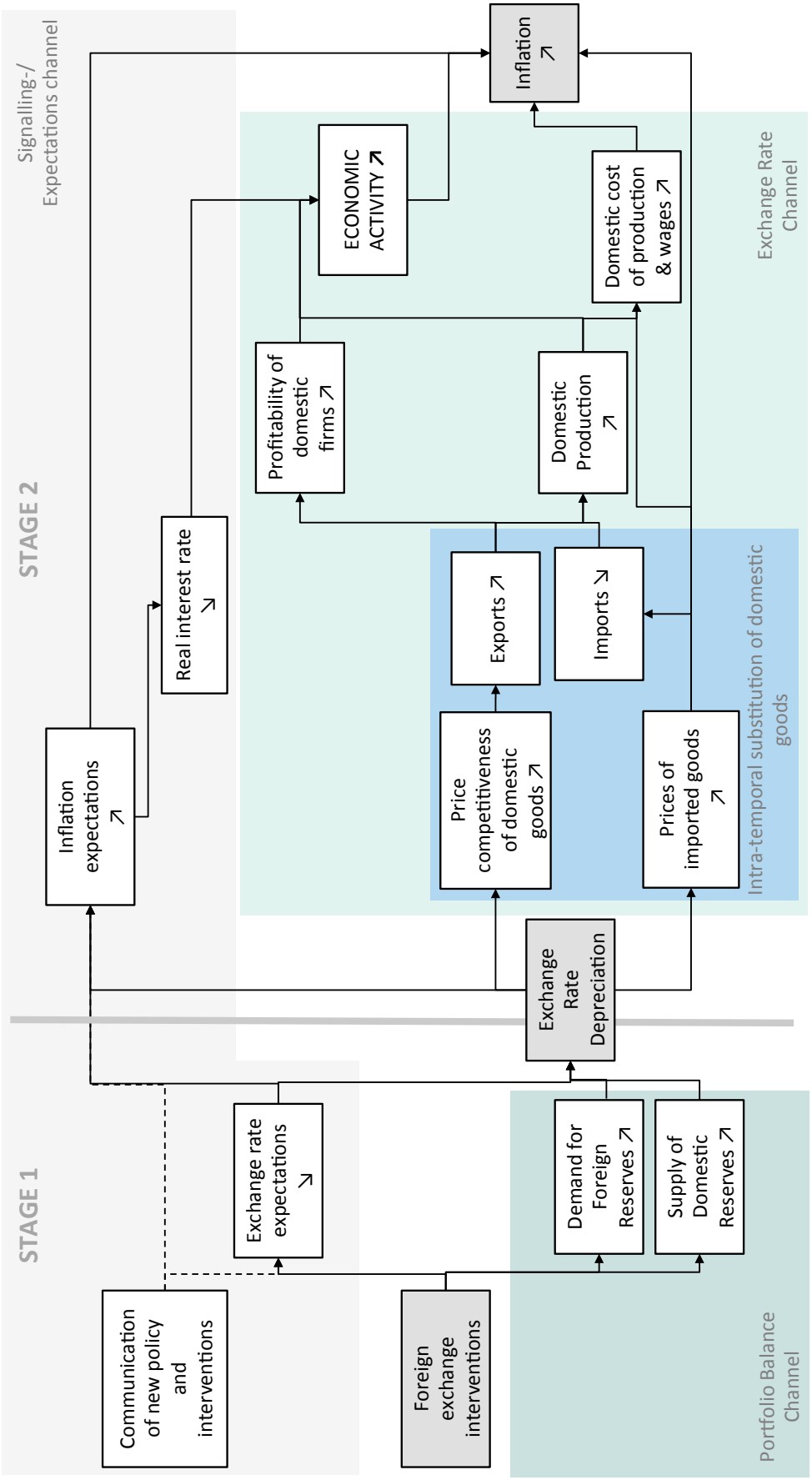

Figure 1: Transmission Channels of Exchange Rate Targeting Policies to Prices

Source: Own sketch

When turning to the second stage, the expectations channel is also relevant[10]: it passes through to the price level independently of the effect on the exchange rate. If the central bank has sufficient credibility, inflation expectations are increased through the communication of such a policy. Furthermore, the foreign exchange interventions have a signalling effect that raise inflation expectations. This increase in inflation expectation decreases the real interest rate, which enhances expenditure and consequently lifts inflation (e.g. Woodford 2003; Eggertsson and Woodford 2003). In order to make use of this channel, central bank communication is essential and should be well managed and supported by a structured forward guidance strategy. More generally, to escape the liquidity trap, expectations of future inflation must be increased. The exchange rate will be a good indicator of expectations of the future price level and therefore represents an effective lever in influencing inflation (Svensson 2004).

The second channel defining the second stage of transmission is often referred to as the *exchange rate channel* and concerns the real economic variables. A depreciation in the exchange rate increases import prices, which has relatively direct effects on inflation, especially in open economies. At the same time, price competitiveness of domestic goods increases as real exchange rate decreases, which leads to an intra-temporal substitution of domestic goods: imports decrease while domestic production as well as exports increase. The resulting improvement in net exports usually outweighs the negative income effect of higher import prices. Thus, there is an increase in overall economic activity and an increase in the cost of domestic factors of production (through an increase in prices of imported intermediate goods as well as an increase in wages as labour becomes more scarce), which again increases prices. Although these effects are being realised with a time lag, this transmission process from the exchange rate to prices is very direct, especially when compared to other unconventional monetary policy tools (Alichi et al. 2015).

The two channels in the second stage are highly intertwined. Also, at the zero lower bound, they amplify each other, which provides the central bank with additional credibility. Especially at constant exchange rates, expectations supported by forward guidance and generally strong communication and transparency significantly strengthen the development of real economic variables. For the formation of expectations, for example, it is important that the central bank communicates credibly that the exchange rate weakening is not a one-off shock but will be sustained. This perception will motivate firms to actually pass the increased production cost on to the consumer, which manifests the price level increase.

3.3 Effectiveness of Exchange Rate Pass-Through to Prices

Exchange rate pass-through is defined as "the percentage change in the local currency price of an imported good resulting from a 1 percent change in the nominal exchange rate between the exporting and importing countries" (Bailliu and Fujii 2004 p.7). The effectiveness of this

10. For the second stage we pay less attention to additional channels that Svensson classifies as "more controversial transmission channels" (Svensson 2001 p.283) involving aggregate demand effects of money, the effect of foreign exchange interventions on the foreign exchange risk premium or price-gap-/real-money-gap effect on inflation.

pass-through and thus the effectiveness of exchange rate targeting policies on prices is unclear and depends strongly on country and timing of the study.

First of all, exchange rate pass-through to prices is incomplete. Consumer prices are expected to react less than import prices. In relation to that, the degree of competition plays a crucial role: the stronger competition, the less flexibility do firms have in adjusting their prices to changes in the exchange rate. *Second*, pass-through is more effective in trade open economies. The higher the import share, the greater the response of exchange rate changes to prices (McCarthy 2000). *Third*, McCarthy (2000) finds that less volatile exchange rates and less volatile GDP development correlate with greater effectiveness. *Fourth*, the design of contracts is decisive: the effectiveness of pass-through depends on in which currency invoicing is defined and if prices in contracts are adjusted for currency changes. *Fifth*, pass-through also depends on the share of non-tradable goods in the consumption basket and their price stickiness. *Sixth*, the flexibility of consumers in changing their consumption basket plays a role as well. It determines how strong the substitution effect is. Also, Bacchetta and Wincoop (2003) find that domestic distribution costs are a factor: since they remain constant, a higher cost share of distribution cost lowers the pass-through. Similarly, the pass-through can be distorted by adjustment costs of price changes, so called menu costs.

However, if interest rates are expected to remain constant, i.e. the country has reached the zero lower bound, the pass-through of exchange rate changes to the price level is naturally stronger. When nominal interest rates are bound while inflation rises in response to a depreciation real long-term interest rates decline (Lízal and Schwarz 2015). This would translate to more stimulus on the real economy and result in a higher effect on output and, hence, on prices.

3.4 Experience with Exchange Rate Targeting at the Zero Lower Bound

Experience with exchange rate targeting policies is scarce, which is why the current state of knowledge on the topic is limited. Exchange rate targeting was commonly used throughout the 1990s, especially in Latin American countries, in order to bring high inflation levels under control. While their experience has been ambiguous, these cases do not provide insights for the case under discussion: these cases did not occur in a zero lower bound case and were rather employed to decrease inflation than to lift it. Only two countries, other than the Czech Republic, have employed similar policies while at the zero lower bound: Japan and Switzerland.

In September 2011 the *Swiss National Bank* (SNB) announced a minimum exchange rate floor of the franc against the euro defended by foreign exchange interventions. Despite following an inflation targeting regime and residing at ultra low interest rates, the SNB's primary goal was to respond to the strong appreciation caused by the franc's safe haven status, not to hit the inflation target or keep the policy until the target is reached. The SNB decided for an exchange rate floor only rather than an active depreciation of their currency. Being highly reliant on exports, the massive appreciation of the Swiss franc in response to a

struggling European economy and the use of Swiss bonds as a safe way of money storing posed a severe threat. Therefore, the SNB opted for this unconventional policy. The introduction of the exchange rate floor has not significantly affected the results of inflation expectations surveys (SNB 2014). Although the SNB was able to maintain the intended level of 1.20 CHF/EUR, a high amount of foreign exchange interventions was required to counteract the appreciating pressure. Its foreign reserves ballooned from about CHF 200 billion prior to September 2011 to CHF 510 billion at the end of 2014, turning Switzerland into one of the biggest foreign reserve holders in the world. The share of its reserves in euros edged up to 46 percent (MacLucas 2015). In January 2015, the SNB ended the peg after the ECB considered quantitative easing which would have required the SNB to purchase large amounts of euro reserves in order to maintain the peg. This could have led to an uncontrolled swelling of the SNB's balance sheet, which had already been critically discussed by the broad public. Despite the public's demand for an exit from the peg, the hasty way the SNB chose to exit caused market turmoil and was objected by pundits (see e.g. El-Erian 2015; Wyplosz 2015). The Swiss experience is valuable for the following analysis because the intervention took the form of a one-sided exchange the rate commitment, supported by foreign exchange interventions. That implies it shares some features with the strategy chosen by the CNB. However, it does not give a specific insight into the effect of exchange rate targeting in averting deflation as that was not the primary target of the SNB. Also, unlike in Svensson's approach and the case of the CNB, the SNB did not pursue an active depreciation of their currency upon initiation of the peg.

Japan also has experience with foreign exchange interventions at the zero lower bound though there was no explicit exchange rate target from the Bank of Japan. Japan operates a floating exchange rate but the authorities have frequently been purchasing and selling reserves nominated in US dollar until 2004 as well as between 2010 and 2012. The aim of these interventions was to slow down or reverse the appreciation of the yen. Fatum and Hutchison (2006) find that the first set of interventions was effective in changing the exchange rate. This example shows that the central bank can successfully alter the exchange rate when interest rates are kept constant. Yet, since the Japanese Yen is recognised as an official reserve currency the conclusions from this experience for the Czech koruna are limited. Also, the Bank of Japan applied various unconventional policy tools at the same time, so no conclusions on the effect from these interventions for inflation can be drawn.

4. Research Design

When the zero lower bound became a challenge more and more central banks around the world had to face, the research field of unconventional monetary policy grew in relevance. Exchange rate targeting is one of these policies: a proposal first laid out by Svensson in 2001 has for the first time been applied by the Czech National Bank in 2013. With initiating this policy, the CNB creates a unique experience that provides the possibility to empirically evaluate this policy. While the CNB itself as well as affiliated researchers like Franta, Holub et al. (2014) and Lízal and Schwarz (2015) provide basic analysis and judgement, to the best

of our knowledge, no quantitative conclusion about the policy's effectiveness has yet been published by an independent party. The current state of knowledge on the effectiveness of the policy is therefore limited. With the policy being in place now for about two and a half years, the period of policy application appears large enough to arrive at a first conclusion about the policy's effectiveness.

The overarching research question of this study is:

> Is exchange rate targeting an effective monetary policy tool at the zero lower bound?

In order to be able to provide an assessment of this question, we analyse the case of the Czech Republic. The analysis can be divided into the following two parts[11]: first, we analyse the role of the exchange rate in a monetary policy context. We define how the Czech economy generally responds to an exogenous output shock in the Euro Area as its major trade partner. Specifically, we are interested in the response of the policy rate and the exchange rate as a means of monetary and economic easing. Based on this observation we can draw conclusions on if and how the ability of easing economic conditions is impaired at the zero lower bound. The underlying question is:

> (a) What role does the exchange rate have for economic easing in the Czech Republic? How does the zero lower bound alter the response of the exchange rate to economic shocks?

We address this questions by making use of a Vector Autoregressive Model comprising Czech as well as Euro Area economic variables. We study the impulse response behaviour of the economy to a shock both in normal times and at the zero lower bound.

Second, we quantify the effect of the policy by analysing the counterfactual inflation and output development in the Czech Republic in the absence of the policy. This allows us to conclude on the following question:

> (b) Was the exchange rate targeting by the Czech National Bank effective in increasing inflation?

Again, we follow a Vector Autoregressive Approach. Based on an alternative exchange rate development excluding depreciation and peg, we derive counterfactual developments of the key variables, economic growth and inflation. From here, we aim to conclude on the effectiveness of the policy in reaching the central bank's goal.

The evaluation of research question (a) is carried out in Section 7 and the second research question is addressed in Section 8. Based on the answer to these research questions and the analysis of the case of the Czech Republic, we provide a general discussion on the effectiveness

11. Effectiveness in this context implies that the policy is effective in fulfilling the central bank's goal, which is, in the case of the Czech Republic as well as many other central banks, mainly price stability.

of exchange rate targeting as a monetary policy tool, provide insights that are valuable for other economies at the zero lower bound and arrive at a conclusion on the overarching question.

5. The Case of the Czech Republic

The Czech Republic is a Central European country that developed towards a market economy in the 1990s by privatising businesses, liberalising markets and opening up towards the West. It became a member of the European Union in May 2004 and joined the Schengen Area in December 2007 (EU 2016). With a merchandise trade share of 159 percent of GDP in 2014[12], the Czech Republic is amongst the most open economies worldwide. The GDP of EUR 155 billion in 2014 represents 1.1 percent of the GDP of the European Union.[13] In general, its main export partners are Euro Area countries (EA18: 63% of total exports in 2014), mainly Germany and Slovakia, as well as Poland (6%) and the United Kingdom (5%, CZSO 2015). Regarding imports, the Euro Area accounts for 53 percent of overall value, followed by China (12%) and Poland (8%) in 2014.

Since joining the EU in May 2004, the convergence process with the rest of the European Union has accelerated: by adopting fiscal and monetary policies, the Czech Republic is aligning its macroeconomic conditions. Initially, the Czech Republic also planned to adopt the euro as its official currency in 2010. However, continuous economic evaluations as well as the public's reluctance lead to an indefinite postponement. Having been a country in transition, the Czech Republic had a GDP growth rate of 2.4 percent from 2005 to 2014, compared to 1.0 percent as EU average.[14] Its purchasing power parity is approaching the EU28 average, however, is still 35 percent below.[15]

Its openness in trade and the strong economic integration with the rest of the European Union leads to high correlations of the development of economic variables between the Euro Area and the Czech Republic. Savva, Neanidis and Osborn (2010) as well as Aslanidis (2010) find a strong synchronisation of business cycles between the Czech Republic and the Euro Area that increased with the Czech Republic joining the European Union. While convergence of the Czech Republic and the Euro Area has been strong since the Czech Republic's joining of the EU, there remains considerable room for long-term economic convergence (CNB 2015a; EC 2014). Derived from its trade openness and economic role within the European economic community, the Czech Republic is considered a small[16] open economy which makes it sensitive towards economic changes in its main export markets.

As the central bank of the Czech Republic, the Czech National Bank is the supervisor of the Czech financial market. Its primary goals are maintaining price stability, supervising the

12. World Development Indicators; Merchandise trade as a share of GDP is the sum of merchandise exports and imports divided by the value of GDP (World Bank 2016).

13. Share of Czech Republic nominal GDP in 2014 compared to the nominal GDP of all 28 EU countries combined (Eurostat 2016).

14. GDP growth rate – volume as percentage change from previous year (Eurostat 2016).

15. Purchasing power parities, price level indices and real expenditures for ESA2010 aggregates (Eurostat 2016).

16. The Czech Republic had a population of 10.5 million in 2015 (Eurostat 2016).

financial system and supporting its balanced development, and ensuring smooth circulation of money and smooth payments (CNB 2016j). While an exchange rate peg as monetary policy regime had been a stabilising force in the early 1990s, it became difficult to hold up when the country slowly opened up to international capital flows and experienced internal political instabilities in 1997 (Alichi et al. 2015). After abandoning the exchange rate peg in 1998, the CNB adapted an inflation targeting regime. To achieve price stability, the CNB is targeting inflation by adjusting the two-week repo rate (CNB 2016h). Still it conducted foreign exchange interventions in a transition period until September 2002 (CNB 2016c). Starting with a target band of 5.5 to 6.5 percent in 1998, the CNB steadily decreased its target towards the current level (a point target). Regular monetary tightening and easing helped support the inflation targeting regime. The CNB managed to get inflation down to a mean of 2.3 percent headline inflation between 1999 and 2007. Since January 2010, the point target has been at 2 percent and the CNB's goal is to ensure that the actual inflation does not differ from the target by more than one percentage point (CNB 2016h).

5.1 Developments Leading to the Implementation of the Exchange Rate Targeting Policy

In 2008, during the global financial crisis, as inflation decreased and most European economies entered a recession, the CNB started to use forward guidance (CNB 2008). The CNB decided to publish the projected development as well as confidence bands in the form of fan charts for the interest rate path in an Inflation Report, including the rationale for this projection. It focused on transparency and communications, and the importance of recognising the conditional nature of the interest rate path. The IMF describes that as a very sophisticated form of forward guidance (Alichi et al. 2015). Between 2007 and 2012, the combination of interest rate adjustments and forward guidance were sufficient to reach the inflation target in most periods. The CNB decreased the policy rate by 4 percentage points over this period (CNB 2016b). Additionally, according to Franta, Holub et al. (2014), the exchange rate proved its ability to act as an automatic adjustment mechanism after the global financial crisis in 2008. Monetary policy easing was significantly aided by a spontaneous depreciation of the koruna in response to a contraction in both external demand and the domestic economy. Nevertheless, while the Czech economy managed to recover slightly throughout 2010 and 2011, it contracted again afterwards due to lower external demand as a consequence of the sovereign debt crisis in the Euro Area as well as weaker domestic demand. The weaker domestic demand was partly caused by a highly restrictive fiscal policy from 2010 to 2013, a VAT hike in 2010 and 2013 (EC 2015), and by generally low consumer and business confidence.

As a consequence of these economic developments, by November 2012, the CNB had exhausted the interest rate as policy instrument. It had lowered its two-week repo rate to 0.05 percent, which it considers the technical zero or zero lower bound (CNB 2016f). Also, it pledged to leave it there for as long as needed until inflationary pressure increased significantly. While other central banks (e.g. ECB, Swedish Riksbank and Bank of Denmark) have lowered their deposit rates to negative values, the CNB states that they would conflict

with the spirit of several laws that use multiples of the repo rate for the calculation of penalties and interests on debt. The existence of the zero lower bound at this level forced the CNB to consider further, unconventional forms of monetary policy. Hence, in Fall 2012, the CNB made the announcement that it was ready to weaken the koruna through exchange rate interventions (CNB 2012). That alone had a significant depreciating effect on the koruna. However, the CNB had not yet defined an exchange rate target level.

Throughout the year, exchange rate targeting as a monetary policy tool was further discussed. An inflation forecast published in Spring 2013 found a continuous decrease in inflation and pointed towards the need for further easing of monetary conditions. At the same time, the recession only slowly faded. The IMF (2013) noted: "The Czech Republic's economic fundamentals are strong. But the economy is in the midst of a prolonged recession because of the Euro Area slump and weak domestic demand. [. . .] If a persistent and large undershooting of the inflation target is in prospect, the CNB should employ additional tools".

During that time, the CNB also assessed different unconventional monetary policy options: According to Franta, Holub et al. (2014), quantitative easing did not seem a suitable instrument for the CNB. With a long-standing liquidity surplus in the banking sector and relatively low long term government bond yields, it did not see a significant lever in this tool. Although it assumed that it would have a significant price effect on bond purchases, it had doubt about the long term effectiveness. Qualitative easing was not considered effective enough either: The scope was not sufficient to use it as monetary policy instrument. Furthermore, an IMF report from 2013 finds only a small fiscal multiplier in the Czech Republic which is why anti-cyclical government spending was not a suitable option either.

In November 2013, deflationary pressure continued and a negative output gap gave rise to a growth in unemployment and cuts in average working hours. Household income, consumption, corporate profits and investment had also fallen sharply (Franta, Holub et al. 2014). In this light, the CNB discussed several monetary policy scenarios (CNB 2013b): assuming the zero lower bound had not been binding, its analysis indicated a need for significantly negative monetary policy rates, at around - 0.9 percent. Since this was not an option, the scenario under passive monetary policy (binding zero lower bound) was discussed: the Bank Board anticipated a significant exchange rate appreciation and undershooting of the inflation target. In addition, an even more significant strengthening of the koruna was anticipated from disappointed expectations of financial market participants if the CNB were not to start intervening in the foreign exchange market (Franta, Holub et al. 2014). At the same time, financial agents expected a depreciation of the euro (e.g. Bruce 2013) in the course of the Greek sovereign debt crisis, which would have led to an automatic relative appreciation of the koruna. Consequently, the CNB decided to act on the announcement it had made a year prior: it set the exchange rate target to 27 CZK/EUR on November 7, 2013 within its inflation targeting regime. According to the CNB, the scenario analysis had confirmed that this was the most effective instrument for averting the risk of deflation and accelerating the return of inflation towards the target while simultaneously delivering a stronger recovery in economic activity (CNB 2013b).

5.2 Policy Framework

The CNB eventually opted for a asymmetric (one-sided) exchange rate commitment towards the euro as dominant currency among its trading partners. It decided on a level of 27CZK/EUR that it would reach through unlimited foreign exchange interventions. While the exchange rate is kept from appreciating above this threshold, further depreciation is not prevented in the one-sided commitment. The CNB stated that it was determined to intervene in the foreign exchange market in such volumes and as long as needed to achieve the desired exchange rate level with the aim of hitting its inflation target in the future (Franta, Holub et al. 2014). These interventions are not matched by sales of domestic assets, i.e. they are un-sterilised and extend the balance sheet.[17] It coupled this approach with extensive communication to stress that while staying in an inflation targeting regime, the announcement represented a long-term change in policy rather than a short-term deviation from behaviour. This targeted at ensuring the credibility of its approach. The use of the exchange rate as an instrument will therefore only be discontinued when monetary tightening becomes necessary. Foreign exchange interventions will at that point terminated, the peg abandoned and interest rates raised above (technical) zero (CNB 2016e).

In order to determine the most effective exchange rate level to target, the CNB constructed several scenarios. The variant best aligned with monetary policy objectives was chosen while respecting the recommendations made in the economic literature. In the selected scenario, the exchange rate of the koruna thus moved close to CZK 27 to the euro which is a significant (4-5 %) weakening. The CNB expected that this would significantly lower the risk of deflation, accelerate the return of inflation towards the target, support a recovery in economic activity in 2014 and enable a more robust exit from the zero lower bound in early 2015 (Franta, Holub et al. 2014).

As previously discussed, communication and transparency are essential in order to build economic agents' expectations towards the exchange rate development. Ideally, the strategy would increase short-term inflation expectations without de-anchoring long-term expectations (Alichi et al. 2015). Therefore, according to Franta, Holub et al. (2014), the CNB intensively debated the degree of transparency. In the case of the Czech Republic it was crucial to signal that the CNB was not adding an additional nominal *objective* for monetary policy but rather just introducing a new *instrument* to reach the goal of price stability in the form of its inflation target (Alichi et al. 2015). It hoped to minimise the level of intervention necessary to maintain the level chosen. The signalling effect of disclosing the exchange rate commitment is conditional on a clear and credible statement that the central bank is ready and willing to intervene without an upper limit to foreign exchange purchases. This approach was also aiming at maximising the impact of inflation expectations. Essential was also that the CNB

17. Contrary to the CNB's approach of unlimited foreign exchange purchases, the IMF had recommended the use of fixed-size interventions. However, the CNB rejected this approach for several reasons: "(i) the small expected liquidity impact of the interventions [...]; (ii) the reliance conversely on the inflation expectations and real interest rate channel in combination with standard exchange rate transmission channels linked with the exchange rate level and its change over time; (iii) the impossibility of determining ex ante the appropriate intervention size delivering an exchange rate weakening consistent with hitting the inflation target; (iv) the related generally debatable effectiveness of this type of intervention in influencing the exchange rate" (as cited by Franta, Holub et al. 2014 p.33).

would stay flexible to change the target level and the exit strategy of the exchange rate targeting policy. In this way, the CNB could strengthen expectations that the weak exchange rate would be maintained for a sufficiently long period of time to provide the required stimulus to the economy and the necessary upward pressure on the rate of inflation (Alichi et al. 2015). Therefore, the CNB began to provide information on the dates before which it would not end the peg. At the same time, it declared that it will only inform the public about its foreign exchange interventions "when it considers this appropriate" (CNB 2016d). The CNB put significant effort into explaining its policy approach to a broad public to establish credibility quickly. This strengthened communication strategy also included a makeover of the CNB's website including a highly detailed question-and-answer Section.

The described approach is clearly based on the policy design described by Svensson (2001). For example, as recommended by Svensson, the CNB puts great emphasis on credibility of its policy by increased communication efforts. Also, the CNB clearly states its state-contingent exit corresponding to Svensson's framework. Furthermore, the CNB actively depreciated the exchange rate in the first period of the policy as Svensson recommends. However, while Svensson suggests a temporary switch to price level targeting, the CNB remains in its inflation targeting regime. In this regard, the CNB's implemented approach differs from Svensson's recommendations. Yet, Lízal and Schwarz (2015) argue that the approach comprises all essential elements of Svensson's theoretical proposal.

5.3 Effectiveness of the Pass-Through in the Czech Republic

In order for an exchange rate targeting policy to be effective, the pass through of this policy to prices needs to be strong. For the Czech Republic, the transmission channels are well researched and described as potent, a fact that sets the stage for the policy under discussion.

Regarding the first stage of transmission, i.e. the effect of foreign exchange interventions on the exchange rate, many scholars, most prominently Disyatat and Galati (2007) and Scalia (2008), find that it is highly potent in the Czech Republic. This is crucial in order to ensure that the required amount of interventions is not overly high.

Concerning the second stage, the Czech Republic as a small open economy with intensive trade relations represents a good starting point for an effective pass-through. However, it is far from complete. Pass-through to import prices is unambiguously high: according to Kamps (2006), in 2004, almost 90 percent of contracts for goods imported to the Czech Republic were denominated in foreign currency (mostly euro). From the initial stage of production to final goods the magnitude of the exchange rate pass-through decreases significantly. Therefore, pass through to consumer prices is below that of producer prices.[18] Relatively strong competition is named as an explanation for this. There is no general consensus on the size of the pass-through to consumer prices for the Czech Republic. The range of pass-through rates from different studies varies between 0 and 80 percent (Lízal and Schwarz 2015). A study by Babecká-Kucharýuková (2009), affiliated with the CNB, finds that total reaction to

18. According to Alichi et al. (2015), approximately 24 percent of the CPI are imported and consumed directly. An additional 9 percentage points are imported as intermediate inputs, processed and then enter the consumption basket.

the exchange rate shock is limited to 25 to 30 percent when considering the sample period 2002 to 2008. As usual for a small open economy, the transmission happens relatively quickly: within the first six months after an exchange rate shock, the transmission to prices is finalised (Babecká-Kucharýuková 2009).

In its 2014 consultation, the IMF was confident that the pass-through would be sufficient to achieve the anticipated goal of target inflation in the near future (IMF 2014). At the same time, the expectations channel has been shown to be highly potent. Already during the foreign exchange interventions in the 1990s, it had a strong effect on inflation (Holub 2004). Arguably, with a highly transparent communication strategy and strong credibility of the CNB in recent years, this channel should be even stronger.

To conclude, while pass-through is far from complete, it is effective. In addition, the CNB's communication strategy is working on strengthening the expectations channel to improve the effectiveness of pass-through further.

5.4 Economic Developments since Policy Initiation

The CNB's general credibility, supported by clear and significant foreign exchange interventions in November 2013 right after the policy's initiation, helped to install the policy. The koruna moved from 25.8 CZK/EUR on November 6, just before the announcement to almost 27 CZK/EUR directly afterwards, which represents about a 4 percent depreciation (see Figure 2 below). After purchasing foreign reserves worth EUR 7.5 billion (about 5 percent of GDP) in November 2013, no additional foreign exchange interventions were required until July 2015 (CNB 2016c) in order to keep the exchange rate close to target. Between December 2013 and December 2015, the exchange rate had a monthly average of 27.4 CZK/EUR. As also displayed below, the CNB managed to credibly keep the exchange rate at the communicated level, which represents a large decrease in volatility of the CZK/EUR exchange rate.

In July 2015, the CNB was forced to intervene again: when the Czech economy grew strongly in 2015, policy makers were facing significant appreciating pressure (Chamonikolas 2015b). Also, the ECB started its quantitative easing program in early 2015, which has been named as another cause of the appreciating pressure on the koruna. Jakub Seidler, chief economist at the Prague-based unit of ING Groep NV, states that investors had started building speculative positions against the CNB, testing its resolution to defend the exchange rate commitment. Nevertheless, he was confident that the CNB would be able to defend the regime. However, analysts were surprised by the high volume of interventions in summer 2015 (Czech News Agency 2016) that continued in August, September, November and December. From July to December 2015, the CNB bought foreign reserves worth almost EUR 9 billion (CNB 2016c). While the level of the peg was initially announced as fixed, the Board noted in Mid 2014 that a future need to weaken the koruna further might be possible (CNB Mintues of the Bank Board Meeting May 2014).

Since the initiation of the policy, inflation developed a lot more positively than suggested by forecasts of scenarios without exchange rate targeting. Already in early 2014, Franta, Holub et al. (2014) conclude that "the risk of protracted deflation in the Czech Republic is a virtually closed topic" (p.3). The Bank Board also judged that the passing through of the

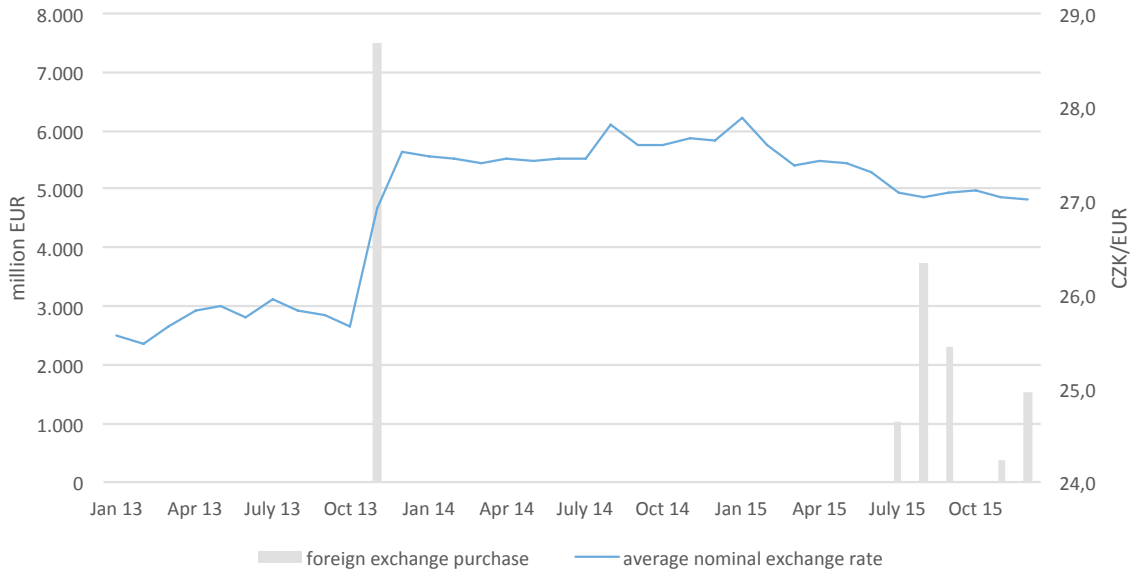

Figure 2: Foreign Exchange Interventions and Exchange Rate Development (2013 to 2015)

Source: Czech National Bank 2016c; European Central Bank 2016a

weakened exchange rate to prices was happening in line with expectations and prevented the projected deflation (CNB Mintues of the Bank Board Meeting May 2014).

Meanwhile, falling energy prices were still keeping a lid on inflation (Chamonikolas 2015a). While prices of imports showed an upward trend throughout 2014, they declined significantly in 2015, mainly driven by the price fall of mineral fuels (see Appendix A.1). Furthermore, subdued inflation in the Euro Area and a slower than expected wage growth had a negative impact on the increase in the inflation rate in the Czech Republic (Alichi et al. 2015).

At the same time though, thanks to a sound communication strategy and the high credibility of the CNB, combined with a positive general economic outlook, inflation expectations have behaved exactly as anticipated. In particular, longer-term inflation expectations have remained well anchored at 2 percent, as desired by the CNB and consistent with effectiveness of the exchange rate policy (Alichi et al. 2015).

Overall, GDP developed favourable since policy initiation. While output growth in 2014 was moderate it picked up during 2015. In the second quarter of 2015 the economy grew at fastest pace in seven years. Improved external demand for Czech exports was considered as main driver for the strong growth (CNB 2015b).

Ever since the initiation of exchange rate targeting, the CNB Bank Board showed its conviction of it being the right choice. Yet, the prolonged deflationary pressure due the development of the oil price lead the board to postpone the exit from the policy several times (CNB Minutes of the Bank Board Meeting May 2014). In addition, the Bank Board noted in November 2015 that Czech monetary policy was being significantly affected by the ECB's policy and that any exit from the exchange rate commitment before the ECB's quantitative easing was discontinued could be very complicated since appreciating pressure would be high (CNB 2015c).

The current economic outlook of the CNB for the Czech Republic assesses the following (Inflation Report I/2016): "The Czech economy expanded by 4.7 percent year on year in 2015 Q3 [...]. The forecast expects annual GDP growth to accelerate further [...]. The overall upward cost pressures on consumer prices will re-emerge this year. [...] The forecast assumes that the exchange rate will be used as a monetary policy instrument [...] until the end of 2016. The 2 percent inflation target will be reached at the start of 2017 [...]" (CNB 2016g pp.6-7).

5.5 State of Research and Evaluation of the Policy

The *CNB Bank Board* itself has deemed the policy successful: from their scenario analyses they concluded that the Czech Republic would have experienced deflation in the past periods had the CNB not intervened.

Michal Franta who is an adviser to the Bank Board and research coordinator for monetary policy at the CNB, wrote a first analysing paper in 2014 with a team of researchers. They conclude that "the developments to date show that [the CNB's policy] was the right choice" (Franta, Holub et al. 2014). They argue that the CNB managed to establish a high degree of credibility expressed through the fact that, especially at that time, foreign exchange interventions had only been conducted on a very limited basis. They explicitly mention the importance of the public debate on the new policy: the CNB was forced to explain its policy as well as its general monetary policy tools to a broad public, which forced it to establish faster and more direct communication procedures. While Franta, Holub et al. (2014) are aware that at the time of their publication, a final judgement of their policy based on the economy's development was not yet reasonable, they state that the goal of averting deflation was reached successfully through the policy. Furthermore, they draw a highly positive outlook both for price and output development.

In Spring 2015 a conference contribution of CNB Bank Board member *Lubomír Lízal and Jiri Schwarz* documented the effectiveness of the policy. By setting up a hypothetical policy-free scenario, they find that without the policy, the Czech economy would have faced deflation throughout all of 2014. Furthermore, they detect a significantly lower level of GDP growth in that scenario. Furthermore, they conduct a sensitivity analysis with regard to the price of oil and find that it has a very strong effect.

In its Article IV consultation, the *IMF* noted in June 2014 that the policy is fulfilling its goal of gradually bringing inflation back to target. It notes that the risk of a self-fulfilling deflationary spiral seems to have been averted which it derives from rising wage growth and positive consumption trends. A year later, the IMF noted that while the Czech economy is growing strongly, challenges remain. Again, they attribute the economic upturn to the monetary policies.

Ali Alichi and a team of affiliates of the IMF also draw a highly positive conclusion in March 2015, roughly 16 months after the initiation of the policy. They find that the CNB, through the policy, managed to avert deflation easily and quickly, especially since communication was used effectively. This caused a high level of understanding of market participants leading to the development of favourable inflation expectations. Exogenous

factors like the decrease in energy prices aside, they conclude that the macroeconomic effects of the November 2013 decision have been as expected.

To the best of our knowledge, no further empirical research has been published that attempts to evaluate the policy and its effects up to this date. Both the work of Franta, Holub et al. (2014) and Lízal and Schwarz (2015) base their analyses on the DSGE model of the CNB and can thus not be deemed entirely independent. Alichi et al. (2015) does not provide a quantitative analysis of the effectiveness, which is why we see significant room for an empirical assessment.

6. The Baseline Model

In the following section, we motivate the formulation of our baseline model that we use throughout the analysis in sections 7 and 8. Besides a description of the underlying variables and data series we explicitly motivate the identifying restrictions imposed on the model. Also we discuss the various specification steps leading to our model selection.

6.1 Baseline Vector Autoregressive Model

We analyse our question of interest by making use of a Vector Autoregressive (VAR) model. An advantageous characteristic of VAR models is that the multivariate system accounts for dynamic feedback between the economic variables since in the unrestricted model all variables are allowed to affect each other over time. This is a relevant feature for our analysis since reverse causalities exist between macroeconomic variables. VAR models are able to capture these reverse relationships as well as influences between variables throughout time. Thus, with an impulse response analysis of a VAR model, we are able to reveal how shocks to an economy transmit dynamically. Furthermore, VAR models avoid the need for a complete specification of a structural model of the economy. Rather they extract the relationship between variables from the data series and thus allow for a rather neutral handling of the economic relationships in place.

Based on the work of Sims (1980), this class of models has become widely established in empirical research on monetary issues as well as for monetary policy evaluation.[19] Moreover, the VAR based analysis of Christiano, Eichenbaum, and Evans (2005) has strongly influenced today's understanding of how monetary policy transmits to the economy.

Alternatively, one could make use of a DSGE model. The advantage of DGSE models over VAR models is that the micro-foundations in DGSE models explicitly incorporate expectations of economic agents. With regard to the policy transmission this presents an important channel as discussed earlier. However, these models require an explicit modelling of the economy in structural equations. Hence, they are less neutral towards the macroeconomic relationships than VAR model. Moreover, all to date published assessments of the policy are solely based on DSGE models. Thus, by instead employing a VAR model we can

19. A summary of related research can be found in Leeper et al.(1996) while the work of Christiano, Eichenbaum, and Evans (1999) discusses various ways of how to analyse the impact of money in the VAR framework.

implicitly evaluate these findings in terms of robustness to alternative modelling approaches.

In the primitive system a VAR with p lags and n variables in matrix form can be written as follows:

$$By_t = c_t + \Gamma_1 y_{t-1} + ... + \Gamma_p y_{t-p} + \varepsilon_t \tag{3}$$

where y_t is a $n \times 1$ vector of endogenous variables included in the system, c_t represents a $n \times 1$ vector of intercept terms, and $\Gamma_1, ...\Gamma_p$ define $n \times n$ matrices of coefficients. The coefficients are obtained through ordinary least squares (OLS) regression of every endogenous variable in y_t on its own lags as well as current and lagged values of all other included variables. The error terms in the $n \times 1$ vector ε_t are white noise processes. In the matrix B of dimension $n \times n$ the diagonal terms are normalised to unity such that:

$$B = \begin{pmatrix} 1 & b_{1,2} & \cdots & b_{1,n-1} & b_{1,n} \\ b_{2,1} & 1 & \cdots & b_{2,n-1} & b_{2,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ b_{n-1,1} & b_{n-1,2} & \cdots & 1 & b_{n-1,n} \\ b_{n,1} & b_{n,2} & \cdots & b_{n,n-1} & 1 \end{pmatrix} \tag{4}$$

Through pre-multiplication with B^{-1} we obtain the VAR in standard form:

$$y_t = A_t + A_1 y_{t-1} + .. + A_p y_{t-p} + e_t = A_t + \sum_{i=1}^{p} A_i y_{t-i} + e_t \tag{5}$$

where $A_t = B^{-1}c_t$, $A_i = B^{-1}\Gamma_i$ and $e_t = B^{-1}\varepsilon_t$.

Due to the fact that the coefficients are estimated through OLS it is important to note that VAR models can suffer from omitted variable bias if important determinants of the variables are missing in the system. In order to avoid an omitted variable bias we need to consider the fact that the Czech Republic as a small open economy is heavily influenced by the developments of other economies.

Through a Forecast Error Variance Decomposition (FEVD) we can affirm this interdependency (see Appendix A.3). The results show that the Czech variables are to a huge extent influenced by developments in the Euro Area variables. In return, by showing that the Czech variables have only negligible influence on the Euro Area we can confirm the assumption that it is a small economy and has limited relevance for economic development abroad.

This interdependence is accounted for by estimating the Czech variables conditional on the evolution of several exogenous variables. Hereby, we follow the example of Lindé (2003), and Franta, Baruník et al. (2014) who also work with small open economy models: both account for the relevance of the development abroad by including exogenous variables to the VAR model. In our analysis, the Czech variables depend on the exogenously defined developments in the Euro Area. Accordingly, our baseline model for the Czech economy is defined as:

$$y_t = A_t + \sum_{i=1}^{p} A_i y_{t-i} + \sum_{i=0}^{p} C_i x_{t-i} + e_t \tag{6}$$

where x_t defines the vector of m exogenous Euro Area variables and and $C_0, .., C_p$ the respective coefficient matrices. We simulate the Euro Area variables separately in a VAR where:

$$x_t = \tilde{C}_t + \sum_{i=1}^{p} \tilde{C}_i x_{t-i} + \tilde{e}_t \tag{7}$$

In accordance with this model representation we assume that Czech variables are endogenously determined by lagged values of all endogenous variables as well as the contemporaneous and lagged exogenous Euro Area variables. Reversely, changes in the Czech economic variables have no effect on the path of the Euro Area variables. By allowing for contemporaneous reactions of Czech variables to Euro Area variables we account for the high level of correlation between the business cycles of the two economies (as found in Fidrmuc and Korhonen 2006 and Frenkel and Nickel 2005). In this sense, the model representation captures the fact that the Czech Republic is a small open economy.

6.2 Variable Selection and Data Description

For the selection of variables we base our analysis on a core set of economic variables, namely output, price development, nominal policy rate, and the exchange rate. This set of variables typically defines the minimum assemblage for analyses of a small open economy and has been chosen similarly in various studies that employ VAR models (e.g. Smets and Wouters 2002; Franta, Horvath and Rusnak 2014).

First of all, we decide to work with a series for real output. While many studies of monetary policy consider the deviations of realised output from potential output (the output gap) it appears more suitable for the aim of our analysis to use real output. Other studies often discuss the effect of a monetary policy shock whereas here, Section 7 is concerned with an output shock. Thus, if we use the output gap, the source of such a shock would be ambiguous as it could stem from either a fall in realised output or changes in the potential output of the economy (or a combination of the two). For the measure of output we use the quarterly seasonally adjusted real GDP series published by Eurostat. For the Euro Area we use the fixed Euro Area 19 (EA19) aggregate in order to avoid sudden jumps in the GDP series in years when new countries join the monetary union, which could generate misleading estimates. For the price level, we use the monthly *Harmonised Index of Consumer Goods (HICP)* published by Eurostat, which we seasonally adjust. For consistency, we again use the fixed EA19 aggregate. In order to obtain a quarterly series of the price index we calculate the quarterly average over three consecutive months. Since both the ECB and the CNB are targeting inflation based on the HICP, this measure is a sensible choice for price growth in the baseline analysis. The *key interest rate* for the Euro Area is the ECB's rate for main refinancing operations (MRO). The CNB's policy rate is presented by the two-week repo rate. For both central bank rates we calculate the quarterly average weighted upon changes of the interest rate. The data series are obtained from the databases of the two central banks. Finally, we use the *nominal bilateral exchange rate (NER)* between the Czech koruna and the euro retrieved from the ECB's Statistical Data Warehouse, which is available in quarterly

averages.

For the VAR estimation we transform real GDP, HICP, and the NER into annualised quarterly growth rates for a variable x in point t as:

$$\Delta x_t = 400 * ln(x_t/x_{t-1}) \tag{8}$$

For the latter this is especially important since we observe a strong decline in the level series (see Figure 12 in Appendix A.4), which we can account for with percentage growth rates.[20]

Due to the fact that the bilateral exchange rate of the koruna to the euro exists only since the introduction of the euro in early 1999, the history of our level data sample is limited to the first quarter of 1999. Consequently, the first observation for the first difference growth rate is available at the second quarter of 1999. Moreover, we restrict the sample to the time up to the introduction of the policy, which was in 2013q4. Thus, we are left with 58 quarterly data points spanning from 1999q2 to 2013q3.[21]

In order to stabilise the series in dynamic simulations and obtain more plausible results we demean the variables.[22] For the choice of the mean value we look at the real path of the variables throughout the sample and consider plausible assumptions for a long-run development of the two economies.

When looking at the underlying data series (see Appendix A.4) we observe an ever-closer convergence in the two economies. While in the first half of the sample the two economies developed at a different growth pace, the difference in output growth narrowed down significantly over the last years and the Czech GDP growth rate followed that of the Euro Area closely. Moreover, since 2009 the IMF has also classified the Czech Republic as a developed economy (IMF 2015c). While there remains room for further convergence (as discussed in Section 5), the level of economic convergence is significant and we therefore assume the longer growth forecast of the two economies to develop similarly going forward. The price developments in the Euro Area and the Czech Republic show a similar picture. With the latter having higher volatility in price growth in the earlier years of the sample, both series are developing more closely in recent years. For the nominal interest rate the economies' co-movement becomes even clearer and both series have had similar levels and dynamics already since early 2003.

Based on these observations, we demean the variables with the same factor in both economies. For the real GDP growth rate the mean is based on the historic average of the five-year real GDP growth forecast for the Euro Area from the Survey of Professional Forecasters (European Central Bank 2016c) and is equal to 2.15 percent. For inflation we reduce

20. An advantage of using the first difference, i.e. quarter-on-quarter change (as compared to the fourth difference, i.e. the year-on-year change) is that quarter-on-quarter analysis saves three observations for our data estimation. This is especially relevant in the rather small sample we are analysing.

21. For the nominal interest rate we observe that in the beginning of the sample the CNB interest rate is exceptionally high and declines rapidly. This is due to the fact that at this point in time the CNB was still in the process of adapting to the newly introduced inflation targeting regime. Yet, estimates do not differ significantly when excluding these first periods, which is why we decide to work with the complete sample.

22. Demeaning is a common practice that is used, for example, in Smets and Wouters 2004 and Stock and Watson 2006.

the data by the inflation target of the central bank, which is identical in the two economies and equals two percent. For the nominal interest rate we base the reasoning on the logic of the Fisher equation where the nominal interest rate equals the real return of interest plus the inflation premium (Walsh 2010). Since the real interest rate is unobservable it has to be estimated. An estimate for the short-term real interest rate for the Euro Area is 1.4 percent (ECB 2004). Adding the inflation premium of the 2 percent target we obtain a mean value of 3.4 percent that we subtract for both economies. For the growth of the nominal exchange rate there exists no such long-term equilibrium, so this series is not demeaned.

With regard to the baseline model (6) the vector of variables for the Czech Republic is[23]:

$$y_t = [\Delta y_{CR}, \pi_{CR}, r_{CR}, \Delta s] \tag{9}$$

The vector for the Euro Area variables is:

$$x_t = [\Delta y_{EA}, \pi_{EA}, r_{EA}] \tag{10}$$

where Δy is the real GDP growth, π is HICP growth as a measure for inflation, r is the policy rate and Δs is the growth of the CZK/EUR exchange rate. Due to the step of demeaning our variables all VAR estimations in the following analysis are estimated without a constant term, so that in equation (6) $A_t = 0$ and in equation (7) $\tilde{C}_t = 0$ respectively.

6.3 Discussion of Identifying Restrictions

In order to unambiguously identify the structural model we have to impose identifying restrictions on the estimated parameters (Enders 2010). For exactly identifying an n-variable VAR model we need to impose $(n^2 - n)/2$ restrictions. Thus, the baseline VAR model for the Czech Republic in equation (6) requires six restrictions and the Euro Area model in equation (7) requires four restrictions. We choose to apply a Cholesky decomposition: the B^{-1}-matrix is decomposed into a lower triangular matrix by setting coefficients equal to zero (Enders 2010). Thereby, we partly restrict the contemporaneous transmission of shocks to the system.[24] In doing so, we have to order the variables and define which is causally prior to another variable. Consequently, the ordering of the variables has implications for the analysis of impulse response functions as well as FEVD (Enders 2010). In order to establish a reasonable relationship between the variables and a sensible shock transmission, we rely on economic theory and empirical evidence.[25] We decide to implement zero-restrictions on the

23. See Appendix A.4 for a detailed overview of data series and sources. Data files as well as the MATLAB®- and Stata®-code can be made available.

24. Due to the fact that the analysis is done on quarterly data having no contemporaneous effect means that variables are not affected within the time span of a quarter.

25. The logic of the ordering applies equally for both economies.

B^{-1}-matrix as well as variable ordering in the following way

$$e_t = B^{-1}\varepsilon_t = \begin{pmatrix} 1 & 0 & 0 & 0 \\ . & 1 & 0 & 0 \\ . & . & 1 & 0 \\ . & . & . & 1 \end{pmatrix} \varepsilon_t \quad \text{with} \quad \varepsilon_t = \begin{pmatrix} \varepsilon_{\Delta y} \\ \varepsilon_{\pi} \\ \varepsilon_{r} \\ \varepsilon_{\Delta s} \end{pmatrix} \tag{11}$$

where $\varepsilon_{\Delta y}, \varepsilon_{\pi}, \varepsilon_{r}, \text{and} \varepsilon_{\Delta s}$ represent shocks to output growth, inflation, the policy rate and the nominal exchange rate growth. This ordering is frequently applied in studies of monetary policy (e.g. Christiano, Eichenbaum and Evans 1999, Lindé 2003, Franta, Horvath and Rusnak 2014), however, it has some implications and interpretations worth noting.

With regard to the *first row* of equation (11) the ordering implies that shocks to neither inflation, the interest rate nor the exchange rate have a contemporaneous effect on output growth since the values for the first row are set to zero. Shocks to inflation, so-called cost-push shocks, only affect output in later periods and not contemporaneously. They influence output as shocks in the marginal costs of production. Since it is assumed that firms are not producing in a market of perfect competition and thus are able to operate their production at a margin, this margin can serve as a buffer to shocks in marginal costs, so firms can keep their output stable in the short run (Walsh 2010). A monetary policy shock, a shock to the policy rate, would also not affect output in the same period. It affects firms' production costs through changes in the cost of capital. Again, through the assumption that firms produce at a margin, such a shock would not immediately trigger changes in the level of output produced but only with a delay. On the other hand a shock in the policy rate could affect output through changing the demand from consumers. However, under the assumption that there exists a habit persistence in consumption preferences, demand and thus real output is unchanged in the short-run (Chistiano, Eichenbaum, and Evans 2005). When it comes to shocks in the exchange rate we rely on the empirical findings of Franta, Horvath and Rusnak (2014) that there is a time-delay in the transmission of changes in the exchange rate on output.

When looking at the *second row* of the B^{-1}-matrix we decide to restrict immediate inflation responses to shocks in the interest rate of the central bank. This is in line with observed nominal rigidities, i.e. the fact that prices are taking time to adjust. These rigidities could, for example, be explained by stickiness of wages, due to frictions in wage contracts or the stickiness of prices for goods, so called menu costs of firms to implement changes in prices. Recent empirical evidence suggests that this stickiness can last for up to a year (Klenow and Malin 2010), so restricting changes in inflation in the first quarter of an interest rate shock appears sensible. The fact that we also restrict direct adjustment to exchange rate shocks is related to findings on the exchange rate pass through to prices. In their study Babecká-Kucharýuková (2009) find that in the Czech Republic overall consumer prices react strongest to exchange rate shocks after a few months, with the bulk being realised after six months. Thus, within the contemporaneous period of a quarter the zero restriction is reasonable for the Czech Republic.

Based on the *third row* we restrict the policy rate to simultaneously respond to shocks in

the exchange rate. This is based on the idea that the underlying interest rate rule that the central bank follows is similar to the one formulated in Taylor (1993). Thus the policy maker consider only values of past inflation, deviations in real output from potential output as well as deviations of current inflation from the inflation target.

The exchange rate remains unrestricted (*line four*): it simultaneously reacts to shocks in all other variables which corresponds to it being observed in real time and thus adjusting immediately to economic developments.

6.4 Model Specification

In a next step, we specify our model by defining a suitable lag length while ensuring stability and avoiding remaining autocorrelation. The model specification is carried out in three steps, where we use formal tests in order to ensure that our model is correctly specified. First we decide about a suitable lag length for the variables taking into account suggested lag lengths from the AIC and BIC information criteria on one hand and the degrees of freedom in our estimation on the other hand. Second, we ensure that the VAR under the chosen lag length is subject to stability. Third, we assess whether there is remaining autocorrelation in the error terms, which has to be ruled out in order to specify a model that captures the data dynamics to a sufficient extent. For the last step we rely on the Lagrangian-multiplier (LM) test in accordance with Johansen (1995).

For the Czech Republic baseline VAR model the AIC criterion suggest to include eight lags and the BIC criterion one lag. The former suggestions would consume almost all degrees of freedom. On the other hand, the latter could lead to miss-specification because of remaining serial auto-correlation. Therefore, we tentatively continue the analysis for two lags. We find that both VAR models are stable when including two lags. Furthermore, the LM-test confirms that there is no serial autocorrelation for the Czech VAR model. Up to eight lag lengths we cannot reject the null-hypothesis of no remaining autocorrelation at any conventional level. For the Euro Area VAR model the test suggests that remaining autocorrelation can only be rejected at the five percent significance level (relatively low but sufficient).[26] Consequently, we set $p = 2$ in the two VAR specifications in equation (6) and (7).

7. Impulse Response Analysis

The following section provides the analysis for research question (a). By making use of the VAR models specified in the previous section, we shed light on the role of the exchange rate for economic easing. Further, we analyse what implications the zero lower bound has for the exchange rate development.

In order to set a realistic framework, we use features that correspond to the situation the Czech as well as the Euro Area economy were in when the exchange rate targeting policy was initiated: while the Czech Republic also saw itself facing a slump in domestic demand, the

26. The LM-test has low power in small samples and tends to falsely reject the null hypothesis of no remaining serial correlation since the critical values are assumed to be asymptotically χ^2.

main reason for the anti-inflationary pressure was the recessionary European environment in response to the sovereign debt crisis (IMF 2013). Therefore, we base our analysis on a negative Euro Area output shock that mimics the size of the output loss due to the European sovereign debt crisis.

From here, we draw conclusions on how much monetary easing through the nominal interest rate becomes necessary to address a shock of that magnitude and what role the exchange rate plays in encountering such shocks. We assess how the zero lower bound impairs the easing process and what this implies for the exchange rate targeting policy.

7.1 Setup of Impulse Responses to an Output Shock in the Euro Area

Since the error matrix of our baseline model in equation (6) only includes disturbance terms of the endogenous variables we cannot directly induce a shock to the exogenous Euro Area output variables in this VAR model. For obtaining the reaction in the endogenous variables to a shock in the exogenous variable we need to simulate the Czech VAR model under two sets of Euro Area variables: one where the Euro Area variables are following their actual path $\{x_t\}_{t=1}^{n}$ and one where we simulate a negative output shock over this path $\{\tilde{x}_t\}_{t=1}^{n}$ where n represents the time horizon. Thus, we obtain simulations of the Czech variables conditional on these two sets of variables

$$\{y_t\}_{t=1}^{n} = \{y|x\} \quad \text{and} \quad \{\tilde{y}_t\}_{t=1}^{n} = \{y|\tilde{x}\} \tag{12}$$

The only difference in the two simulations is the path of the exogenous Euro Area variables. Consequently, the difference between the two simulations for the Czech variables represents the impulse response to an external Euro Area output shock:

$$\text{IRF}_{CR} = \{\tilde{y}_t\}_{t=1}^{n} - \{y_t\}_{t=1}^{n} \tag{13}$$

For the scale of the output shock we consider the overall reduction in Euro Area real GDP after the 2012 European sovereign debt crisis when comparing it to the level of output that could have been realised if GDP had been growing at the pre-crisis growth rate. The respective GDP reduction is approximated by a shock of 6 percent.

7.2 Confidence Bands

For the confidence bands of the IRF coefficients we apply a bootstrapping procedure through which we correct for the fact that the residuals of the VAR models do not appear to be normally distributed.[27] This procedure is as follows: based on the estimated VAR and the resulting series of residuals a set of residuals is drawn with replacement from the actual

27. In the multivariate Jarque-Bera test of normality we obtain a test statistic of 29.3 for the Euro Area VAR model and 20.2 for the Czech Republic VAR model. Comparing this against the ten percent critical value 10.6 and 13.4, we can clearly reject the null hypothesis of normally distributed residuals in the two VAR models.

residuals.[28] Subsequently, the residuals and the VAR estimates are used for reconstruction of a multitude of data sets. These data samples thus have the same statistical properties as the original data set. Based on those artificial data sets we then repeatedly estimate the impulse responses. The collection of IRF estimates is sorted from smallest to largest, so that the 2.5 and 97.5 percentile estimate distribution is considered as the respective lower and upper bound of the 95 percent confidence band. Afterwards the upper and lower bound are adjusted for small sample bias through adding the difference of the actual impulse and the median impulse from the bootstrapped samples.

7.3 Impulse Responses in Normal Times

The impulse responses of the Euro Area economy as well as the Czech economy to a negative Euro Area output shock are depicted in Figure 3 and 4 below.

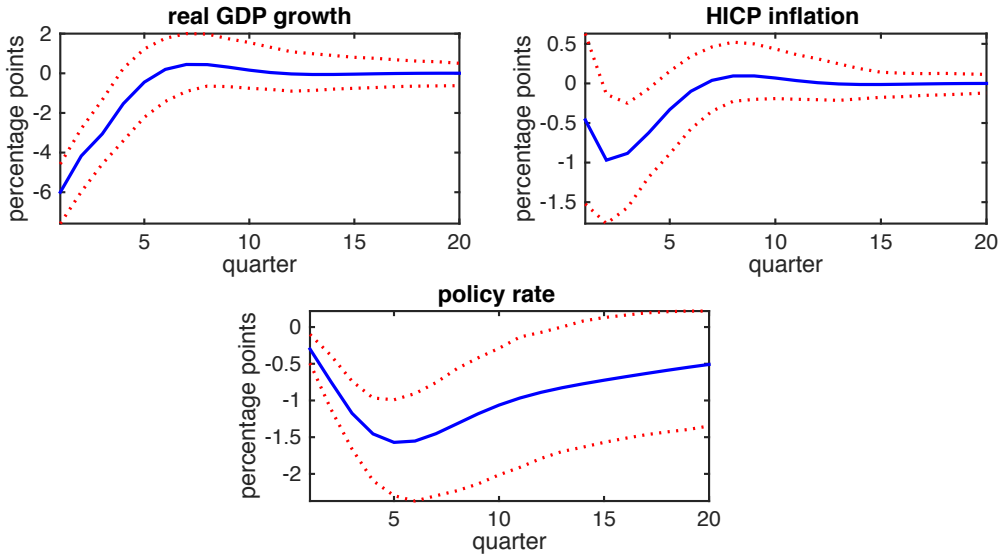

Figure 3: Euro Area Impulse Responses to Negative Domestic Output Shock

Note: The solid line presents the point estimate, dotted lines mark the 95 percent confidence bands.
Source: Own calculations

28. Since a large number of bootstrap samples is required (Efron 1994) we choose a draw of $T = 1,000$. Further, in order to avoid problems with the initial condition we discard the first 50 observations (Enders 2010).

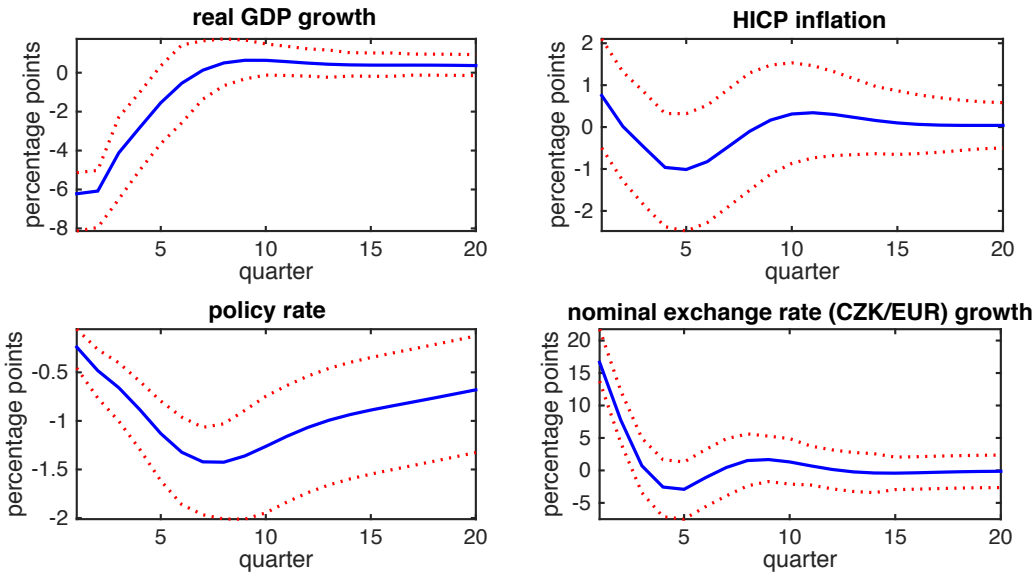

Figure 4: Czech Impulse Responses to Negative Output Shock in the Euro Area

Note: The solid line presents the point estimate, dotted lines mark the 95 percent confidence bands. An increase in the nominal exchange rate equals a depreciation.
Source: Own calculations

When looking at the Euro Area impulse responses we see that their evolution is in line with what we would expect. The strong decline in real output causes prices to fall and the central bank rate is lowered in order to provide monetary easing. Due to the fact that we do not observe positive growth at any quarter after the shock the level path of real GDP will now develop below the pre-shock path. The same is true for the path of inflation.

When considering the ECB's policy rate after the shock there is a high persistence in the reduction of the interest rate. This is in line with Smets and Wouters (2005) who equally observe a high persistence in the interest rate response to a shock in output for the euro area. The persistently reduced policy rate can be explained by the fact that both GDP and inflation levels remain below their pre-shock state. In this sense the central bank provides further stimulus with the aim of bringing the economy back to pre-shock levels.

The responses of Czech variables show the strong interdependence between the Czech economy and the developments in the Euro Area: when the Euro Area output growth drops by 6.4 percent, the Czech output growth drops slightly stronger. The strong co-movement between the Euro Area and the Czech variables confirms the relatively strong business cycle synchronisation found for example by Savva, Neanidis and Osborn (2010) as well as Aslanidis (2010). The decline in output lasts a little longer in the Czech Republic. In correspondence to the decline in output, Czech inflation falls. Again, we observe that the policy rate is lowered over a long time to provide stimulus to the economy. Highly interesting for our further analysis is the fact that while both economies lower their policy rates for a significant period to respond to the output shock, the Czech policy rate stays lower for longer. The CZK/EUR exchange rate depreciates in response to the shock. Here, the reaction is only of very short duration when comparing it to the other variables.

7.4 Implications of the Zero Lower Bound

The results in normal times show that both countries lower interest rates in response to the output shock. A combined version of the interest rate responses to the output shock is presented in Figure 5 below. While the ECB's policy rate is lowered slightly further than the CNB's interest rate, the decrease in the Czech economy is more persistent. The Euro Area interest rate declines strongest in the fifth quarter after the shock the Czech IRF for the policy rate reaches its trough in the eighth quarter. Subsequently, it stays below the Euro Area interest rate.

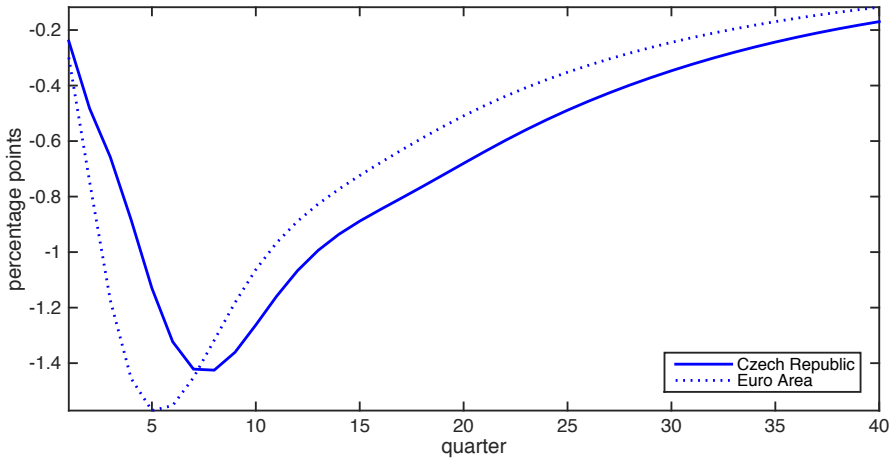

Figure 5: Impulse Responses of Policy Rates to Negative Output Shock in the Euro Area in Normal Times

Source: Own calculations

The UIP relates the interest rate differential of two countries and the expected future exchange rate: the difference in interest rates between two countries equals the expected change in exchange rates between the countries' currencies. Based on a version of the UIP condition that takes into account the future path of interest rates of the two countries we can derive implications from this observation on the exchange rate path. Equation (14) essentially determines the exchange rate evolution based on the area between the two interest rate paths. In the equation s_t presents the nominal exchange rate (CZK/EUR), i is the interest rate of the home country (Czech Republic), and i^* the interest rate of the country abroad (Euro Area).[29]

$$s_t = -\sum_{i=0}^{\infty} E_t(i_{t+i} - i^*_{t+i}) \tag{14}$$

According to this formula, if the sum of all future Czech interest rate differentials is below that of the Euro Area, the exchange rate depreciates (s_t turns positive). With regard to the baseline IRF analysis, this relationship seems to hold, since the graph demonstrates

29. For a derivation of this version of the UIP, refer to Appendix A.2.

that Czech rates remain lower on the overall horizon.[30] The depreciating response that the UIP suggests corresponds to a depreciation in the baseline IRF. Corresponding to the uncovered interest parity, it is the overall stronger monetary easing by the CNB that enables the depreciation of the Czech koruna we observe.

This relationship implies that at the zero lower bound the CNB is restricted in monetary easing in two ways: on the one hand, cannot lower its interest rate further. On the other hand, because the interest rate cannot be lowered, a depreciation is disabled.

While the room for interest rate easing in the Euro Area is also limited, the ECB's lower bound is below that of the CNB. The Czech Republic reached the 0.05 percent lower bound of the policy rate already in late 2012 while the ECB was able to decrease interest rates further. Since the MRO was set to 0 percent in March 2016 (ECB 2016a) the ECB's policy rate lies indeed below the one of the CNB. Also, the ECB launched several other unconventional policies that are targeted at easing monetary conditions, lowering market interest rates further.

In accordance with equation (14), the exchange rate appreciates (s_t turns negative), causing further economic downturn. The appreciation weakens the competitiveness of exporters and hence domestic production. This in turn lowers domestic price growth. Also, an appreciation makes imports relatively cheaper, causing a reduction of import prices. Thus, both GDP and inflation are negatively affected.

8. Counterfactual Analysis

In the following part, the effectiveness of the Czech exchange rate policy is analysed. This is done through a counterfactual study and respective isolation of the effect of the exchange rate depreciation on the macroeconomy, namely the development of inflation and real output. From here, we infer insights on the effectiveness on the policy.

8.1 Construction of the Counterfactual Scenario

In the analysis of the counterfactual, we want to conclude on how much economic impact the initiation of the exchange rate policy has had to date. Thus, we compare the realised path of the macroeconomy with an alternative scenario, in which the policy is absent. In order to obtain the economic development in the absence of the policy we need to quantify the effect from the artificially depreciated exchange rate path. When subtracting this macroeconomic effect of the policy from the realised path of the variables, we arrive at the desired quantification of a world without the policy. Schematically, this can presented as follows[31]:

$$\mathrm{CR}_{\mathrm{real}} - \text{policy effect} = \mathrm{CR}_{\mathrm{counterfactual}} \tag{15}$$

30. A forward simulation of 40 quarters appears appropriate for approximating the long-term horizon of the shock since at that time the reaction in the interest rates is almost abated.

31. Both scenarios equally include all other endogenous and exogenous shocks to the economy and the sole difference is the presence or absence of the policy.

For the size of the policy effect we periodically induce exchange rate shocks to the economy. Those shocks equal the difference of an alternative exchange rate development without the policy and the actual exchange rate path after introduction of the policy. Consequently, the series of shocks captures the effect from the depreciation, i.e. the policy effect.

As can be seen from the impulse responses to an exchange rate shock in the Czech VAR (Figure 13 in A.5), a depreciation of the exchange rate triggers a rise in the policy rate from the central bank. The interest rate is increased in order to reverse the depreciation and to tighten the easier monetary conditions directly. In the underlying case, however, inflation is below target and therefore the CNB keeps the interest rate at its low level. It intends to keep it there until the inflation target is reached. In order to simulate this passive monetary policy scenario, we introduce interest rate shocks whenever the interest rate would react to the positive exchange rate shock.[32]

8.2 Alternative Exchange Rate Path

The starting point for the counterfactual analysis is an alternative path of the nominal exchange rate from which we can quantify the size of currency depreciation from the policy and thus the size of the shocks we need to simulate. On the predictability of exchange rate movements Meese and Rogoff (1983) find that various plausible macro-models fail to predict exchange rate developments in out of sample forecasts. Moreover, they conclude that the random walk model performs equally well in the short-run when compared to forecasts of those macro-models. Since our data sample of the bilateral CZK/EUR exchange rate is limited to a little more than twenty years an assessment on whether this observation holds also for the currency pair of our study cannot be carried out. Therefore, we assume that the findings of Meese and Rogoff (1983) equally apply for the CZK/EUR exchange rate. Thus, our best guess for the exchange rate development in the absence of the policy is a constant path and we assume the level exchange rate prior to policy initiation to endure. The counterfactual exchange rate is equal to the value from the third quarter of 2013, which is 25.85 CZK/EUR.[33]

Looking at Figure 6, it can be demonstrated how the exchange rate shocks for the counterfactual analysis are scaled. They are of the size such that the counterfactual path of the nominal exchange rate (solid line) catches up with the development of the true path (dotted line) in every quarter. This results in depreciating shocks between three to six percent.

32. The IRFs to a positive standard deviation shock in interest rates are presented in Figure 13. Given that our VAR model is a linear model, the path of a negative interest rate shock is the mere mirror image of the positive shock.

33. Compared to projections of the CNB the chosen exchange rate path in the counterfactual is slightly conservative. Before the initiation of the policy the central bank expected a baseline scenario of the NER well below 25.5 CZK/EUR if interest rates would remain at their zero lower bound level (Franta, Holub et al. 2014).

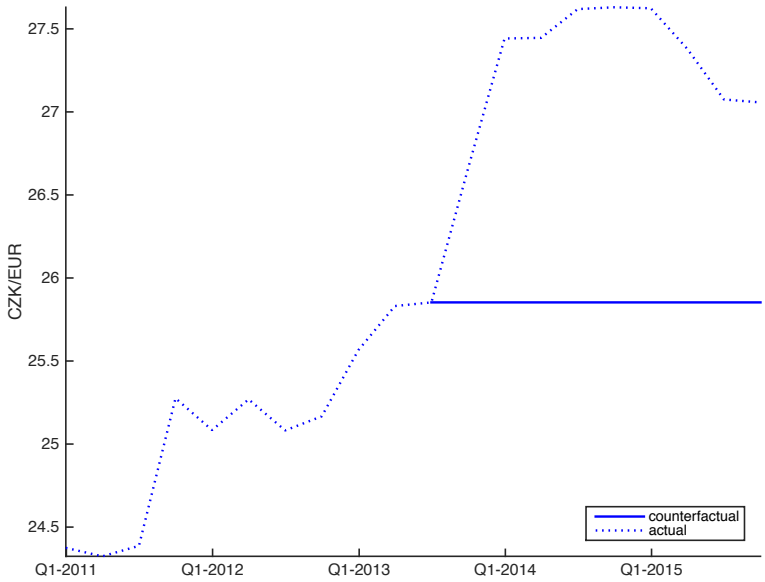

Figure 6: Alternative Nominal Exchange Rate Path (2011 to 2015)

Source: Own calculations; European Central Bank 2016a

8.3 Counterfactual Analysis for Inflation and GDP growth

The counterfactual and the real path of both inflation and GDP are shown in Figure 7 and Figure 8 respectively. We can observe clear differences in the paths of realised and counterfactual development of inflation and a small but significant effect on GDP growth.[34]

With regard to the price development the counterfactual develops below the realised path in all quarters. During the year 2014 the economy would have experienced three quarters of deflation with only the third quarter having slightly positive price growth on a year-on-year basis. Over the course of 2015 the deflationary development would have reached its climax with less than -0.8 percent price growth in the first quarter of 2015. The difference between counterfactual and realised scenario equals about 0.9 percentage points. For the last periods of 2015 this gap narrows down slightly. However, the counterfactual path still lies in deflationary territory. The observation that the effect on inflation is realised quickly corresponds to a rather quick pass-through from exchange rate shocks on prices in the Czech Republic (Babecká-Kucharýuková 2009).

34. For both variables the real path and counterfactual path are equal in the first quarter, which is due to the fact that based on our identification of the Cholesky matrix outlined in equation (11) exchange rate shocks do not transmit contemporaneously to other variables.

Figure 7: Counterfactual Development of year-over-year HICP Inflation (2013 to 2015)

Source: Own calculations; Eurostat (2016)

Turning to the alternative path of real GDP growth pictured in Figure 8 we find that in a world without the exchange rate policy, the Czech output growth would have developed slightly below the observed path. The total difference in GDP growth over the nine quarters amounts to 0.44 percentage points. Looking at the year 2015, GDP in the counterfactual would have been 187 million EUR below that in the observed scenario. This translates into 0.11 percent lower GDP in the counterfactual. While the effect from the policy on GDP growth is less pronounced than for inflation it is still significant.

The effect on GDP growth from the exchange rate depreciation is rather small (see Figure 13). This can be explained by the fact that while exports are enhanced, prices of imports are raised and thus consumption of these goods is lowered. These effects seem to counteract each other, leading to only a very small effect on output growth from the depreciation. The magnitude of the GDP effect we observe in the counterfactual is caused by the fact that we limit movement in the interest rate since it resides at the zero lower bound. As can be seen from the impulse response to an interest rate shock (see Figure 14), restricting deviation in interest rate significantly stimulates GDP growth.

Figure 8: Counterfactual Development of year-over-year Real GDP Growth (2013 to 2015)

Source: Own calculations; Eurostat (2016)

8.4 Robustness

8.4.1 Robustness with Respect to Varying Sub-Sample

In order to take into account possible parameter instability of our VAR model we consider a different sub-sample. This can serve as an approximate check of structural breaks in the data. However, due to the fact that restricting the sample also reduces the data points, the estimates might loose precision. Thus, we primarily consider the here obtained results as a qualitative comparison. Particularly, breaks might have occurred during the financial crisis of 2008 and its aftermath. We therefore shorten the estimation sample to 2008q2, which equals a total of 38 data observations. We use the baseline model specification of two lags for the estimation. The VAR model is subject to stability and the null hypothesis of no remaining autocorrelation cannot be rejected at conventional significance levels. The counterfactual for inflation and GDP growth as well as the underlying IRFs are presented in Section A.6. Looking at inflation (Figure 15) we can confirm the results obtained in the baseline analysis. Again, the alternative scenario suggests that the Czech Republic would have experienced strong deflation in the absence of the policy. Considering the path of real GDP growth, the robustness check confirms that the policy did not benefit GDP strongly. The sub-sample estimates suggest that a depreciation reduces GDP. This could be due to lower precision of the estimates. However, a previous analysis on exchange rate shocks and their effect on output for the Czech Republic equally finds that a depreciation of the exchange rate causes output to fall (Franta, Horvath and Rusnak 2014). This points at the fact that a depreciation has ambiguous effects for GDP growth. To sum up, we can confirm robustness of our results.

8.4.2 Robustness with Respect to the Price Measure

Since the relationship between the exchange rate and price development presents the essence of our counterfactual we want to check whether this relationship is robust to using a different price measure. An alternative measure of price growth that we employ is the growth rate of the GDP deflator π_t^{GDP}. We obtain the deflator through division of nominal and real GDP and subsequently compute the annualised quarterly growth rate:

$$\pi_t^{GDP} = 400 * ln(P_t^{GDP}/P_{t-1}^{GDP}) \quad \text{where} \quad P_t^{GDP} = GDP_t^{nom}/GDP_t^{real} \tag{16}$$

For the VAR model estimation we use π_t^{GDP} instead of HICP inflation for both the Czech Republic and the Euro Area. Before estimating, the growth rate is again demeaned with the inflation target of 2 percent. Again, we can confirm stability of the VAR model and LM-test on remaining serial autocorrelation suggests that there is no correlation left in our error terms.

Naturally, exchanging the price measure will lead to a different counterfactual scenario. Therefore, we limit this robustness analysis to the study of the IRF to an exchange rate shock when comparing it to the one of our baseline model. The graph presented in Figure 18 shows that when using the GDP deflator instead of HICP inflation a depreciating shock to the exchange rate leads to an increase in prices. For the GDP deflator a 50 percent smaller exchange rate shock causes a comparable effect on prices. This is not surprising since the deflator comprises a wider range of prices than the consumer price index. For example, it includes import prices, which are most directly affected by changes in the exchange rate. Thus, the model appears to robustly establish the relationship between price and exchange rate growth.

9. Results

9.1 Research Question (a)

The study of the impulse response behaviour for the Czech Republic shows that in normal times the exchange rate depreciates strongly in response to an exogenous output shock. In reference to the UIP condition, this exchange rate depreciation is enabled by the fact that the CNB lowers interest rates more persistently than the ECB. Hence, the exchange rate provides additional monetary easing.

However, in times where the central bank has no further or only limited room for lowering interest rates the exchange rate response is severely hampered. Given the possibility of monetary easing abroad, the interest rate differential results in appreciative pressure on the exchange rate. Thus, the ability to absorb shocks is constraint in two ways: first, easing is constrained by lacking room for downward manoeuvre in the interest rate. Second, since the interest rate is constraint there is no automatic depreciation. These observations provide evidence for the need for additional forms of policy stimulus.

9.2 Research Question (b)

The results of the counterfactual scenario provide evidence for the effectiveness of the exchange rate policy in lifting inflation. Based on our counterfactual path for inflation the Czech Republic would have experienced several quarters of strong deflation of up to -0.85 percent in the absence of the policy: an effect of almost 0.9 percentage points. These findings suggest that the exchange rate targeting policy has proved to be effective for the Czech Republic in increasing inflation. Further, the effect of the policy on GDP growth is significant. Overall, GDP growth was 0.44 percentage points higher than in the absence of the policy.

9.3 Limitations

While VAR models are a widely used tool for monetary policy analysis and evaluation, several limitations to our results should be discussed. First, our VAR model does not allow for dynamic habit formation of economic agents. This is especially relevant in the counterfactual analysis. Here, the depreciating shocks have the same impulse scope on the economy in every quarter. Thus, we assume to surprise economic agents to the same extent in every period. However, it could be assumed that the extent by which the exchange rate shocks transmit to the economy might change with time as agents anticipate the shocks.

Second, our analysis assumes linear relationships between the variables. However, for example in periods of deflation the relationship between the variables might change, since anticipating a lower price level in future periods changes agents' behaviour. This becomes relevant when constructing the counterfactual where our results suggest the economy would have entered deflationary territory. Yet, the change from positive to negative price growth should have a more drastic effect on GDP than our counterfactual suggests. Since the VAR model assumes a linear relation between the variables, it cannot account for non-linearity that occurs at negative price growth.

Third, as discussed earlier, pass-through of exchange rate changes to prices is enhanced at the zero lower bound. In our model, however, we assume exchange rate shocks to transmit at the zero lower bound like in normal times: since our data includes mostly non zero lower bound observations this is not captured in the impulse response behaviour. Also, the linear model is unable to distinguish between the case of normal times and the zero lower bound. Thus, our results might underestimate the effect of the policy slightly.

Furthermore, the relatively simple VAR model we employ assumes parameter stability throughout time. However, the Czech Republic joined the European Union and entered the stage of being classified as developed economy within our data set. The former incident might have changed the economic relationship between the Euro Area and the Czech Republic for example through closer trade ties. The latter suggests that the economy was still transforming during our sample estimation and thus the relationship among the Czech variables might have changed over time. This possible parameter change is not accounted for in the estimation of our analysis. This shortcoming could be addressed by estimating a VAR model with time varying parameters. However, given our small sample size this would result in very few degrees of freedom.

For the counterfactual exchange rate path the constant level we assume presents a strongly simplifying assumption. The fact that the euro strongly depreciated during the counterfactual period could for have lead to an appreciation of the euro/koruna exchange rate. Since the results for the effectiveness of the policy depend on this path other exchange rate assumptions will lead to differing results. However, any such construction underlies high levels of uncertainty, which is why we decided to avoid further assumptions.

9.4 Comparison of Results with the CNB's Analyses

Franta, Holub et al. (2014) present the evolution of GDP and inflation in absence of the policy that was expected by the CNB prior to policy initiation. The CNB forecasted two consecutive quarters of deflation in the case of passive monetary policy without exchange rate targeting and expected to reach positive price growth thereafter. Using nine additional quarters of data, our analysis confirms a deflationary scenario. Yet, our results show a more drastic path of prolonged deflation. This difference in results, however, is not unexpected. As shown in Appendix A.1, the oil price decline throughout 2015, while being positive for GDP growth, decreased overall inflation levels. This slump was unanticipated by the CNB prior to the policy initiation.

In mid 2015, *Lízal and Schwarz (2015)* document the effectiveness of the policy with the same DSGE model as Franta, Holub et al. (2014). By constructing a policy-free scenario, they find that the Czech economy would have faced deflation throughout all of 2014 reaching up to -2 percent. While this is a more drastic scenario than the one in our analysis, it shares the same tendency. Also, for GDP growth they find a significantly lower development in the absence of the policy. In their results the effect is stronger as they estimate the counterfactual GDP growth to develop almost 2 percentage points below the realised path. Using a DSGE model, the CNB is likely to better account for disproportional effects at times of deflation.

10. Discussion

10.1 Lessons from the Czech Case

While we find that exchange rate targeting brought significant monetary easing to the Czech economy, our analysis does not focus on providing insights on the reasons for this. In the following, we describe the specific conditions observed in the Czech Republic and discuss how they potentially played a role for the effectiveness of the policy.

First of all, the CNB has gained significant credibility following the privatisation of the banking sector, the compliance with EU regulations and an ambitious transparency initiative. Supposedly, this credibility limits the amount of foreign exchange interventions necessary to sustain the peg and suppresses appreciating pressure. Initially, the policy caught many economic agents by surprise and was not unanimously positively received (see e.g. Carney 2013; Strauss 2016; Bardsley 2013). At the same time, professionals agreed that the CNB's credibility is sufficient in order to conduct the announced policy effectively. The media

interpreted the move as a sign for rising prices[35], in line with the CNB's intention. From the start, this perception of the policy helped to anchor inflation expectations sufficiently far from deflation in order to enforce a pass-through of the policy to inflation. The CNB's focus on credibility was supported by the peg being bilateral. While a peg with a portfolio of currencies of trade partners is also a possible option, opting for the bilateral approach is more transparent and thus more comprehensive for the general public. This decision possibly enhanced the level of accountability, which again strengthened credibility and thus the policy's effectiveness.

A second crucial factor regarding the policy's effectiveness is the Czech Republic's outstanding openness. Being amongst the world's most trade open economies makes the country a highly suitable candidate for exchange rate based monetary policies. A strong pass-through of exchange rate changes to prices sets the stage for efficient monetary policy.

Third, the CNB decided to depreciate the koruna to 27 CZK/EUR. This step was crucial, as our counterfactual analysis shows: had the CNB initiated a peg without the depreciation, the Czech Republic would have faced several periods of deflation. Simply introducing an exchange rate floor, as it was done by the Swiss National Bank, would not have been effective enough for the CNB.

10.2 Benefits and Drawbacks of Exchange Rate Targeting

First of all, the transmission of the policy to real variables is relatively effective. As Alichi et al. (2015) note, exchange rate targeting has much clearer linkages from central bank policy actions to real economic variables than other unconventional monetary policy tools. Accordingly, it should be more effective in achieving the central bank's goal.

Also, exchange rate targeting is effective even if a country has an abundance of liquidity. While excess liquidity makes other tools like quantitative easing relatively ineffective since they focus on injecting additional liquidity to the market, exchange rate targeting is a potent tool for these countries (Lízal and Schwarz 2015).

Bernanke, Reinhart and Sack (2004) note a clear benefit of exchange rate targeting: a commitment in terms of the exchange rate is verifiable and easy to understand for the general public since the central bank's announcement can be accompanied by an immediate and visible change in the exchange rate through foreign exchange interventions. For many other unconventional monetary policies this is not the case. This results in a high level of credibility, which shapes expectations that are crucial for the working of the policy. Credibility-enhancing is also that there is no limit to foreign exchange interventions in case large transactions become necessary.

On the other hand, however, very high amounts of foreign exchange interventions that might be required in order to counteract appreciating pressure, blow up a central bank's balance sheet. While the central bank's goal of price stability is not negatively affected by that, holding excessive reserves expose a central bank to foreign exchange risks that need to be managed. If the domestic currency appreciates at a later point in time, assets

35. The Prague Post titles, for example "Czech Prices to rise due to forex intervention" (Bardsley 2013).

denominated in foreign currencies have to be revalued, which would cause financial losses for the central bank (Lízal and Schwarz 2013). Even though a loss of a central bank has no real economic consequences, it could impair credibility. Also, a large balance sheet of the central bank provides the banking sector with a structural liquidity surplus if interventions remain unsterilised (Basu and Varoudakis 2013).

Another drawback is referred to as the "Beggar-Thy-Neighbour Effect" (Coenen and Wieland 2003). To some extent, depending on the size of the economy, exchange rate targeting policies require the cooperation of the country's main trading partners that must allow the central bank to actually devalue the currency. Since spillovers might occur, the implementation of such a policy must be carefully designed and politically supported. Alichi et al. (2015) describe this as a key concern about Svensson's proposal. They voice the criticism that when employed in the context of a global crisis by a relatively large economy, it could hurt other countries through a relative appreciation of their currency. As Stevens[36] comments on Svensson's (2001) study, the approach is suitable for small open economies, yet, its functionality is debatable for others. These relative effects between countries is also the reason why exchange rate targeting will always have to remain a tool for a minority of countries: since it relies on a relative effect between economies, it would become ineffective if applied by a large number of central banks.

Further resistance to such a policy might come from international investors: a depreciation of the domestic currency might be difficult to pursue if the country has a strong external position.[37] In this case, the depreciation would affect the wealth of agents outside of the domestic country, which might cause criticism. Aiming at fostering global monetary cooperation, the IMF names this as a major counter-argument for the implementation of exchange rate based policies. Another group that is negatively affected and might oppose the policy are importing firms since prices of imports are increased in case of a depreciation.

10.3 Discussion of External Validity

Our analysis shows how beneficial the exchange rate targeting approach has been for the Czech economy, which leads us to the discussion if it should be added to the monetary policy toolkit in more general terms. While it being "foolproof" is a bold statement, its application appears indeed relatively straight forward and contains multiple benefits over other unconventional monetary policies. Nevertheless, lessons for other countries will need to be drawn carefully. Therefore, we want to discuss several factors that are relevant for the effectiveness of such a policy.

First of all, *credibility* is an essential factor. As discussed above, few other central banks enjoy the same credibility as the Czech National Bank (Alichi et al. 2015). It is crucial to succeeding in changing expectations and thus limiting the amount of necessary foreign exchange interventions to support the policy. Furthermore, transparency and thus credibility is supported if the peg can be established bilaterally, i.e. if the economy has a major trading

36. This comment is part of the NBER version of Svensson's (2001) publication.

37. External or cross-border positions are "asset and liability positions vis-à-vis banks and non-banks located in a country other than the country of residence of the reporting bank" (OECD 2001).

partner. Thus, for example, small European countries outside the Euro Area appear eligible to apply such a policy.

Second, a high level of *openness* is supportive. In a very open economy, the exchange rate is more potent, as the effects of depreciation on demand, inflation and expected inflation are enhanced. This was also the centre of discussion when exchange rate targeting was considered to guide Japan out of its liquidity trap. Japan's trade share of GDP was low by the standards of OECD countries and thus the effectiveness of such a policy was doubted.

Third, the policy is best applicable in *small* economies. While an application of the policy in a relatively small economy like the Czech has little to no effect on the larger neighbour, a currency depreciation in a relatively large economy clearly affects the smaller neighbours. Sceptics of Svensson (2001) argue that, especially in the short term, the currency devaluation affects the patterns of trade. The economy benefits from weakening the economies of their trade partners. Svensson, however, retorts that growth in domestic demand would create second-round effects that ultimately raise imports, offsetting the terms-of-trade effects created by the devaluation. Whether these effects would be realised early enough to prevent political tension is difficult to judge (Bernanke, Reinhart and Sack 2004). In 2004, Svensson extends his initial argument and states that by cooperation, the negative external effects of such a policy could be mitigated. He is convinced that exchange rate targeting is well applicable for small as well as large economies. While this debate remains unsettled and the answer depends on the exact case it is applied to, concerns about beggar-thy-neighbour effects are clearly less prevalent in smaller economies.

Fourth, the country needs to be in a position to purchase theoretically unlimited amounts of foreign reserves. This potentially excludes countries like, for example, Chile (which also resides at the zero lower bound) from applying such a policy: it has been regularly noted by the IMF that Chile's amounts of foreign reserves are already at a worryingly high level and should thus be reduced rather than build up (IMF 2015b).

Overall, however, external validity remains relatively limited with regards to other economies. While the Czech case shows that exchange rate targeting can clearly be effective and beneficial, a detailed individual assessment will always be required since the success depends on country-specific (liquidity, amount of foreign exchange reserves, trade structure, production basket, level of zero lower bound etc.) as well as time-related factors (economic development in trade economies etc.).

10.4 The Case of Sweden

Lars Svensson has, already several years back, mentioned *Sweden* as a suitable candidate for his proposed policy. The Bank Board of the Swedish Riksbank of which Lars Svensson was the Deputy Governor at that time had already discussed Svensson's "foolproof way" in 2009[38] and considered it a valid option. However, the policy rate had at that point not reached its lower limit and the policy step was thus not put into practice. Since then, the Swedish central bank has continued lowering its main policy rate significantly and started employing

38. Minutes of Monetary Policy Meeting February 2009.

quantitative easing.[39] By now, however, Sweden has reached one of the lowest interest rate levels of all economies at -0.5 percent (Swedish Riksbank 2016a) and the quantitative easing program has been applied relatively extensively (purchases will amount to SEK 245 billion in total by the end of 2016; Swedish Riksbank 2016c). Thus, the board started to discuss exchange rate based policies again.[40]

In multiple recent bank board meetings, the Riksbank made clear that if global monetary policy becomes even more expansionary, the Swedish krona would be at risk to appreciate faster than forecasted, which would make it harder to reach the inflation target of 2 percent. It also stated that it is ready to instantly intervene in the foreign exchange market if that becomes necessary. However, the bank board also notes that it has no target for the exchange rate. At the same time, the krona's value in relation to other currencies is an important factor in the inflation forecast (Swedish Riksbank 2016b). Martin (2016) describe that the strong currency is making it harder and harder to reach the two percent annual inflation target of the Swedish Riksbank. However, Deputy Governor Martin Flodén entered a reservation against the decision to use any sort of exchange rate based policies. He is does not consider currency interventions to be a suitable tool to make monetary policy more expansionary in the current situation (Swedish Riksbank 2016b). This stance is in line with the opinion of the IMF who states that due to Sweden's strong external position it should restrain from exchange rate based policies (IMF 2015d).

Sweden is a small, open economy whose central bank enjoys strong credibility. With the Euro Area being a significant trade partner, a bilateral peg with the euro could theoretically be transparently installed. Taking all this into account, exchange rate targeting appears to be a suitable tool for Sweden. However, we refrain from giving a recommendation on this issue since it is a highly complex and politically sensitive decision that needs to be analysed in depth.

10.5 Academic Outlook

The time frame of the Czech policy is still limited and a final judgement over success or failure of the policy can only be drawn once the inflation target is reached and the CNB decides to exit the exchange rate peg. Preliminarily, however, the policy can be deemed successful: deflation was averted and inflation seems to be slowly moving back to target. Yet, further costs and benefits need to be taken into account to provide a global assessment. While these factors are not the focus of the central bank, they are still relevant as they may cause political resistance as the case of Switzerland has demonstrated. This final evaluation, however, will only be possible at a later point.

Furthermore, the policy might not yet have shown its full potential. While the ECB might intend to pursue further monetary easing and possibly has not even reached the zero lower bound (Steenis 2016), the exchange rate targeting approach might be valuable for an

39. A major difference between the Czech Republic and Sweden is the fact that the Czech Republic has a high level of liquidity, which Sweden does not, which is why quantitative easing is a more effective option for the Swedish Riksbank as compared to the CNB.

40. Note: Svensson has left the bank board of the Riksbank by now.

extended period.

The exit from such a policy is crucial for the overall outcome (Borio and Disyatat 2010). The importance of the exit approach has been shown, for example, by the case of Switzerland. In the case of the Czech Republic, an early exit might come as a surprise to economic agents while a delayed one might raise questions about policy objectives. The CNB has tried to address this issue by being state- and time specific about their exit strategy. The CNB, however, assumes that even beyond the exit from the policy, it has an easing effect on monetary conditions. It assumes that any appreciation following the discontinuation of the commitment would be dampened by hedging of exchange rate risk by exporters during the existence of the commitment (CNB 2016i). Also, it argues that the weaker exchange rate of the koruna was in the meantime passing through to domestic prices and other nominal variables and thus a sudden appreciation post exit is not to be expected. This, however, remains speculation and a final analysis will have to be postponed further.

Finally, room for research remains with regards to the applicability in other economies. A sensible step for researchers as well as central bankers would be to determine, which other economies could benefit from such a policy.

11. Conclusion

In reference to our overarching research question, the Czech case confirms that exchange rate targeting is an effective monetary policy tool for economies at the zero lower bound. In Section 8, we find that an exchange rate depreciation is crucial for monetary easing. While such a depreciation happens automatically in normal times, it needs to be artificially induced at the zero lower bound. In Section 9, we find that the exchange rate targeting framework the CNB applied has been effective in averting inflation. At the same time, it appears to have a small but significant effect on GDP growth.

We conclude that for a small open economy whose central bank enjoys high levels of credibility, a depreciation of the currency followed by a one-sided exchange rate peg has the power of lifting inflation. It should thus be considered as a monetary policy toolkit of central banks at the zero lower bound.

12. Summary

In 2012, the Czech Republic reached its zero lower bound on interest rates. Since inflation remained subdued, the Czech National Bank was under pressure to employ further monetary easing. In November 2013, it decided to depreciate the Czech koruna to a fixed exchange rate level of 27 CZK/EUR and declared that it was determined to keep it at that level until the inflation target is reached. The one-sided peg is supported by foreign exchange interventions. Through this strategy, the CNB was the first central bank that translated a theoretical approach, designed by Svensson (2001), into practice.

We set out our study in order to analyse whether we can determine, based on the case of the Czech Republic, if exchange rate targeting is an effective monetary policy tool. We

do so by first looking at the behaviour of the exchange rate in response to foreign output shocks and find that the exchange rate depreciates, creating a significant monetary easing effect. We show that this effect is impaired by the zero lower bound. Thus, we find that while a depreciation is effectively easing monetary conditions, it needs to happen artificially now since the standard mechanism has become ineffective.

Second, we define a counterfactual scenario of the Czech variables for the period since the CNB initiated the policy. We find that the exchange rate targeting approach was the key element in averting severe deflation during that period. As was feared at the time of the policy initiation, the Czech economy would have faced prolonged periods of deflation. It would have entered a deflation in mid 2014 and would not have been able to escape it before the end of 2015. Deflation could have reached up to almost 0.9 percent in the first quarter of 2015. It also would have had to compromise on GDP growth. While a final judgements about the success of the policy will have to be postponed until after the CNB exits the peg, the economic outlook as well as the results from our counterfactual are highly promising and let us confirm the policy as being successful.

Thus, we conclude that the Czech case shows that exchange rate targeting as defined by Svensson (2001) is effective in easing monetary policy in an economy that faces the liquidity trap. It should thus be added to the unconventional monetary policy toolkit. Exchange rate based approaches have very clear linkages from monetary policy action to aggregate demand and inflation and are thus highly effective in reaching policy targets. The fact that the Czech Republic is a small and highly open economy and the CNB enjoys high levels of credibility, enhance the effectiveness of the policy and limit the amount of foreign exchange interventions necessary.

At the time of writing, the CNB does not see itself facing a risk of deflation and foreign trade and domestic demand are recovering even faster than initially expected. While the inflation target is not reached and exit from the policy has been delayed, the risky decision of employing a non-proven monetary policy strategy has paid of. While we are careful in formulating concrete recommendations on which central bank should consider applying the strategy, we arrive at some general lessons that might be insightful for other central banks in similar situations and clearly recommend other central banks with similar characteristics to consider it.

Thus, we are able to contribute to the academic field of unconventional monetary policy research that is highly relevant for the global economy at the moment. It might even become more important since researchers assume that the zero lower bound might not be a temporary phenomenon but rather the result of long term structural changes in interest rates and thus be here to stay. This would imply that policies like exchange rate targeting might become even more relevant in the future.

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A. Appendix

A.1 Breakdown of Import Price Development in the Czech Republic

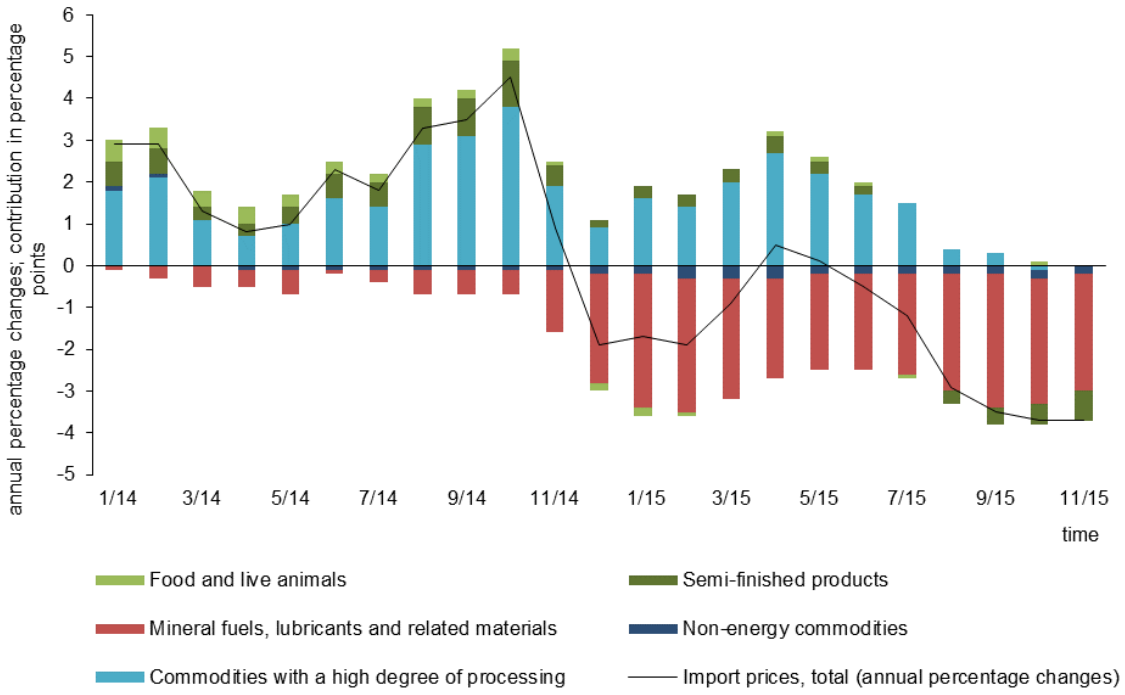

Figure 9: Breakdown of Import Price Development in the Czech Republic (2014 to 2015)

Source: Czech National Bank 2016g

A.2 Uncovered Interest Parity

A.2.1 Concept

The uncovered interest parity describes the link between the expected future exchange rate and the interest rate differential between two countries (see e.g. Iwata and Wu 2006):

$$E_t(s_{t+1}) - s_t = i_t - i_t^* \tag{17}$$

where s_t is the spot exchange rate at time t and i_t and i_t^* are the domestic and foreign interest rates, respectively.[41] If domestic and foreign bonds are perfect substitutes, and international capital is fully mobile, the two bonds can only pay different interest rates if agents expect there will be a compensating movement in the exchange rate in the future. To examine this relationship empirically, one can run the following regression:

$$s_{t+1} - s_t = \alpha + \beta(i_t - i_t^*) + u_t \tag{18}$$

If the UIP holds, $\alpha = 0$ and $\beta = 1$. Whether the UIP holds or not has long been a topic of debate and extensive research. Multiple empirical studies have found significantly negative estimates of β and thus shown that the UIP does not hold (see e.g. Engel 1996; Flood and Rose 2002). This finding is referred to as the forward premium puzzle. Still, the UIP remains a key relation in countless economic models and therefore regularly causes debates between researchers (e.g. Svensson 2001 or Christiano 2000 vs. McCallum 2000).

A.2.2 Uncovered Interest Parity in the Czech Republic

For the case of the Czech Republic, the UIP implies that all other things being equal, an interest-rate increase by the CNB strengthens the koruna relative to the euro. Conversely, an interest-rate reduction of the ECB also strengthens the koruna relative to the euro, leading to an appreciation. Triandafil and Richter (2012) show that in the Czech Republic between 2001 and 2011, the UIP did not hold entirely due to a positive risk premium they associate with high volatility of the exchange rate.[42]

41. In some cases, a risk premium is added to the equation.

42. The increasing level of economic development and decreasing volatility are likely to have improved the holding of the UIP by decreasing the risk premium. Therefore, for our analysis we use a form of the UIP that excludes a risk premium.

A.2.3 Deriving the Infinite Horizon UIP Condition

In order to quantify an exchange rate effect based on the UIP, we need to find a format that bases the exchange rate level on the interest rate differential into infinity. We start with a rearranged form of equation (17):

$$s_t = E_t s_{t+1} - (i_t - i_t^*) \tag{19}$$

We transfer it into the next period and take its expected value:

$$E_t s_{t+1} = E_t s_{t+2} - E_t(i_{t+1} - i_{t+1}^*) \tag{20}$$

When inserting that into equation (19), we get:

$$s_t = E_t s_{t+2} - E_t(i_{t+1} - i_{t+1}^*) - (i_t - i_t^*) \tag{21}$$

Continuing steps (20) and (21), i.e. continuing this process to infinity we can assume that $E_t s_{t+\infty}$ approaches infinity and arrive at equation (14):

$$s_t = -\sum_{i=0}^{\infty} E_t(i_{t+i} - i_{t+i}^*)$$

A.3 Forecast Error Variance Decomposition

FEVD defines the contribution of innovations from all variables in the system to the h-step ahead forecast to one variable j (Lütkepohl 2005). Since the combined share of contributions from all innovations in the system are normalised to one we can draw conclusions about the relative importance of shocks from a variable k for the determinacy of variable j as well as the share of movement in the sequence that is explained by its own shocks e_{jt} (Enders 2010).

The FEVD estimates below are obtained by estimating a VAR model where we allow for mutual influence of all variables i.e. by estimating a combined VAR model with the vector of endogenous variables z_t where the endogenous variables of x_t and y_t of equation (7) and (6) respectively were stacked on each other such that $z_t = [x_t \quad y_t]$. The VAR model was identified using Cholesky decomposition, so we still account for the fact that the Euro Area variables are causally prior to the Czech variables, which is reflected in the specification of the baseline model in equation (6) by including contemporaneous values of Euro Area variables. The VAR model is estimated using two lags according to the specification of the previous models. The sample is equivalent to our previously described estimations. Further, the model specification leads to a stable VAR model.

The results are as follows: for the Czech variables it is obvious that innovations to the Euro Area variables are highly relevant for their evolution. On the other hand, for the Euro Area variables the influence of the Czech variables appears to have negligible effect. Even though this influence increases in time, we do not see a contradiction to the small open economy assumption as in these periods the absolute size of the Czech shocks are statistically no longer different from zero within a 95 percent confidence bands. Based on these observations we do not expect that the specification of the baseline model in equation (6) suffers from significant omitted variables bias that would distort the results of our analysis.

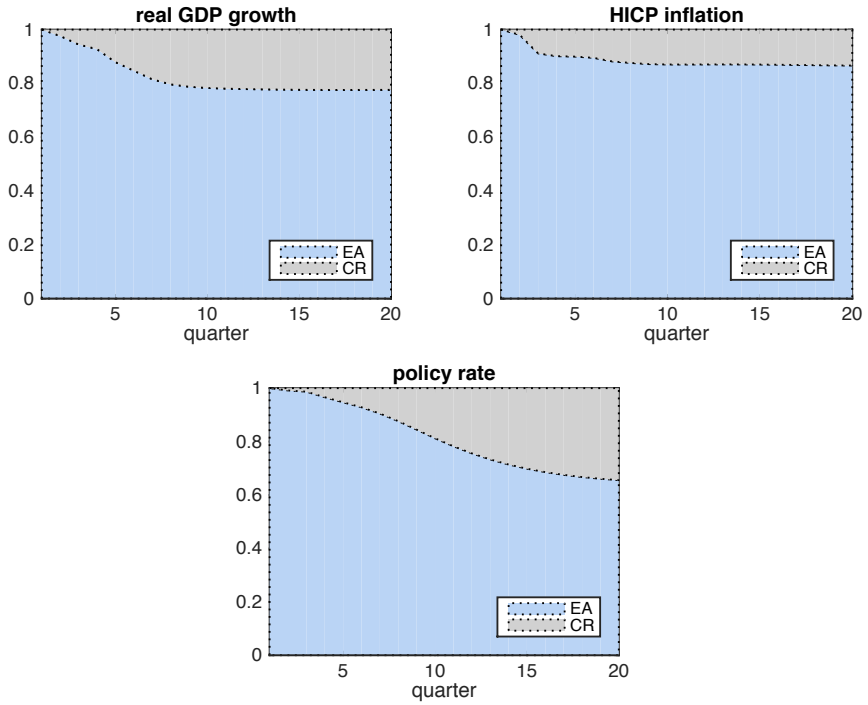

Figure 10: Forecast Error Variance Decomposition for Euro Area Variables

Source: Own calculations

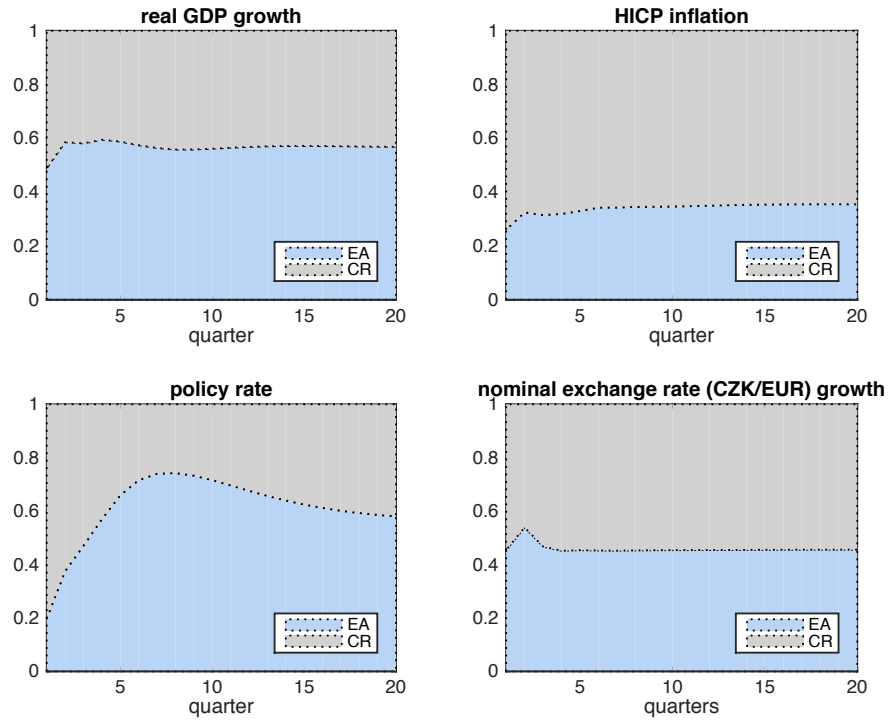

Figure 11: Forecast Error Variance Decomposition for Czech Variables

Source: Own calculations

A.4 Data Overview

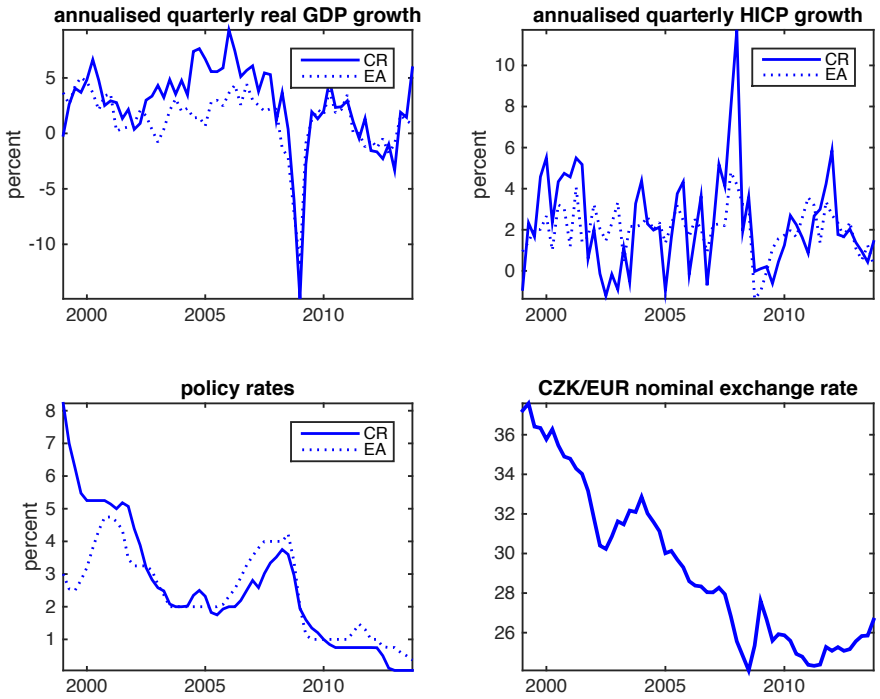

Figure 12: The Underlying Data Series

Source: Eurostat 2016; European Central Bank 2016a; Czech National Bank 2016b

Variable	Variable name	Source	Original variable format	Transformations	Demeaning
Real GDP growth	Δy_{EA}; Δy_{CR}	Eurostat	real GDP in million EUR; seasonally adjusted and adjusted by working days; in quarters; (Euro Area: EA19)	generating annualised quarterly growth rates	by 2.15 percent (historic average of the five-year real GDP growth forecast for the Euro Area from the Survey of Professional Forecasters)
Inflation (HICP growth)	π_{EA}; π_{CR}	Eurostat	monthly HICP, 2005=100 (Euro Area: EA19)	seasonally adjusting using US Census Bureau X12 adjustment program; generating quarterly averages; generating annualised quarterly growth rates	by 2 percent (respective inflation target)
Policy rate	r_{EA}	ECB Statistical Data Warehouse	MRO in percent (by date of decision)	generating quarterly averages	by 3.4 percent (short-term real interest rate of the EA: 1.4 percent + inflation target: 2 percent)
	r_{CR}	CNB	Repo rate in percent (by date of decision)		
Nominal exchange rate growth	Δs	ECB Statistical Data Warehouse	bilateral; quarterly averages; in CZK	annualised quarterly growth rates	not demeaned

Overview of Data and Sources

Note: The data used is the data available when the process of this study was started, i.e. in January 2016.

A.5 Czech Impulse Responses

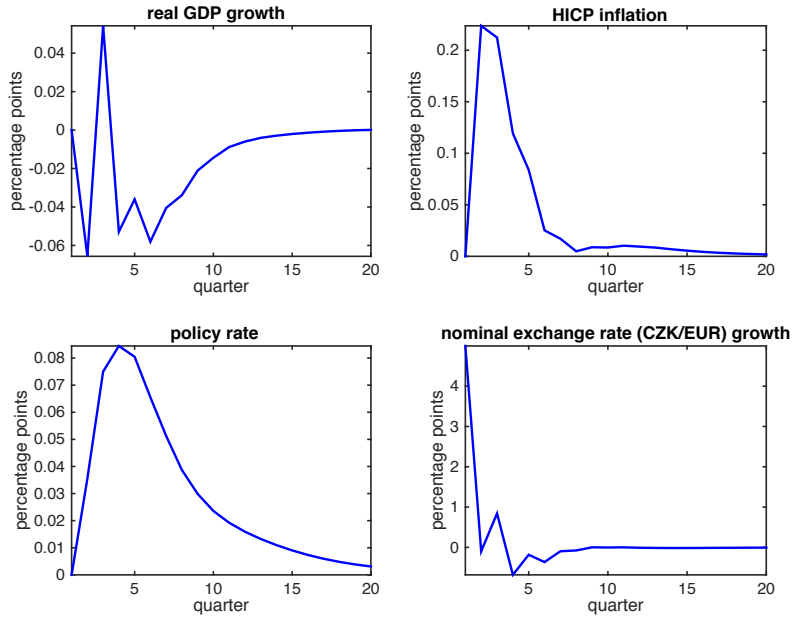

Figure 13: Czech Impulse Responses to Exchange Rate Shock

Note: An increase in the nominal exchange rate equals a depreciation.
Source: Own calculations

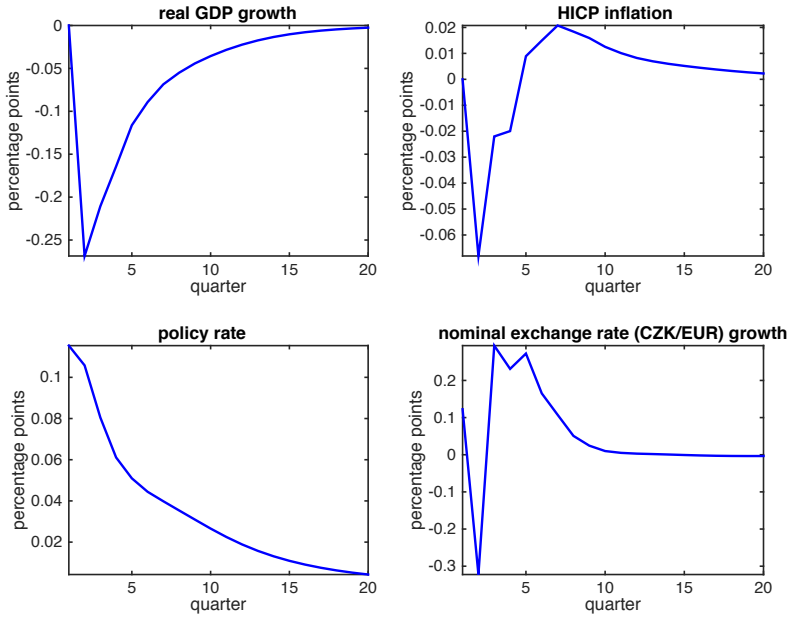

Figure 14: Czech Impulse Responses to Interest Rate Shock

Note: An increase in the nominal exchange rate equals a depreciation.
Source: Own calculations

A.6 Robustness

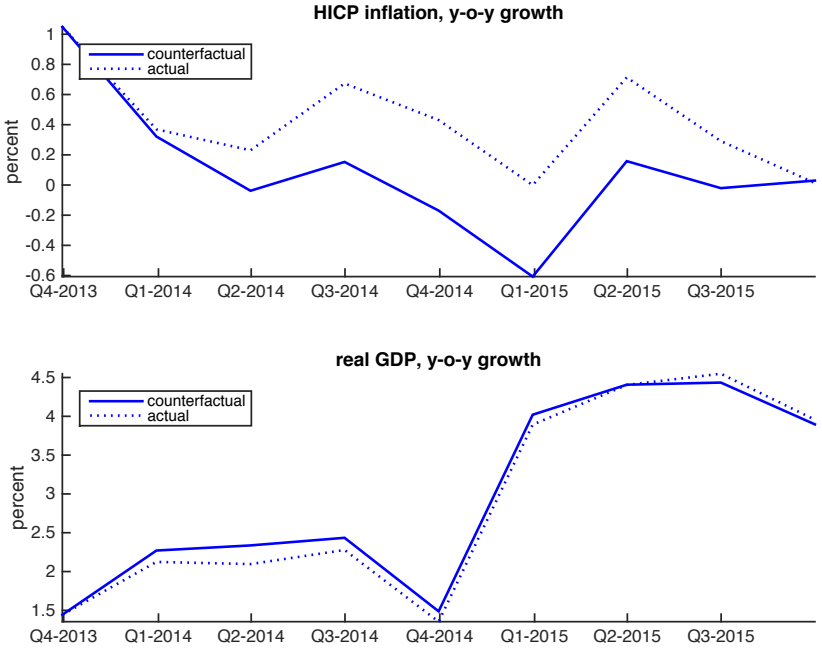

Figure 15: Counterfactual Development, sample 1999 to 2008

Source: Own calculations

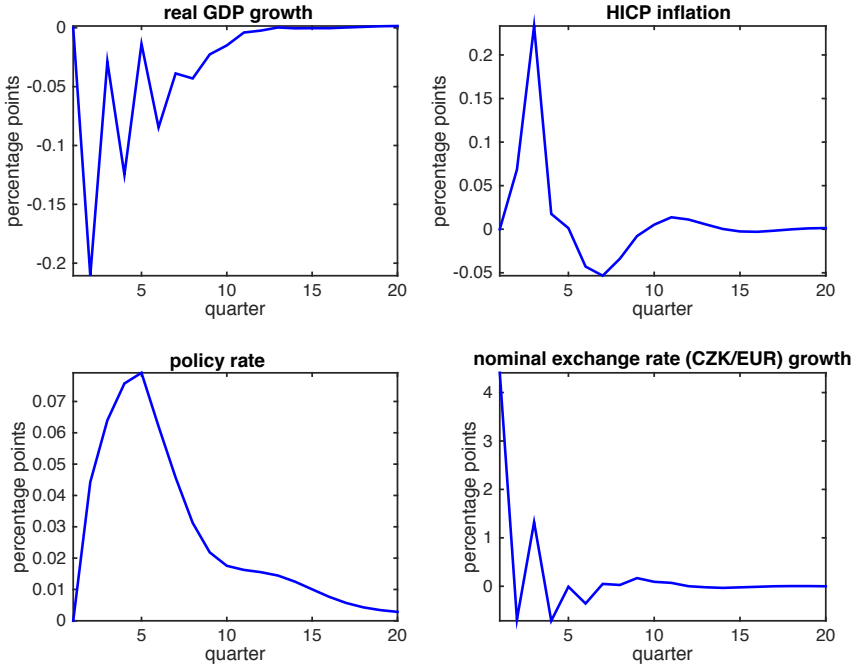

Figure 16: Czech Impulse Responses to Exchange Rate Shock, sample 1999 to 2008

Note: An increase in the nominal exchange rate equals a depreciation.
Source: Own calculations

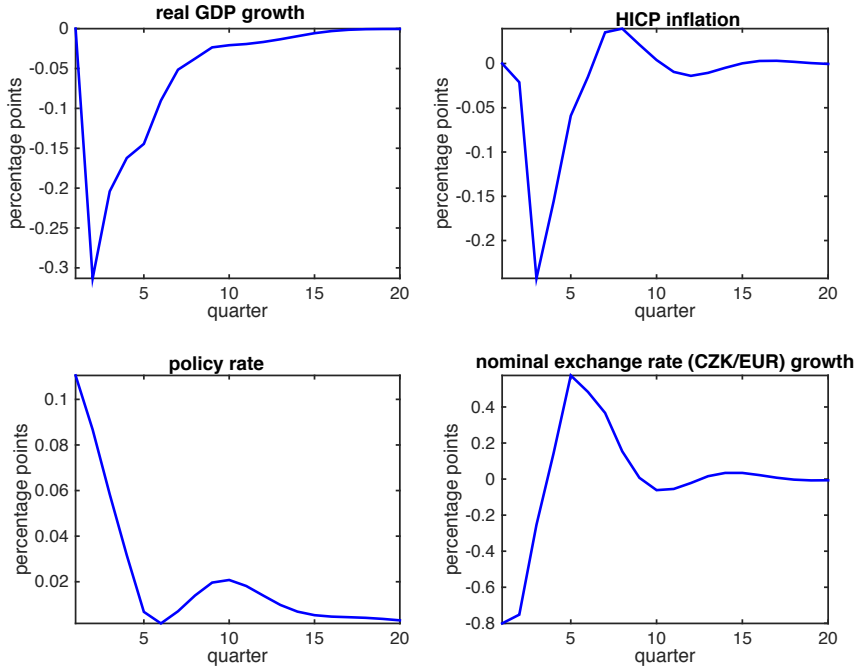

Figure 17: Czech Impulse Responses to Interest Rate Shock, sample 1999 to 2008

Note: An increase in the nominal exchange rate equals a depreciation.
Source: Own calculations

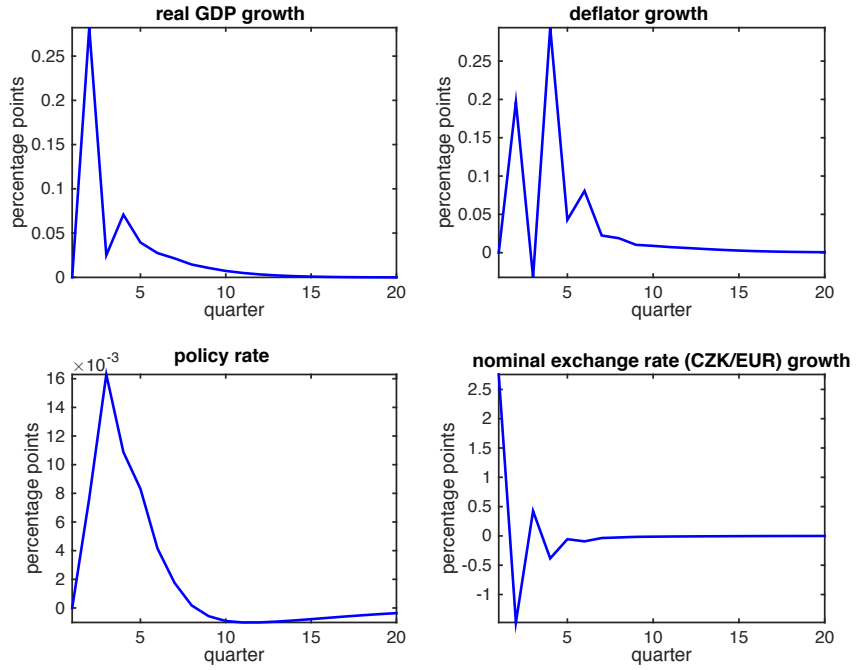

Figure 18: Czech Impulse Responses to Exchange Rate Shock Using GDP Deflator

Note: An increase in the nominal exchange rate equals a depreciation.
Source: Own calculations