WORKING PAPER SERIES 10

2018

Michal Franta, Tomáš Holub, Branislav Saxa

Balance Sheet Implications of the Czech National Bank's Exchange Rate Commitment

CNB CZECH NATIONAL BANK

WORKING PAPER SERIES

Balance Sheet Implications of the Czech National Bank's Exchange Rate Commitment

Michal Franta
Tomáš Holub
Branislav Saxa

10/2018

CNB WORKING PAPER SERIES

The Working Paper Series of the Czech National Bank (CNB) is intended to disseminate the results of the CNB's research projects as well as the other research activities of both the staff of the CNB and collaborating outside contributors, including invited speakers. The Series aims to present original research contributions relevant to central banks. It is refereed internationally. The referee process is managed by the CNB Research Division. The working papers are circulated to stimulate discussion. The views expressed are those of the authors and do not necessarily reflect the official views of the CNB.

Distributed by the Czech National Bank. Available at http://www.cnb.cz.

Reviewed by: Bernd Schlusche (FED)
Jan Vlček (Czech National Bank)

Project Coordinator: Jan Babecký

Balance Sheet Implications of the Czech National Bank's Exchange Rate Commitment

Michal Franta, Tomáš Holub, Branislav Saxa*

Abstract

We present projections of the Czech National Bank's balance sheet after the discontinuation of the exchange rate commitment. Our model addresses the situation of a large central bank balance sheet with assets consisting almost exclusively of foreign exchange reserves in the circumstances of a catching-up economy exhibiting an exchange rate appreciation trend. Apart from the baseline projection, several counter-factual scenarios are discussed. The scenarios concern the evolution of the balance sheet in the cases of no exchange rate commitment and a commitment with earlier discontinuation. The simulated counter-factual duration of negative CNB equity, and thus the period of no profit distribution to the government, does not differ substantially from the baseline. The fiscal implications of the exchange rate commitment are thus estimated to be relatively small and related only to the period after the year 2030. Our stochastic simulations, however, show that the uncertainty bands are very wide. In addition, we show that the simulation tool can be employed to discuss the consequences of a long-run decline in currency in circulation, the composition of the asset side and the resumption of foreign exchange income sales by the central bank.

Abstrakt

Článek prezentuje projekce bilance České národní banky po ukončení kurzového závazku. Použitý model je vhodný pro modelování velké bilance centrální banky s aktivy téměř výhradně ve formě cizoměnových rezerv v prostředí konvergující ekonomiky vykazující trendové posilování kurzu. Kromě základního scénáře je diskutováno i několik srovnávacích scénářů, které se týkají vývoje bilance v případě nezavedení kurzového závazku nebo jeho dřívějšího ukončení. Dle simulací se doba trvání záporného vlastního jmění ČNB, a tedy doba nulových transferů zisků centrální banky vládě, ve srovnávacích scénářích zásadně neliší od základního scénáře. Odhadované fiskální implikace kurzového závazku jsou tedy relativně

* Michal Franta, Czech National Bank, michal.franta@cnb.cz

Tomáš Holub, Czech National Bank and Charles University, tomas.holub@cnb.cz

Branislav Saxa, Czech National Bank, branislav.saxa@cnb.cz

We would like to thank Kamil Galuščák, Dana Hájková, Michal Hlaváček, Bernd Schlusche, Marek Šesták, Jan Vlček and seminar participants at the Slovak Economic Association Meeting 2017 and at the Czech National Bank for valuable comments. We are grateful to Adam Kučera for providing us with term premia estimates for USD and EUR bonds, Martin Motl for sharing with us the data presented in Figure 2 and Jaromír Tonner for counter-factual estimates of the macroeconomic variables without the exchange rate floor. This work was supported by Czech National Bank Research Project No. MP1/18. The opinions expressed in this paper are those of the authors and not necessarily those of the Czech National Bank.

malé a vztahují se až k období po roce 2030. Stochastické simulace nicméně ukazují, že míra nejistoty je výrazná. V článku dále ukazujeme, že může být simulační nástroj využit v diskusích o důsledcích dlouhodobého poklesu oběživa, o skladbě strany aktiv bilance a o obnovení odprodejů výnosů z cizoměnových rezerv centrální bankou.

JEL Codes: E47, E52, E58.

Keywords: Central bank balance sheet, deterministic simulations, stochastic simulations.

Nontechnical Summary

The exchange rate commitment, which was in place from 7 November 2013 until 6 April 2017, led to a substantial increase in the size of the balance sheet of the Czech National Bank (CNB). The rise was a consequence of actions directed towards meeting the inflation target – the CNB's main objective. Although the size of the balance sheet is not a primary concern of the monetary authority, a rich discussion has arisen. The indirect fiscal implications, in the form of a reduction in potential profit transfers from the central bank to the government, lie at the centre of this debate.

This paper provides a quantitative assessment of the balance sheet implications of the CNB's exchange rate commitment. It presents 30-year projections of the CNB's balance sheet after the discontinuation of the commitment. Therefore, long-run issues related to the sustainability of central bank finances are examined.

The literature dealing with projections of central bank balance sheets is scarce and focuses mainly on central banks in advanced economies, which face a qualitatively different situation. In contrast, for example, to the Fed and ECB, the asset side of the CNB's balance sheet comprises almost exclusively foreign exchange reserves. In addition, the Czech economy is a small, open, catching-up economy exhibiting an exchange rate appreciation trend.

We develop a simple model of the CNB's balance sheet that is tailored to the specific situation of the CNB's balance sheet and the Czech economy and that is also relevant to other small open economies in general. Apart from the baseline projection, which represents the most probable evolution of the balance sheet, several counter-factual scenarios are discussed. Two of the scenarios are related to the exchange rate commitment – the absence of the commitment and an earlier exit from the commitment. The other two scenarios simulate the effect of a long-run decline in currency in circulation and the resumption of foreign exchange income sales. It is also shown that the simulation tool can be used to examine the composition of the asset side.

We conclude that in the baseline scenario, the CNB can be expected to stay in negative equity for about two decades, with a peak roughly ten years from now at around 6–7% of GDP. This balance sheet outlook resembles the CNB's previous experience with negative equity, which did not represent any issue for the financial solvency or policy conduct of the central bank. The counter-factual simulations of no exchange rate commitment and earlier discontinuation of the commitment suggest that the central bank's equity would have stayed negative until at least the year 2030 anyway. The fiscal implications of the exchange rate commitment related to the expansion of the central bank's balance sheet thus seem to be relatively small (especially if one also takes into account the other indirect fiscal effects, which are clearly positive) and fairly distant in time.

1. Introduction

This paper focuses on the central bank balance sheet aspect of the Czech National Bank's exchange rate commitment, which was in place as an unconventional monetary policy instrument from 7 November 2013 until 6 April 2017. From one point of view, this is the least important aspect of all. When the commitment was introduced, the Czech National Bank (CNB) made it clear that its balance sheet consequences were seen as being of strictly secondary importance relative to the monetary policy objectives. The central bank has also repeatedly emphasised that its exchange rate losses have no direct fiscal implications in terms of requiring a transfer from the government budget, as the central bank will be able to repay the losses out of its future profits, i.e. it remains solvent in the long run. Such issues have received interest from researchers, who have focused on unconventional monetary policies of major central banks such as the US Fed and the ECB. They have mostly concluded that the risk of central bank insolvency is "real in theory, but remote in practice" (Hall and Reis, 2015), or even "truly negligible" (Cavallo et al., 2018). Nonetheless, it is important to ask if such a conclusion also holds for a CNB-like central bank with assets consisting almost exclusively of foreign exchange reserves in the circumstances of a small, open, catching-up economy exhibiting an exchange rate appreciation trend.

At the same time, the CNB's exchange rate commitment may have indirect fiscal implications in terms of reducing potential profit transfers from the central bank to the government in the future. There seems to be a relatively widespread belief in the Czech Republic outside the central bank that such indirect fiscal costs may be of first-order importance and almost immediate. As a result, the CNB's balance sheet aspect will most probably remain a topic of public debate for a protracted period of time. Indeed, after the exchange rate commitment proved effective in terms of preventing deflation and boosting the economic recovery (see Brůha and Tonner, 2017) and was discontinued in a remarkably smooth manner, the main line of criticism of this publicly unpopular policy (see Franta et al., 2014) has shifted to the fiscal consequences of the CNB's financial losses. These losses originate from the revaluation of its massively increased foreign exchange reserves in a situation of an appreciating exchange rate. Given the size of the reserves and the long-term real equilibrium appreciation trend of the Czech koruna, this phenomenon is likely to persist for an extended period of time. It is necessary for the CNB to be able to address this issue in a quantitative analytical framework.

Therefore, we develop and employ a simple model of the CNB's balance sheet. We follow an approach similar to Cincibuch et al. (2009), but with some important differences in emphasis. The earlier paper focused strongly on central bank balance sheet issues associated with the process of economic convergence towards advanced countries. Currently, those issues remain relevant but are quantitatively less important given the more advanced stage of economic convergence in the Czech Republic and the lower speed of the catching-up process in the post-crisis period. On the other hand, the model of Cincibuch et al. (2009) was very rudimentary in terms of modelling the yields on foreign exchange reserves. In fact, it assumed that all the reserves were allocated in euro and generated earnings equivalent to a one-year government bond. This was a justifiable simplification at that time, given the very conservative FX reserves management strategy followed by the CNB in the 2000s. However, there is currently a need to reflect the ongoing changes in the CNB's reserve management, and we thus model them much more carefully in this paper. Moreover, all the simulations presented in Cincibuch et al. (2009) were deterministic, while we move to stochastic simulations in our paper, showing the wide range of uncertainty

surrounding the baseline projections. In addition to conveying a sense of the uncertainty of the results, stochastic simulations enable probabilistic assessment of various issues (such as the probability of negative equity in a given year) and examination of questions that cannot be examined in the deterministic setting (such as changes in the composition of the FX reserves portfolio).

We conclude that in the baseline scenario, the CNB can be expected to stay in negative equity for about two decades, with a peak roughly ten years from now at around 6–7% of GDP. This situation resembles the CNB's previous experience with negative equity from 1998 until 2013, which did not lead to any solvency issues or difficulties in pursuing appropriate policies. The financial or "policy" solvency of the CNB is thus not endangered (even though the uncertainty bands are very wide according to our stochastic simulations). At the same time, these findings may at first sight suggest non-negligible indirect fiscal implications of the exchange rate commitment. However, the counter-factual simulations of no exchange rate commitment and earlier discontinuation of the commitment show that the central bank's equity would have stayed negative until at least the year 2030 anyway. Given the institutional arrangements, this means that there would probably have been no profit transfers from the CNB to the Czech government in any case until that year. From that point of view, the fiscal implications of the exchange rate commitment related to the expansion of the central bank's balance sheet seem to be relatively small (especially if one also takes into account the other indirect fiscal effects, which are clearly positive) and fairly distant in time. This conclusion is relevant not just to the CNB at present, but in general to all small open economies with central bank balance sheets dominated by foreign exchange reserves that might consider using the exchange rate as an unconventional monetary policy instrument in the future.

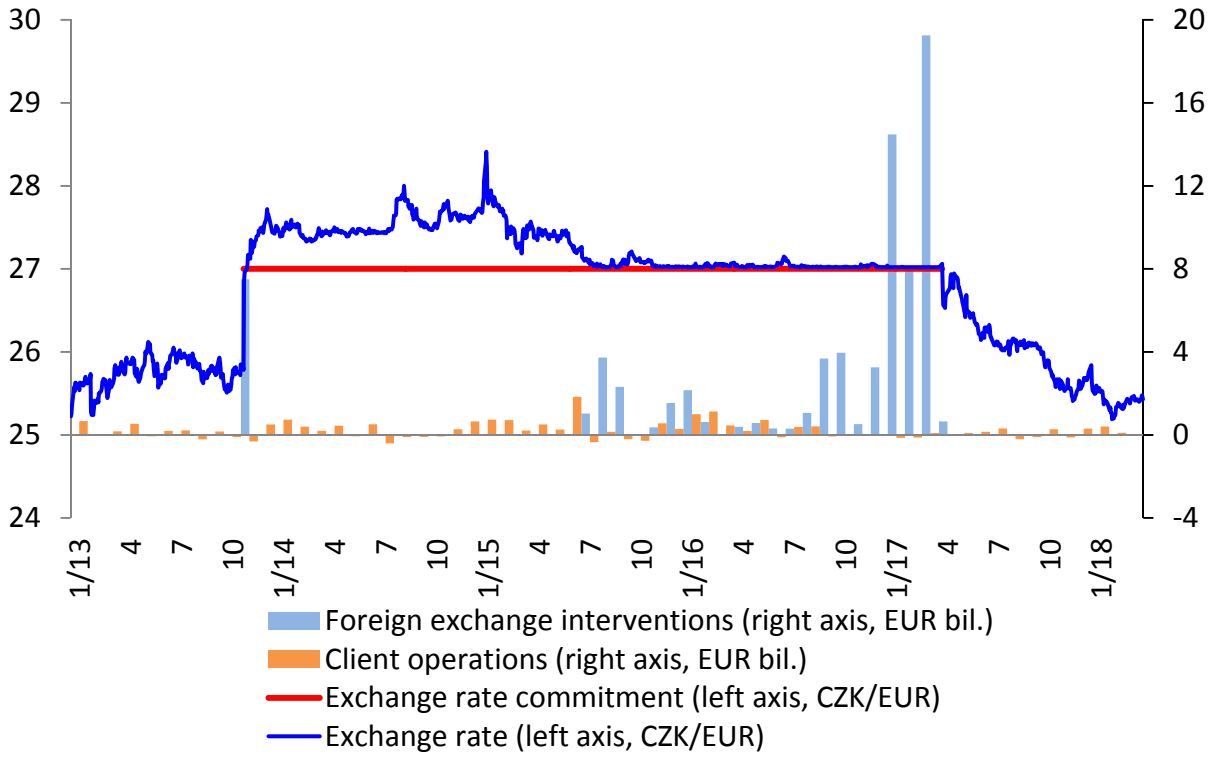
The paper is organised as follows. In section 2 we summarise key stylised facts associated with the balance sheet implications of the CNB's exchange rate commitment. Section 3 develops the balance sheet model. Section 4 provides stochastic simulations of future CNB balance sheet developments. Section 5 uses the framework to simulate several policy scenarios, bringing a quantitative dimension to the recent public debate. Section 6 summarises and concludes. Appendix A presents the macro models applied in the stochastic simulations, while Appendix B compares our results with those based on the Cincibuch et al. (2009) model. Finally, Appendix C presents some additional results and Appendix D provides several notes on the asset side composition.

2. Stylised Facts on the Expansion and Composition of the CNB's Balance Sheet

The CNB introduced its exchange rate commitment on 7 November 2013 in order to avoid deflation and to speed up the return of inflation to the 2% target (Franta et al., 2014). To establish the exchange rate commitment and build its credibility, the CNB had to purchase foreign exchange reserves worth EUR 7.5 billion (Figure 1) during the first few days of the commitment. For the next 19 months, the exchange rate was above the exchange rate "floor", so the CNB did not have to intervene in the foreign exchange market. In this period, the foreign exchange reserves were thus increasing only due to "client operations", related mainly to the drawdown of EU funds. From mid-2015, however, the exchange rate moved close to the announced "floor", influenced by

the quantitative easing of the ECB and continued favourable developments in the domestic economy. The CNB thus had to start intervening whenever needed. The most pronounced wave of interventions then took place in the first quarter of 2017. By then, it was apparent that the exchange rate commitment was coming to an end, and exporting companies were thus hedging against possible future exchange rate appreciation. At the same time, financial investors were building massive long positions in CZK. The exchange rate commitment was discontinued on 6 April 2017, once the CNB Board had concluded that the conditions had been met for sustainable achievement of the 2% inflation target in the future. Altogether, the FX interventions amounted to EUR 75.9 billion between November 2013 and April 2017 (another EUR 11 billion was purchased as part of client operations in the same period). Since the exit, though, there have been no foreign exchange interventions, as the exchange rate developments have been very smooth.

Figure 1: The CNB's FX Operations during the Exchange Rate Commitment



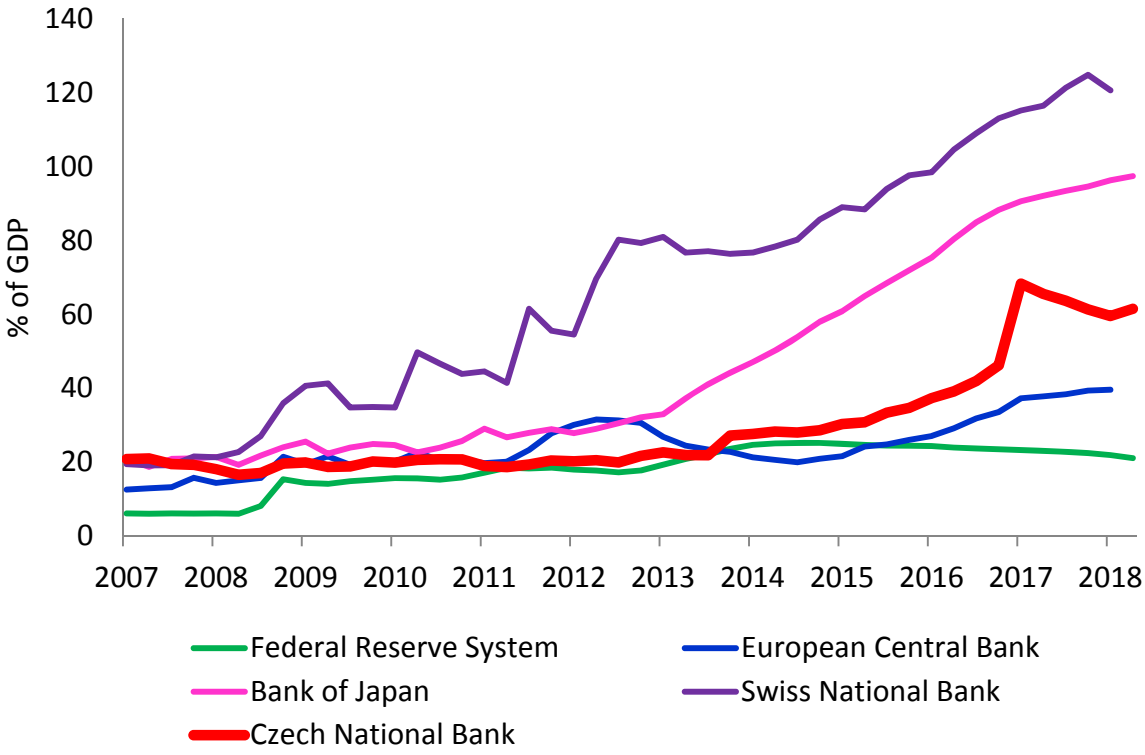
Source: CNB

As a result, the CNB experienced a significant increase in its balance sheet size.[1] Relative to GDP, its balance sheet expansion was more significant than that of the US Fed or the ECB. The most significant difference compared to these two major central banks arose in the first quarter of 2017, when the CNB's foreign exchange reserves jumped rapidly (Figure 2). Among other central banks, only the Swiss National Bank and the Bank of Japan have seen bigger increases in their balance sheet size. Since the exit from the exchange rate commitment, the CNB's balance sheet

[1] Before 2013, the CNB's balance sheet size relative to GDP had been declining from its late-2002 peak, and later stagnating. This was partly due to a programme of selling income on the CNB's FX reserves, which had been in place since 2004. In November 2012, the CNB Bank Board decided to suspend these sales, as the central bank was getting ready for the potential use of the exchange rate as a monetary policy instrument (see Franta et al., 2014). We discuss the balance sheet consequences of the possible future resumption of this programme in section 5.4.

has started to decline gradually in relation to GDP. This reflects the absence of any further foreign interventions, relatively swift nominal GDP growth and a decline in the CZK value of the FX reserves due to exchange rate appreciation.

Figure 2: The Central Bank's Balance Sheet Size in International Comparison



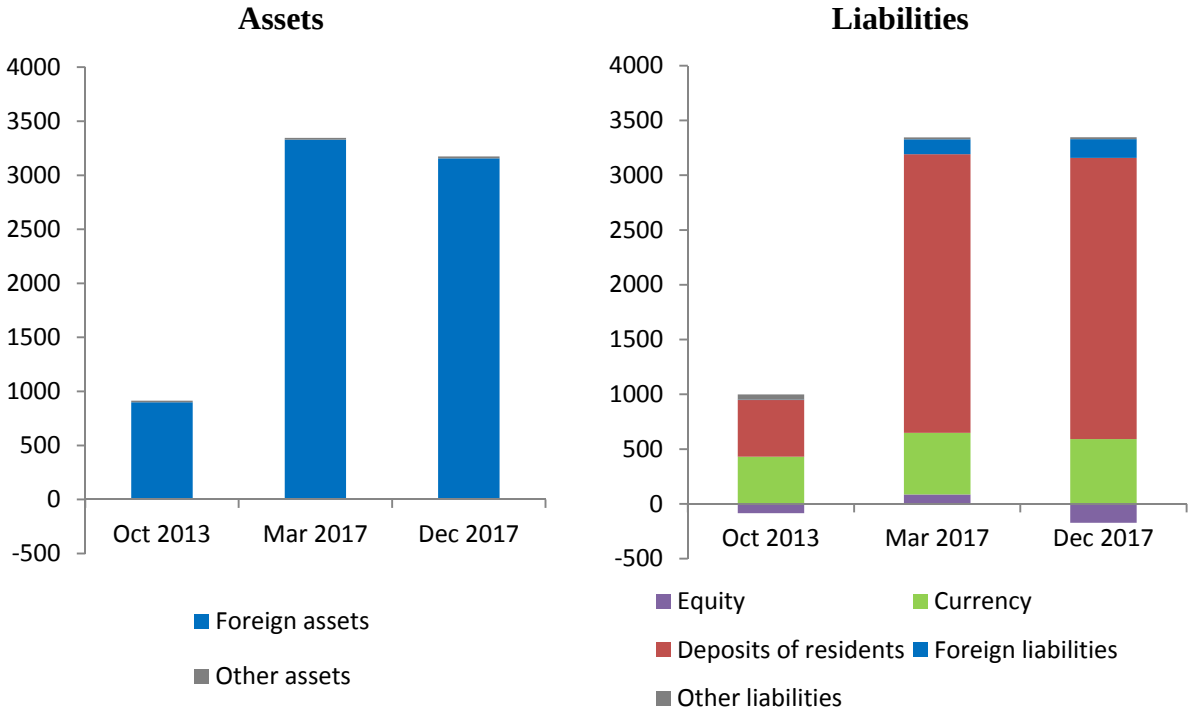
Source: Bloomberg, CNB calculations

As well as changing in size, the CNB's balance sheet has changed in composition, albeit less radically. This can be seen in Figure 3, which compares the central bank's balance sheet before the exchange rate commitment (October 2013) with that immediately before the exit (March 2017) and at the end of 2017. The asset side has remained fully dominated by foreign assets, the bulk of which are composed of the CNB's foreign exchange reserves.[2] The CNB's other assets are negligible. On the liability side, currency issued by the CNB has continued to grow steadily, but most of the increase has been concentrated in deposits of residents. These consist mainly of commercial bank reserves placed at the CNB (which include required reserves, 2W repo operations, the O/N deposit facility and free reserves), as well as government deposits at the central bank. Foreign liabilities have increased, too, but to a much smaller extent than foreign assets, implying significantly increased exposure of the CNB's balance sheet to exchange rate changes. Compared with the situation before the exchange rate commitment, a significantly larger share of the liability side is now interest-bearing, in contrast to the interest-free currency that constitutes the base for the CNB's seigniorage (monetary income). The equity of the CNB was negative before the exchange rate commitment (at CZK -85 billion in October 2013). It turned

[2] The FX reserves were already a dominant part of the CNB's assets before November 2013, reflecting (i) an inflow of foreign capital under the fixed exchange rate regime that had been in place until May 1997, (ii) three waves of foreign exchange interventions in the 1998–2002 period (see Geršl and Holub, 2006), and (iii) purchases of foreign currencies from the government, related initially mainly to privatisation revenues and later on to the drawdown of EU funds.

positive during the commitment period (CZK 86 billion in March 2017), but has moved back into negative territory since then (CZK -172 billion at the end of 2017). The CNB's other liabilities have been very small.

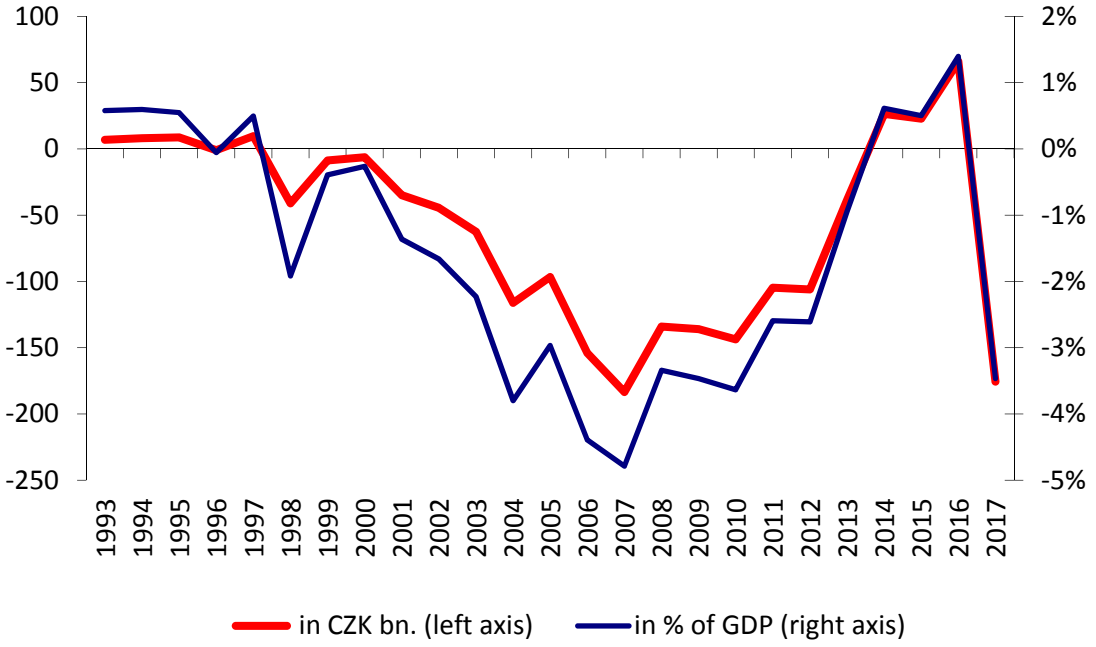
Figure 3: Composition of the CNB's Balance Sheet (in CZK billions)



Source: CNB

As can be seen in Figure 4, the CNB actually had negative equity for 16 years before the exchange rate commitment was introduced, from 1998 until 2013. It peaked at almost CZK -200 billion in 2007, which at that time was equivalent to slightly less than 5% of annual GDP. In the late 1990s, the negative equity was related to the cost of bank bail-outs, which were partly financed by the central bank. Later on, the CNB's losses originated from valuation losses associated with an appreciating trend of the koruna against all major reserve currencies, given the dominance of foreign exchange reserves on the asset side of the CNB's balance sheet and its mark-to-market approach to exchange rate changes (see Cincibuch et al., 2009; Frait and Holub, 2011). The CNB followed a strategy of gradually repaying its accumulated losses out of future profits, as it did not experience any negative impact of negative equity on its policies (Benecká et al., 2012) or independence. The accumulated losses were indeed fully repaid in 2014 (i.e. much earlier than suggested in Cincibuch et al., 2009) thanks to depreciation of the koruna against the euro associated with the exchange rate commitment and to even more pronounced depreciation of the koruna against the US dollar. The practically zero sterilisation costs during the episode of a technically zero interest rate helped improve the CNB's profitability, too. However, since the exit from the CNB's commitment, appreciation of the koruna against the euro (by almost 6%) and the US dollar (by 17%) have brought the central bank back into negative equity. At the end of 2017, its size in absolute nominal terms broadly matched the pre-crisis peak of 2007. Relative to GDP, it was slightly smaller due to a higher level of domestic economic activity in nominal terms.

Figure 4: The CNB's Equity

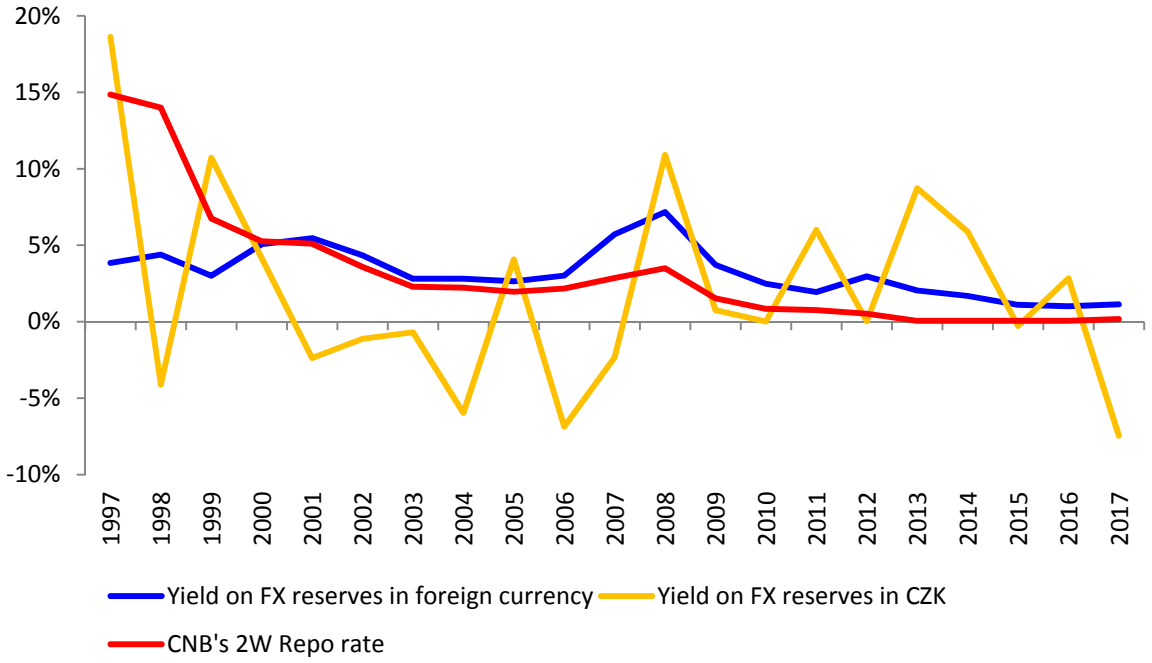


Source: CNB, authors' calculations

Given the structure of its balance sheet presented in Figure 3, the CNB's financial results are predominantly affected by two factors. First, they reflect the yields on foreign exchange reserves expressed in CZK, which consist of the yields in foreign currencies and the impact of changes in the exchange rate of the Czech koruna against a basket of reserve currencies. Exchange rate changes and capital gains or losses on assets in the CNB's reserves portfolio are both marked-to-market and thus immediately affect the central bank's equity.[3] Second, the interest rates paid on the deposits of residents at the CNB – mainly remunerated at the 2W repo rate – are the main item on the costs side. As can be seen in Figure 5, the yields on the CNB's FX reserves in foreign currencies have consistently exceeded the 2W repo rate in the last 10–15 years. However, exchange rate changes have often dominated in terms of CZK yields and thus the overall profit and loss account of the CNB.

[3] Exchange rate gains and losses enter the CNB's profit and loss account and thus also its equity. The same is true for all realised capital gains or losses on assets in the FX reserves portfolio, as well as for any unrealised gains and losses in its stock indexes part. Unrealised capital gains or losses on fixed-income assets (bonds) are not shown in the profit and loss account, but instead are put into a revaluation reserve, which, however, is a part of the CNB's equity, too. For more information on the CNB's accounting procedures, see CNB (2018). In our simulations, we abstract from the distinction between realised and unrealised gains on bonds.

Figure 5: The CNB's Sterilisation Costs and Yields on FX Reserves



Source: CNB

Looking into the future, the two key questions for the CNB's ability to repay its current accumulated loss are thus (i) whether the positive differential between the foreign currency yield on the FX reserves and the 2W repo rate remains in place (especially as the CNB has started to normalise its monetary policy well ahead of the ECB), and (ii) if the nominal currency appreciation is smaller or larger than this differential on average. The answer to the former question partly depends on how the CNB's foreign exchange reserves are managed regarding the risk-return trade-off. The latter question is related to the future pace of convergence of the Czech economy to the advanced countries.

The repayment of accumulated losses will – like in the past episode – be facilitated by favourable institutional arrangements related to the CNB's profit distribution. The CNB always retains all its profits until its accumulated losses are fully repaid and its equity returns to positive figures. In the meantime, the government has no obligation to recapitalise the central bank. This is important to bear in mind when drawing conclusions about the potential fiscal consequences of the various policies simulated in the subsequent part of this paper. In particular, the crucial outcome is the duration of the negative equity in various scenarios rather than the size of the negative equity in any particular year or at its peak. This is because the government gets no profit transfer no matter how large the negative equity is. At the same time, the year when the CNB's accounting equity returns above zero must be viewed as the earliest possible date of starting profit transfers, although this does not mean they would start automatically. This is because the CNB Board has the right to decide to allocate a portion of the profits – up to 100% – to building up the central bank's financial reserves, with only the remaining share of the profits going to the government.

3. Model of the Czech National Bank's Balance Sheet

In this section we develop a model for analysing balance sheet issues for a CNB-like central bank. The following equations assume a simplified structure of the CNB's balance sheet, with assets comprising foreign assets only and liabilities encompassing currency in circulation, deposits of residents (predominantly banks and to a lesser extent the government) and equity. These are the dominant components of the CNB's balance sheet (see above in section 2).[4]

Income in year t, Inc_t, comprises the yield on holdings of foreign assets at the end of the previous year, FX_{t-1}, which are assumed to be denominated in euros (70%) and US dollars (30%). The effective yield on foreign assets expressed in the domestic currency is the weighted sum of the foreign portfolio yields and the appreciation/depreciation of the koruna with respect to the euro and the dollar:[5]

$$Inc_t = 0.7\left(yield_t^{EUR} + \Delta e_t^{EUR}\right)FX_{t-1} + 0.3\left(yield_t^{USD} + \Delta e_t^{USD}\right)FX_{t-1}.$$

For both euro and US dollar-denominated assets, we assume that 90% of the assets will yield a return equal to the expected yield on one-year bonds,[6] while the remaining 10% of the assets are invested in a stock portfolio.[7]

The next year's foreign assets increase by current year income. Moreover, we add the possibility of autonomous changes in FX holdings made by the central bank during year t, $FXInt_t$. Such transactions could include FX interventions, EU fund purchases and sales of income on FX reserves. Including this term allows the model to be used to conduct various policy-relevant simulations.

$$FX_t = FX_{t-1} + Inc_t + FXInt_t$$

The expenses of the CNB, Exp_t, include interest payments on the deposits of residents. We assume that the interest rate applied is equal to the main policy rate, i.e. the two-week repo rate paid on the CNB's main monetary policy facility.[8] Operational costs, OC_t, are included and are assumed to be a constant fraction of nominal GDP, specifically the average fraction observed over the period 2006–2015.

---

[4] To make the observed values of the balance sheet items numerically consistent we distribute all other non-zero items into the three dominant categories. External liabilities are added with a minus sign to foreign assets, and all other items (remaining liabilities, loans to residents, fixed assets and remaining assets) are added with the relevant sign to deposits of residents.

[5] The equation employed for income is an approximation. For a given foreign currency, income equals $\left(\frac{E_{t+1}}{E_t}(1 + yield_t) - 1\right)FX_{t-1}$, where E_t denotes the nominal exchange rate at the beginning of period t. Standard logarithmic approximation then implies the formula for income.

[6] At the end of 2017, the durations of the EUR and USD investment tranches were 2.7 and 5 years respectively. The durations of the liquidity tranches were approximately 0.1 year in both the EUR and USD portfolios.

[7] Here we implicitly assume that the FX portfolio is re-invested each period in order to maintain the assumed composition in terms of both currency and bond and stock composition. Several notes concerning the stock-bond ratio can be found in Appendix D.

[8] Domestic banks can deposit their excess liquidity at the CNB for a two-week period on the basis of repurchase agreements ("repos") at a rate not exceeding – but typically very close to – the two-week repo rate.

$$Exp_t = i_t^{CZ} Dep_{t-1} + OC_t .$$

Overall liabilities evolve according to the standard law of motion extended to include the possibility of direct FX transactions by the bank, which is reflected by the liability side.

$$Liab_t = Liab_{t-1} + Exp_t + FXInt_t .$$

Deposits are calculated as the residual of total liabilities and currency in circulation ($Cash_t$):

$$Dep_t = Liab_t - Cash_t ,$$

where the growth rate of currency in circulation is approximated by nominal GDP growth g_t:[9]

$$Cash_t = (1 + g_t) Cash_{t-1} .$$

The profit or loss of the central bank is defined as the difference between income and expenses. Equity is then defined as the difference between central bank assets and liabilities; its current level reflects equity in the previous year adjusted for the profit or loss:

$$\Pi_t = Inc_t - Exp_t$$
$$Eq_t = FX_t - Liab_t .$$

The projections of the balance sheet items and the income statement are based on the macroeconomic forecast officially published by the CNB,[10] the equilibrium values employed in the CNB's forecasting process and the outlooks for financial variables taken from yield curves and historical averages of stock returns.

The macroeconomic outlook for the domestic monetary policy rate, nominal output and exchange rates for the first two years of the projection is taken from the official CNB forecast. The outlook beyond two years ahead is approximated using the equilibrium values (Table 1, first row). They converge linearly to the equilibrium values expected at the end of the convergence process (Table 1, second row), which is assumed to occur after 20 years. The termination of the convergence process resembles the situation of euro area entry, because in such a situation the foreign monetary policy interest rate becomes the domestic rate and the exchange rate with respect to the euro can be viewed as fixed. So, we can reasonably interpret the situation after 20 years in both ways.[11]

The expected yield on the one-year euro bond used to approximate the euro bond portfolio yield is based on the 3M Euribor outlook from the CNB's forecast adjusted for the spread between the

[9] An alternative to the usual assumption of currency growth equal to nominal GDP growth is to model money demand explicitly, as in Veracierto (2018).

[10] The forecast published in Inflation Report I/2018.

[11] We do not, however, take into account that euro adoption would imply CNB participation in the redistribution of monetary income among euro area central banks. This issue was analysed in Cincibuch et al. (2008).

three-month rate and the one-year rate for the first six years of simulations.[12] The expected yield on the one-year US treasury bond is based on the observed financial market yield curve and estimates of the term premia for the first ten years of simulations.[13] After six and ten years, the expected yields for both the euro and dollar bond portfolios converge to the equilibrium value, calculated as the equilibrium value of the 3M Euribor assumed in the CNB forecasting process increased by the average difference between the three-month rate and the one-year euro bond yield.[14] The equilibrium yield is assumed starting with the twentieth year of the outlook. The expected yield on the stock portfolio is approximated by the average historical stock market yields in the respective currencies over the whole projection horizon. For both the EUR and USD market, the value is set to 6% p.a.[15]

Table 1: Equilibrium Values

	3M Pribor	3M Pribor - 2W repo spread	Inflation	Currency in circulation growth rate	CZK/EUR yoy change	CZK/USD yoy change	3M Euribor	Portfolio return	
								EUR	USD
CNB forecast	3.00	0.24	2.00	5.00	-1.50	-1.50	3.50	-	-
End of convergence (or Eurozone entry)	3.50	0.24	2.00	3.00	0.00	0.00	3.50	4.02	4.02

To obtain stochastic projections of the CNB's income statement and balance sheet items we follow the methodology employed in Ferris et al. (2017). As a starting point the modal path defined above is taken. Then 10,000 forecast paths of the macroeconomic variables around the modal path are generated.[16] The forecast paths reflect the size of the shocks and their effects estimated on historical data. The core model used to generate the set of paths is a small-scale Bayesian vector autoregression (BVAR) one tailored to the Czech economy. In addition, simple satellite models are employed to generate forecast paths for stock returns and CZK/USD appreciation/depreciation. The accuracy of the underlying macro-models is crucial for the accuracy of the stochastic projections of the balance sheet. Therefore, details of the models and some additional results are presented in Appendix A.

[12] ECB (2017) provides estimates of 10Y term premia which are slightly higher than the term premium implied by the compounded 1Y EUR interest rate outlook applied in the CNB forecast and the observed yield curve. We therefore view the EUR interest rate outlook based on the CNB forecast as reasonable.

[13] The USD portfolio forward rate is calculated using the yield curve and term premia estimates from the no-arbitrage term structure model described in Adrian et al. (2013). The data are available at http://libertystreeteconomics.newyorkfed.org/2014/05/treasury-term-premia-1961-present.html.

[14] The average difference between the 3M Euribor and the one-year euro bond yield is computed over the periods 2004Q1–2007Q4 and 2009Q1–2017Q4, i.e. with the exception of 2008, when the spreads reflected a money market freeze. The spread equals 0.3 p.p.

[15] In reality, this yield will be time-varying and negatively correlated with the government bond yield. This negative correlation was in fact the main reason for adding the equities to the CNB's reserve portfolio. It is implemented in the stochastic simulations presented in Section 4 via the variance-covariance matrix of annual yields.

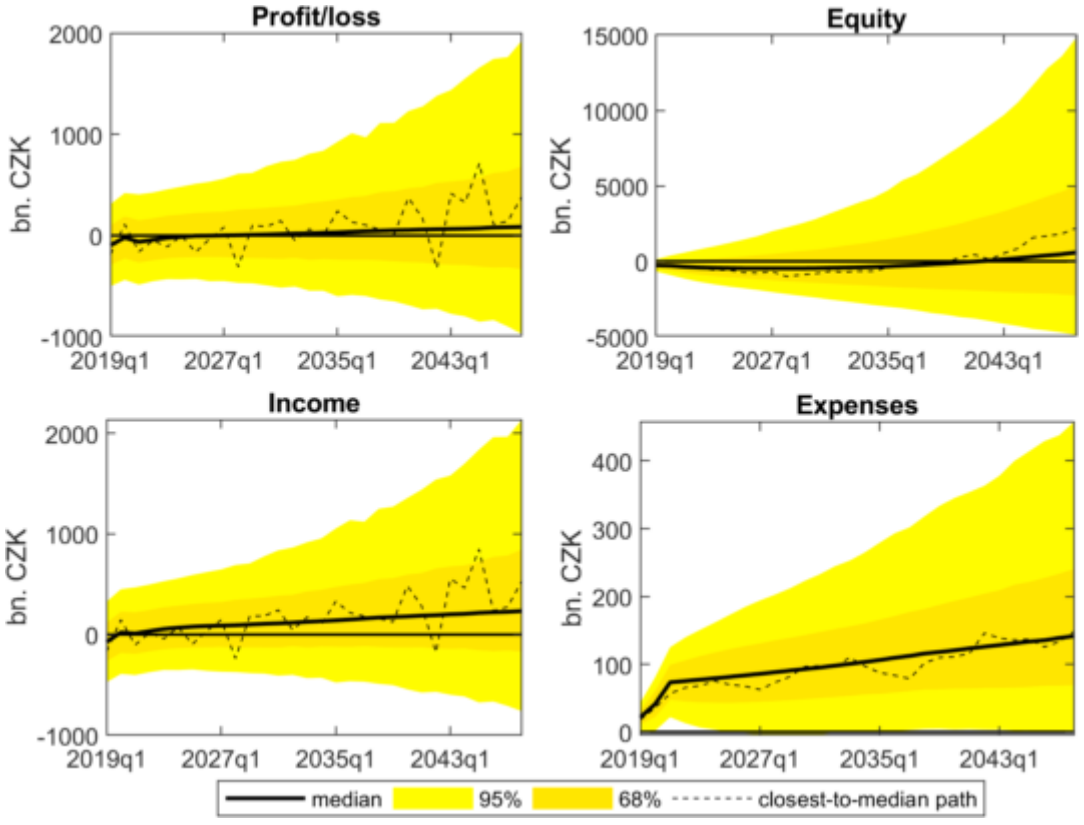
[16] To check whether 10,000 draws is a sufficient number, a robustness exercise with 2,500 draws only is carried out, yielding very similar results.

Finally, note that the system of accounting identities describing the evolution of the balance sheet items is not linear. From the point of view of the stochastic projections the system includes products and sums of distributions which are not in general independent. As a consequence, the mean and median of the stochastic projections differ from the deterministic projections, which would be based solely on the modal paths of the macroeconomic variables defined above, and the projected intervals are not symmetric. A comparison of deterministic and stochastic projections can be found in Appendix C.

4. Benchmark Simulation

The simulation is based on the values of the balance sheet items as of 31 December 2017 and the CNB's official macroeconomic forecast published in Inflation Report I/2018, i.e. the forecast that starts with 2018 as the first forecasted year. The simulations are at yearly frequency. The first simulated values relate to the first quarter of 2019, i.e. flows represent the period 2018Q1–2018Q4 and stock variables pertain to the first day of 2019. The projection period covers 30 years.

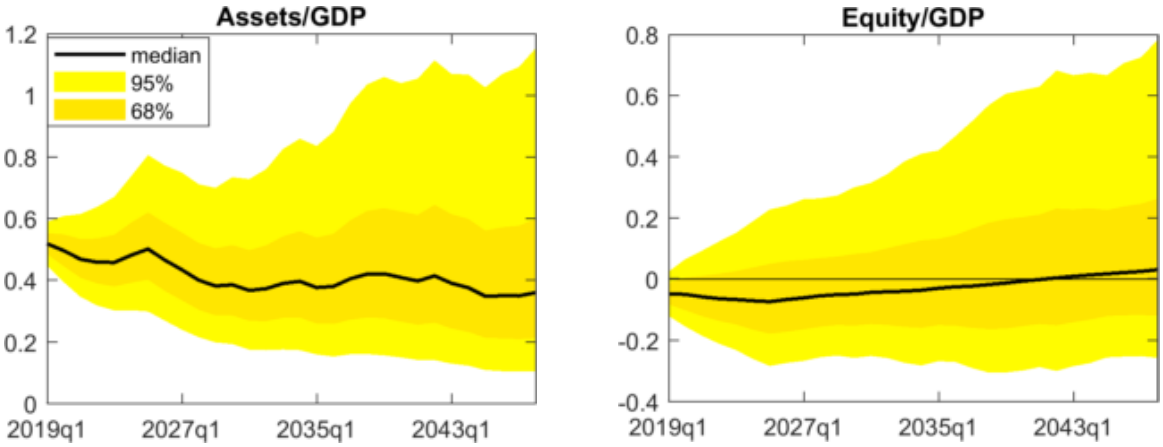
Figure 6: CNB Balance Sheet Outlook (baseline scenario)



Note: The "closest-to-median path" is the forecast path closest to the pointwise medians of all four simulated quantities (see footnote 17).

Figure 6 shows the baseline simulation of the CNB income statement outlook together with the evolution of equity.[17] The uncertainty around the median projections expressed by the 68% and 95% of the distributions is substantial and grows with the length of the projection horizon. The presented quantities are in nominal terms and the equations imply that they grow exponentially. This wide range of uncertainty can be illustrated on past experience using deterministic simulations based on Cincibuch et al. (2009) at the CNB. While this model initially – in the phase of fast convergence and exchange rate appreciation – significantly underestimated the extent of the CNB's losses and negative equity, the situation changed abruptly with the unexpected major shock generated by the global crisis. This led to much faster elimination of the CNB's negative equity compared to the simulations, followed by rapid re-emergence of the losses once the central bank discontinued its exchange rate commitment in 2017 (and the dollar simultaneously started to depreciate against the euro). In general, the financial outcome and equity of a central bank with the CNB's balance sheet size and structure can be strongly counter-cyclical; it tends to improve in adverse situations with a depreciating currency and deteriorate in cyclical upswings with an appreciating currency. But given that the deterministic simulations draw their macroeconomic assumptions from sources that are by definition not able to forecast major future cyclical swings, the uncertainty around them is huge.

Figure 7: Projections of the Total Assets to GDP and Equity to GDP Ratios



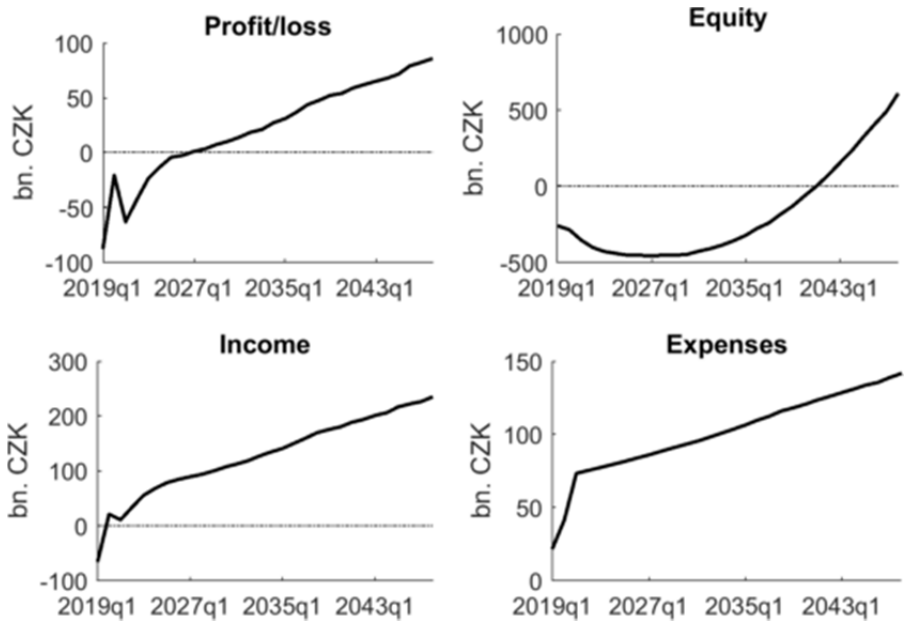
To assess the evolution of balance sheet items from the point of view of their sustainability, the ratios of total assets to nominal GDP and equity to GDP can be simulated. This is done in Figure 7, which shows (in the left panel) that the median projection of the total assets to GDP ratio is located below 0.5 for the whole 30 years with the exception of the first year. The probability that the size of the balance sheet exceeds that of GDP starts at zero and reaches 0.03 at the end of the projection horizon. Only two central banks of advanced economies currently exhibit a ratio exceeding 0.5 – the Bank of Japan and the Swiss National Bank. Regarding the expected ratio of equity to GDP, Figure 7 (right panel) suggests that the median never falls below -8% of GDP. The

[17] Note that the median profit is not necessarily equal to the difference between the median income and the median expenses, because the forecast paths underlying the three medians can differ. For a given forecast path the equality holds. The solution could be to take the forecast path that implies the closest-to-median profit, income and expenses and work with that path. Such path is shown in Figure 6, which suggests that no additional information on the dynamics of the system in general is provided by using the closest-to-median paths instead of the pointwise median paths. We therefore stick to the standard approach and present pointwise medians in the paper.

probability of negative equity starts at 0.91 and 0.82 in 2018 and 2019 respectively and decreases steadily towards 0.43 in 30 years.

To obtain a more focused picture, Figure 8 presents the medians of the benchmark stochastic projections (with all the above reservations concerning the reliability of the projections in mind). It turns out that the loss will be highest in the first year of the projection at approximately CZK 88 billion, which is equivalent to 1.6% of the GDP forecasted for that period. The loss will then diminish and turn into a profit after eight years in 2026. As a consequence, the equity will be negative for roughly the next two decades, the lowest point being negative equity of CZK 458 billion (i.e. 6.6% of GDP). Appendix B shows that these results are qualitatively similar to the outcomes of the earlier model of Cincibuch et al. (2009), but are somewhat more optimistic overall in the longer term given our more nuanced approximation of future yields on the CNB's foreign exchange reserves.

Figure 8: CNB Balance Sheet Outlook (medians)



From the historical perspective, the negative equity expected during the coming 23 years is not so far from the CNB's past experience of negative equity lasting 16 years over the period 1998 to 2013 (see section 2). Moreover, without the exchange rate commitment, the span of the period of negative equity starting at the end of the 1990s would have been longer (see section 5.1 below). In terms of the size of the accumulated loss, the near future is close to the situation the CNB faced in 2007, when its negative equity approached 5% of GDP.

5. Policy Scenarios

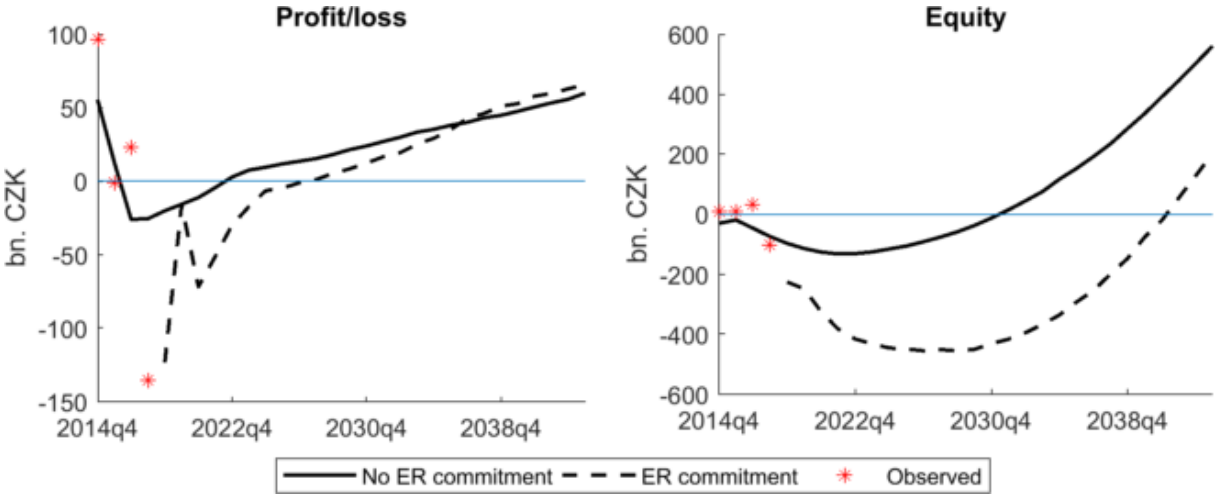
Several policy scenarios are discussed in this section. The aim of the first two is to contribute to the public debate that has arisen around the central bank balance sheet recently in the Czech Republic. The debate revolves around the fiscal consequences of the exchange rate commitment, based on the idea that with a different past monetary policy the CNB would soon have been able

to start paying dividends to the Czech government.[18] We provide a quantitative assessment of this idea, something which has so far not been delivered by its proponents. The last two scenarios address the possible long-run decline in the amount of currency in circulation and the scope for active management of the central bank's balance sheet by means of resuming the programme of selling yields on the FX reserves.

5.1 Counter-factual Scenario of No Exchange Rate Commitment

The first scenario considers the situation of no exchange rate commitment. The use of the exchange rate as an additional monetary policy tool was introduced in November 2013 and discontinued in April 2017. The scenario works with the balance sheet items as of 31 October 2013, i.e. without the central bank's purchases of euros related to the floor. The counter-factual estimates of GDP growth, the domestic interest rate and the CZK/EUR and CZK/USD exchange rates are taken from Brůha and Tonner (2017) based on the DSGE model with the labour market block described in Tonner et al. (2015). The estimates of the evolution of domestic variables without the floor are available for the period 2013Q4–2015Q4. For the following years we assume a transition to the steady state similarly to the benchmark case. We therefore abstract from the observed shocks that apparently hit the economy in 2016 and 2017. For foreign variables (EUR and USD interest rates), the observed values are taken for the first four years of the counter-factual projection and the outlooks are based on the most recent market expectations afterwards.[19]

Figure 9: No Exchange Rate Commitment



Note: The benchmark simulation (ER commitment) is computed starting with 2017Q4–2018Q3 to follow the timing of the no-ER-commitment scenario. The original benchmark simulation started with 2018Q1–2018Q4.

Figure 9 shows that without the exchange rate commitment, the CNB's equity in the first three years would have been lower than the observed actual numbers (red crosses). This is due to lower

[18] In reality, the CNB has never paid a dividend to the government since it was established in 1993 (with one negligible exception). The debate is thus in itself very hypothetical.

[19] Note that the counter-factual scenario is based on a model where endogenous variables reach steady state sooner or later and where economic agents with rational expectations consider the inflation target as fully credible. In reality, one of the motivations for the introduction of the exchange rate commitment was the risk of the deflationary spiral where expectations become unanchored on the inflation target. Such scenario would lead to much more adverse developments of the Czech economy than the counter-factual scenario considers.

GDP (and currency) growth and especially due to a stronger currency in the counter-factual scenario without the commitment. Owing to these less favourable macroeconomic developments, the CNB would have made larger losses on its foreign exchange reserves, which were smaller but still substantial before the exchange rate commitment was introduced (see section 2). Subsequently, the size of the negative equity would have been less than half that in the benchmark simulation due to a lower stock of foreign exchange reserves and resulting more benign revaluation losses (in combination with the assumption of no deflation spiral in the counter-factual scenario and neutrality of monetary policy for long-term real economic developments). The time span of negative equity, however, would be 18 years from the beginning of the simulation. Interestingly, this is not much less than in the benchmark case with the exchange rate commitment, where negative equity is projected for 23 years (although starting in 2017/2018). In terms of the CNB's (in-)ability to pay dividends to the government, the counter-factual simulation is thus no more optimistic than the benchmark until around 2030. This shows the importance of quantifying the counter-factual scenario if one wants to discuss the fiscal consequences of the CNB's exchange rate commitment in depth.[20]

5.2 Hypothetical Termination of the Exchange Rate Commitment at the End of 2016

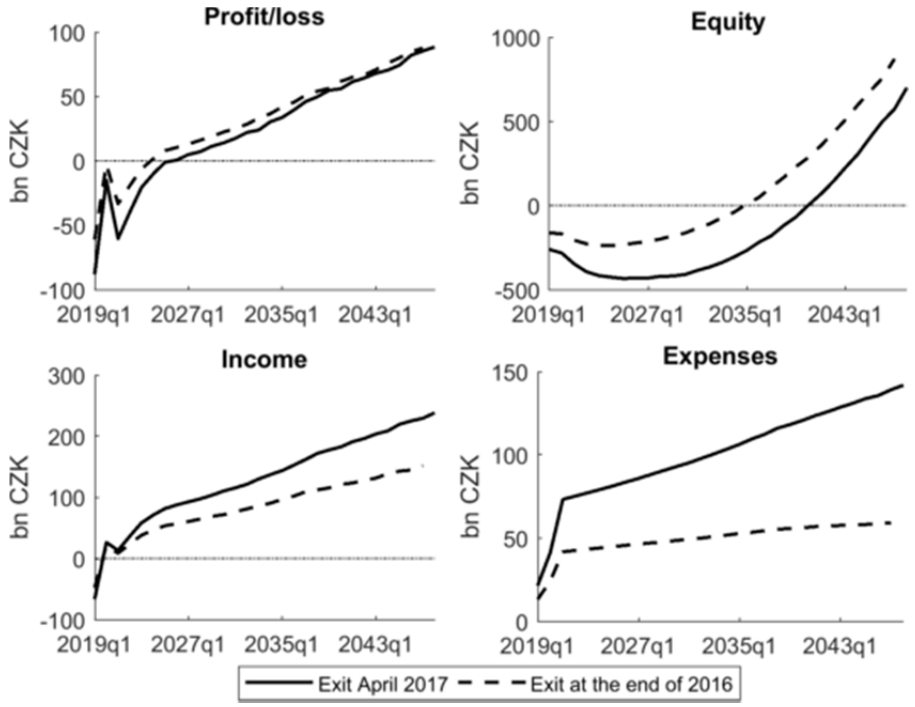
The second policy scenario concerns the question how the balance sheet and its outlook would have looked if the exchange rate commitment had been terminated at the end of 2016. This situation is a subject of local public debate. The popular argument goes that an earlier exit at the end of 2016 would have led to a much smaller balance sheet and consequently to an earlier potential transfer of profits to the Ministry of Finance. The extension of the CNB's exchange rate commitment into 2017 is thus criticised for having had major (and – implicitly presumed – almost immediate) fiscal implications.

There are two major flaws to this argument. First, in September 2016 the CNB committed not to "*discontinue the use of the exchange rate as a monetary policy instrument before 2017 Q2*" (CNB, 2016). It is extremely unrealistic to assume that the increase in the CNB's FX reserves in November and December 2016 would have been the same as the one observed in reality without this extended commitment. Most probably, exporters would have hedged before the end of 2016, and financial investors would have done the same as regards building their long CZK speculative positions. There is no significant reason to believe that the overall size of the CNB's balance sheet expansion would have been much lower, it would just have had a different timing. The only way to avoid the observed balance sheet increase would probably have been to extend the "hard" commitment in autumn 2016 and then break it. However, this would have been extremely harmful to the CNB's credibility. At the same time, the exchange rate developments after such a surprising exit would probably have been much less smooth than in reality; and with a more pronounced CZK appreciation, the CNB's equity might have turned more negative even with a smaller balance sheet.

[20] Moreover, when assessing the overall fiscal consequences of the exchange rate commitment, one cannot just look at the CNB's equity and potential future transfers of profits from the central bank to the government. In the hypothetical scenario without the commitment, the lower nominal GDP growth would lead mainly to a deterioration in the primary government budget balance as a result of lower revenues, and to an adverse denominator effect. In addition, the higher interest rate would increase the costs of debt service. Using the "no exchange rate commitment" counter-factual scenario in Brůha and Tonner (2017), the CNB's fiscal experts have estimated the debt/GDP ratio as reaching 42.7% at the end of 2015 in the hypothetical scenario without the commitment, compared to the observed 40% level.

Second, even if one ignores the above fundamental issues, none of the CNB's critics have taken the trouble to quantify the implications of a smaller central bank balance sheet. In Figure 10, we thus provide a simulation with the – extremely unlikely – assumption that the CNB's balance sheet expansion in 2017 Q1 would not have happened and everything else would have remained the same.

Figure 10: Early Exit from the Exchange Rate Commitment (medians)



The scenario is based on the balance sheet data as of 31 December 2016, the observed data for 2017 and the macroeconomic forecast from Inflation Report I/2018. It turns out that in the event of an end-2016 exit, profits would turn positive two years earlier (i.e. in 2024) and equity five years earlier than in the baseline. Therefore, the fiscal implications of the extension of the CNB's exchange rate commitment – if there are any, given all the above disclaimers – relate to a relatively short period in the fairly distant future.

5.3 Long-run Decline in Currency in Circulation

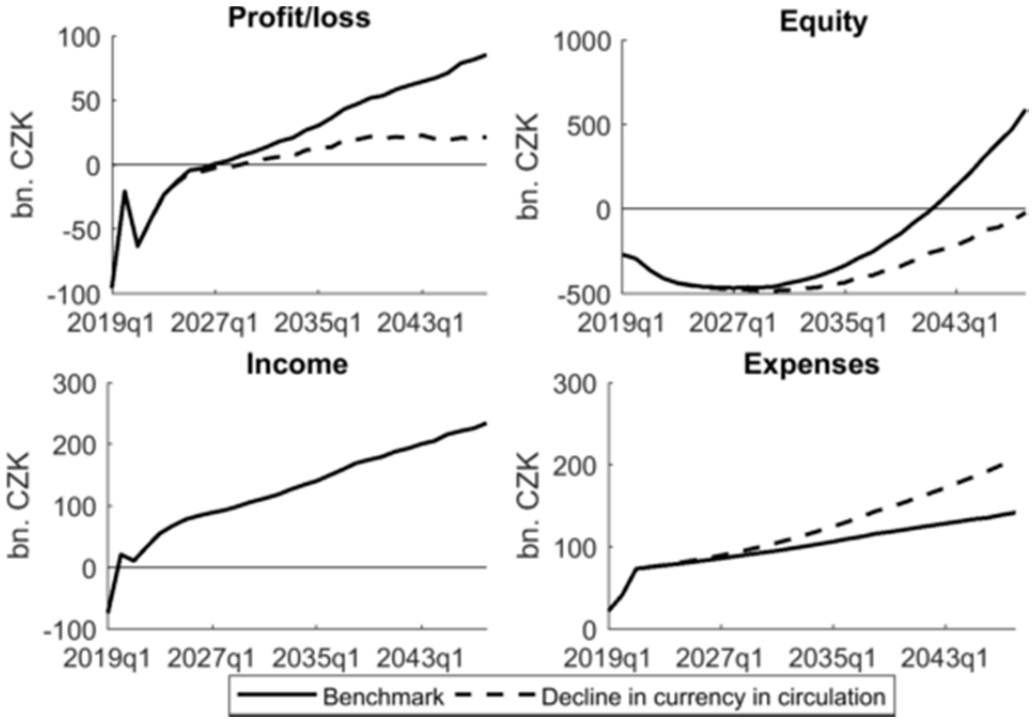
The third scenario is intended to shed some light on the CNB's finances in the event of a long-run decline in currency in circulation relative to GDP. One possible reason for such a decline would be a switch to non-cash payment systems. This issue is discussed for the Czech Republic and other OECD countries by Komárek et al. (2018). Even though they conclude that the popularity of cash is unlikely to drop significantly in the Czech Republic any time soon, in spite of all the advances in payment technologies, it is relevant to keep this option in mind, especially when discussing long timescales.

The situation is modelled by relaxing the assumption of currency growth being equal to nominal GDP growth. The value and volume of cash transactions in the economy are no longer approximated by nominal GDP growth, and an increasing proportion of transactions are carried out in other forms of money. In the scenario we assume that the ratio of growth of money in

circulation to nominal GDP growth decreases from +1 to -2 in 30 years. The numbers are chosen to approximately mimic the trend observed in Sweden over the last two decades. Note, however, that Sweden represents an extreme case in terms of its recent decline in currency in circulation.[21]

The resulting outlook for the CNB balance sheet and a comparison with the benchmark specification can be found in Figure 11. Profit and equity are lower due to lower seigniorage (monetary income). The switch to positive profits would take place two years later than in the baseline scenario, whilst equity would approach zero at the end of the projection horizon in the scenario with declining currency in circulation. Income from FX holdings is not affected and expenses would be higher because of a large amount of interest-bearing commercial bank reserves – lower currency in circulation implies a larger amount of deposits for a given amount of liabilities. Overall, the simulated extreme decline in the cash ratio does not alter the ultimate switch to positive profit and equity and thus is not a major threat to the sustainability of the CNB's finances.

Figure 11: Declining Currency in Circulation (medians)



5.4 Sales of FX Income

The fourth scenario captures an example of active management of the CNB's balance sheet size in which the evolution of the asset side – and thus also the liability side – differs from simple autonomous expansion due to earnings on foreign assets (expressed in the domestic currency). In particular, we focus on the option of resuming the CNB's earlier programme of selling yields on FX reserves. We assume that such sales would resume after two years (i.e. in 2020). In the

[21] Wang and Williams (2017) report that Sweden and Norway are the only countries for which nominal GDP growth exceeded currency in circulation growth over the period 2006–2016.

scenario, the entire interest income on the FX reserves is sold to a commercial bank and a corresponding amount of bank reserves on the liability side disappears.

For the sake of simplicity, we assume that these sales are sufficiently small not to deflect the exchange rate path – and thus the trajectory of all other macroeconomic variables – from the baseline simulation.[22] The average CZK value of the FX reserves sales during the period from April 2004 to October 2012 was approximately CZK 19 billion, or 0.5% of GDP, per year. The volume was set so as not to affect the CZK/EUR market significantly. In our scenario, the value of the FX sales starts at CZK 15 billion in 2020, rises to CZK 118 billion in 2040 and then remains at that level (see the evolution of income in Figure 12). In terms of GDP, the sales represent 0.3% in 2020, go up to 1.0% in 2040 and then decline to 0.9% at the end of the projection period, following the increase in the foreign interest rate in the first 20 years of the projection along with decreasing nominal GDP growth. Taking into account the growing openness of the Czech economy (and thus the size and depth of the CZK/EUR market) the assumption of no effect of FX sales on the exchange rate in the scenario is plausible.

Figure 12: Sales of FX Income after Two Years (medians)

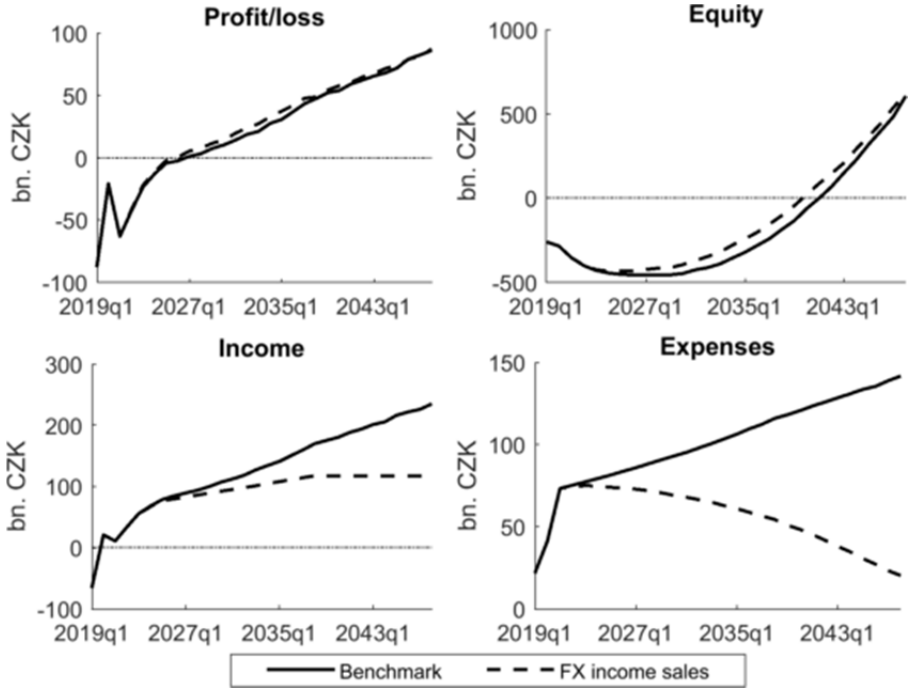
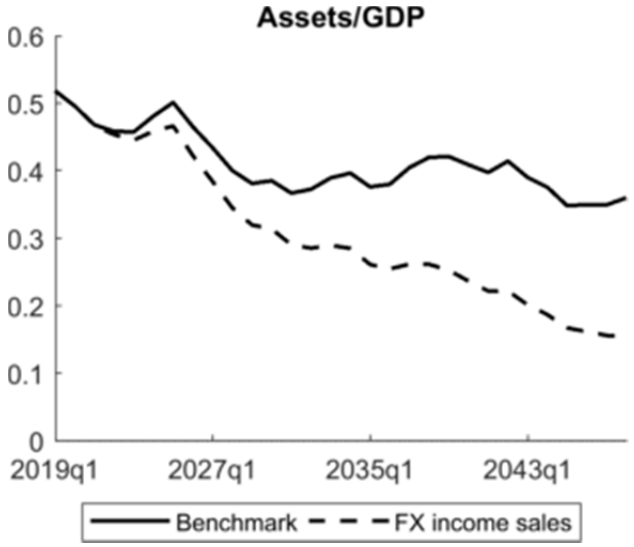


Figure 12 suggests that the effect of the sales is not substantial in terms of the CNB's profits and equity. The profit marginally increases in the medium term, owing mainly to a decline in bank deposits at the CNB that have to be remunerated at the monetary policy rate, which slightly outweighs the lower income on the FX reserves. The equity thus turns positive marginally earlier than in the baseline simulation, but the difference is extremely small. This shows that the eventual resumption of sales of earnings on FX reserves should not be viewed as a measure to address the CNB's negative equity issue. However, it could contribute significantly to reducing the CNB's

[22] If the sales of FX yields were having a significant appreciation effect on the currency, they would worsen the CNB's losses and could also endanger the achievement of the 2% inflation target. The central bank would thus need to reduce their size to a level consistent with minimising the exchange rate effect.

balance sheet size relative to GDP, as suggested by Figure 13, which compares the size of the balance sheet in the benchmark case and the case of FX sales. Such a reduction could be viewed as a step towards making the CNB's balance sheet better prepared for a possible new round of unconventional monetary policy measures, should it be needed in the (relatively distant) future. It turns out that over the 30 years of the projection the size of the balance sheet relative to GDP would decline towards the levels experienced before the unconventional measures were introduced.

Figure 13: Assets/GDP Ratio for Sales of FX Income Starting after Two Years (medians)



6. Conclusions

The size of the CNB's balance sheet has recently increased substantially as a consequence of the exchange rate commitment backed by purchases of euro. As the asset side of the balance sheet consists almost solely of foreign assets, and exchange rate changes are marked-to-market, any appreciation of the Czech currency is reflected in accounting losses and negatively affects the central bank's finances. The Czech koruna is exhibiting a real appreciation trend due to economic convergence, so some further losses are likely. Given the lively public debate related to the CNB's Financial Reports, our paper focuses on projections of the CNB's balance sheet and the uncertainty surrounding them. In addition, several policy scenarios are examined to clarify various aspects of the CNB's finances.

Regarding central bank losses or negative equity, the literature often discusses the threat to the central bank's independence and therefore the credibility of its monetary policy (e.g. Stella, 1997). Empirical papers investigate the relationship between the central bank's balance sheet and inflation (Klüh and Stella, 2008; Benecká et al., 2012). Furthermore, there are several theoretical studies based on general equilibrium models that examine the possible channels through which a large central bank balance sheet can affect the conduct of monetary policy and ultimately inflation (Del Negro and Sims, 2015; Benigno and Nisticó, 2015; Park, 2015). However, all studies suggest that potential problems with fulfilling the goals of monetary policy can arise only when the central bank's loss is substantial and unsustainable.

In this paper, we demonstrate that the outlook for the CNB's balance sheet does not differ qualitatively from what has been experienced in the last two decades, and as such the fulfilment of monetary policy aims should not be endangered. In particular, the CNB exhibited negative equity for 16 years between 1998 and 2013, with the peak level corresponding to 5% of GDP. In our baseline projection, the equity is projected to remain negative for the next 23 years at a level not exceeding 7% of GDP. As the CNB has not faced any loss of independence or ability to control inflation due to the losses and negative equity it has recorded in the past, we conclude that the projected situation does not imply any problems for the central bank's operations in the future.

Apart from the most probable outlook for the CNB's balance sheet items, the simulation tool can be used for various policy-relevant exercises. In this paper, we follow four scenarios – two related to the exchange rate commitment (absence of the commitment, earlier exit from the commitment) and the other two to more general economic questions (a long-run decline in the currency-to-GDP ratio and sales of FX income by the central bank).

The counter-factual scenarios related to the exchange rate commitment suggest that the commitment (and its duration) did not alter the outlook for central bank finances qualitatively. In particular, in both of these scenarios the CNB would currently be exhibiting negative equity and would continue to do so for an extended period of time. Given that the CNB pays no profit transfers to the government as long as it has accumulated losses in its balance sheet, no matter what size, the exchange rate commitment and the design of its exit have no immediate or medium-term adverse fiscal implications. In both counter-factual scenarios, no profit transfers are possible before the year 2030. These conclusions are relevant not just to the CNB at present, but in general to all small open catching-up economies with central bank balance sheets dominated by foreign exchange reserves that might consider using the exchange rate as an unconventional monetary policy instrument in the future.

Regarding the general economic scenarios, it turns out that a decline in the currency-to-GDP ratio and a start of sales of yields on FX reserves do not significantly change the outlook for the CNB's equity. There are many other possible applications of the simulation tool. One important possibility is stress-testing of the CNB balance sheet along the lines of Christensen et al. (2015).[23]

[23] Christensen at al. (2015) focus on interest rate risk, as the US Fed's balance sheet comprises US mortgage-backed securities. In the CNB case, the focus would be on exchange rate risk.

References

ADRIAN, T., R. K. CRUMP, AND E. MOENCH (2013): "Pricing the Term Structure with Linear Regression." *Journal of Financial Economics* 110(1), pp. 110–138.

ANDRLE, M., T. HLÉDIK, O. KAMENÍK, AND J. VLČEK (2009): "Implementing the New Structural Model of the Czech National Bank." CNB Working Paper No. 2/2009.

BENECKÁ, S., T. HOLUB, N. L. KADLČÁKOVÁ, AND I. KUBICOVÁ (2012): "Does Central Bank Financial Strength Matter for Inflation? An Empirical Analysis." CNB Working Paper No. 3/2012.

BENIGNO, P. AND S. NISTICÓ (2015): "Non-Neutrality of Open Market Operations." CEPR Discussion Paper 10594.

BRÁZDIK, F. AND M. FRANTA (2017): "A BVAR Model for Forecasting of Czech Inflation." CNB Working Paper No. 7/2017.

BRŮHA, J. AND J. TONNER (2017): "An Exchange Rate Floor as an Instrument of Monetary Policy: An Ex-post Assessment of the Czech Experience." CNB Working Paper No. 4/2017.

BUITER, W. (2008): "Can Central Banks Go Broke?" CEPR Policy Insight No. 24.

CARPENTER, S., J. IHRIG, E. KLEE, D. QUINN, AND A. BOOTE (2015): "The Federal Reserve's Balance Sheet and Earnings: A Primer and Projections." *International Journal of Central Banking* 11(2), pp. 237–283.

CARUANA (2012): "Why Central Bank Balance Sheets Matter" in: "Are Central Bank Balance Sheets in Asia Too Large?" *BIS Papers* 66, pp. 2–9.

CAVALLO, M., M. DEL NEGRO, W. S. FRAME, J. GRASING, B. A. MALIN, AND C. ROSA (2018): "Fiscal Implications of the Federal Reserve's Balance Sheet Normalization." Working Paper No. 747, Federal Reserve Bank of Minneapolis.

CHRISTENSEN, J. H. E., F. X. DIEBOLD, AND G. D. RUDEBUSCH (2011): "The Affine Arbitrage-Free Class of Nelson-Siegel Term Structure Models." *Journal of Econometrics* 164(1), pp. 4–20.

CHRISTENSEN, J. H. E., J. A. LOPEZ, AND G. D. RUDEBUSCH (2015): "A Probability-Based Stress Test of Federal Reserve Assets and Income." *Journal of Monetary Economics* 73, pp. 26–43.

CINCIBUCH, M., T. HOLUB, AND J. HURNÍK (2008): "Central Bank Losses and Economic Convergence." CNB Working Paper No. 3/2008.

CINCIBUCH, M., T. HOLUB, AND J. HURNÍK (2009): "Central Bank Losses and Economic Convergence." *Czech Journal of Economics and Finance* 59(3), pp. 190–215.

CNB (2016): "Statement of the Bank Board for the press conference following the monetary policy meeting, 29 Sep 2016", Czech National Bank, available at http://www.cnb.cz/en/monetary_policy/bank_board_minutes/2016/160929_prohlaseni.html.

CNB (2018): "Financial statements for the year ended 31 December 2017", available at

http://www.cnb.cz/miranda2/export/sites/www.cnb.cz/en/about_cnb/performance/download/ruz_2017_en.pdf

DEL NEGRO, M. AND C. SIMS (2015): "When Does a Central Bank's Balance Sheet Require Fiscal Support?" *Journal of Monetary Economics* 73, pp. 1–19.

DIEPPE, A., R. LAGRAND, AND B. VAN ROYE (2016): "The BEAR Toolbox." ECB Working Paper No. 1934.

ECB (2017): "Financial Stability Review." European Central Bank, November 2017.

FERRIS, E. E. S., J. K. SOO, AND B. SCHLUSCHE (2017): "Confidence Interval Projections of the Federal Reserve Balance Sheet and Income." FEDS Notes, Washington: Board of Governors of the Federal Reserve System, January 13.

FRAIT, J. AND T. HOLUB (2011): "Exchange Rate Appreciation and Negative Central Bank Capital: Is There a Problem?" in: *The Capital Needs of Central Banks*, S. Milton and P. Sinclair (eds), Routledge, London and New York, ISBN: 978-0-415-55328-5.

FRANTA, M., T. HOLUB, P. KRÁL, I. KUBICOVÁ, K. ŠMÍDKOVÁ, AND B. VAŠÍČEK (2014): "The Exchange Rate as an Instrument at Zero Interest Rates: The Case of the Czech Republic." CNB Research and Policy Note No. 3/2014.

GERŠL, A. AND T. HOLUB (2006): "Foreign Exchange Interventions under Inflation Targeting: the Czech Experience." *Contemporary Economic Policy* 24(4), pp. 475–491.

HALL, R. E. AND R. REIS (2015): "Maintaining Central-Bank Financial Stability Under New-Style Central Banking." NBER Working Paper No. 21173.

JEANNE, O. AND L. E. O. SVENSSON (2007): "Credible Commitment to Optimal Escape from a Liquidity Trap: The Role of the Balance Sheet of an Independent Central Bank." *American Economic Review* 97(1), pp. 474–490.

KLÜH, U. AND P. STELLA (2008): "Central Bank Financial Strength and Policy Performance: An Econometric Evaluation." IMF Working Paper No. 08/176.

KOMÁREK, L., I. POLÁŠKOVÁ, AND M. HLAVÁČEK (2018): "Why Is Cash Still Popular? Evidence from OECD Countries." Global Economic Outlook, CNB, March 2018.

PARK, S. G. (2015): "Central Banks' Quasi-Fiscal Policies and Inflation." *International Journal of Central Banking* 11(2).

POLANSKY, S. (2016): "Abandoning a Currency Peg." The Region, Federal Reserve Bank of Minneapolis.

RUDEBUSCH, G. AND T. WU (2008): "A Macro-Finance Model of Term Structure, Monetary Policy, and the Economy." *Economic Journal* 118, pp. 906–926.

STEELE, G. AND J. WHITTAKER (2012): "Don't Look to Seigniorage to Save the Euro." www.econmonitor.com.

STELLA, P. (1997): "Do Central Banks Need Capital?" IMF Working Paper No. 97/83.

SWANSON, E. T. (2007): "What We Do and Don't Know about the Term Premium." FRBSF Economic Letter, Federal Reserve Bank of San Francisco.

TONNER, J., S. TVRZ, AND O. VASICEK (2015): "Labour Market Modelling Within a DSGE Approach." CNB Working Paper No. 6/2015.

VERACIERTO, M. (2018): "A Monetarist View of the Fed's Balance Sheet Normalization Period." *Economic Perspectives* 42(2).

WILLIAMS, J. AND C. WANG (2017): "Reports of the Death of Cash Are Greatly Exaggerated." SF Fed Blog, Federal Reserve Bank of San Francisco.

Appendix A: Macro Models

The main macroeconomic model used to generate the forecast paths entering the balance sheet accounting identities is a small-scale vector autoregression one estimated by Bayesian techniques (BVAR). The Bayesian approach is a natural choice because the forecast paths can be generated directly during the estimation of the model. Even though the balance sheet projections are of yearly frequency, the underlying macro model is estimated on quarterly data because of the very short time span that would be available for yearly data. For a detailed description of the model and its estimation see Brázdik and Franta (2017). The main reason for the use of the mean-adjusted version of the BVAR model is to guarantee sensible forecasts even at the long end of the forecasting horizon.[24]

The model contains three foreign variables (foreign demand growth, foreign inflation and the foreign interest rate) and four domestic variables (real GDP growth, monetary-policy relevant inflation, the short-term interest rate and the exchange rate change). The variables are in annualised quarter-on-quarter changes, except for the interest rates, which are in levels. In addition, the model incorporates block exogeneity of foreign variables to reflect the fact that the Czech economy is a small open economy such that domestic shocks and variables do not affect foreign variables. Furthermore, the model features mean-adjustment, which allows us to incorporate information about the steady state of macroeconomic variables directly into the estimation procedure in the form of a prior on the steady state. The imposed means of the steady state priors coincide with the equilibrium values used for the construction of the deterministic path defined in the main text.

The BVAR model is estimated on the period 1998Q1–2017Q3, and iterated forecasts for up to 120 quarters are generated reflecting the estimated model parameters. The forecast paths are then processed in several steps. First, the paths that are generated by unstable VARs are discarded (the ratio of the discarded paths is 0.05). We thus impose the condition that unstable forecast paths of macroeconomic variables are not a sensible description of the economic outlook.[25] Second, the median of the forecast paths for a given horizon and variable is subtracted from the forecast paths. The aim is to obtain paths that reflect solely the effects of possible shocks on the macroeconomic variables based on the estimated historical shocks.[26] Subtracting the median filters out the initial conditions, the transition to the steady state and the steady state itself – those are provided by the deterministic path defined outside the model. The resulting forecast paths are then the same as if

[24] The reason why the main CNB forecasting model, which is a standard medium-scale New Keynesian DSGE model, is not used to generate the forecast paths of the macroeconomic variables in this paper is threefold. First, generating a high number of paths based on a complex DSGE model is computationally infeasible. Second, using a simpler VAR-type model allows us to account for the uncertainty of the model parameters in the balance sheet simulations. The uncertainty associated with the parameters of the model is presumably large for the Czech economy and should be accounted for in stochastic simulations of the balance sheet. Third, in contrast to the CNB's DSGE model, foreign variables are treated as endogenous in the BVAR model and forecast paths of the foreign interest rate can thus be generated.

[25] Note that a stable outlook for macroeconomic variables does not imply a stable outlook for the central bank balance sheet. The stability of the balance sheet also hinges on the relative steady state values of the economic variables. Possible combinations of steady state values that lead to indefinite loss accumulation for a converging economy are discussed in Cincibuch et al. (2009). Cincibuch et al. (2009) show that the risk premium and the equilibrium real exchange rate are crucial factors for the possibility of central bank capital displaying explosive dynamics.

[26] Note that structural shocks are not identified and we work with reduced-form shocks.

they had been simulated using just impulse response functions and estimated shocks. Finally, the forecast paths are transformed into yearly frequency by taking averages over four quarters.

Figure A1 shows the forecast paths of the BVAR model in the form of 95% confidence intervals. The forecasting starts in 2017Q4. The paths contain the paths generated by unstable VARs as visible in the forecasts of foreign and domestic interest rates (the 3M Euribor and the 3M Pribor). The effect of excluding unstable paths is depicted by Figure A2. Note that pointwise confidence bands are presented. However, the whole paths enter the balance sheet simulation.

Figure A1: Distribution of Forecasts from the BVAR Model

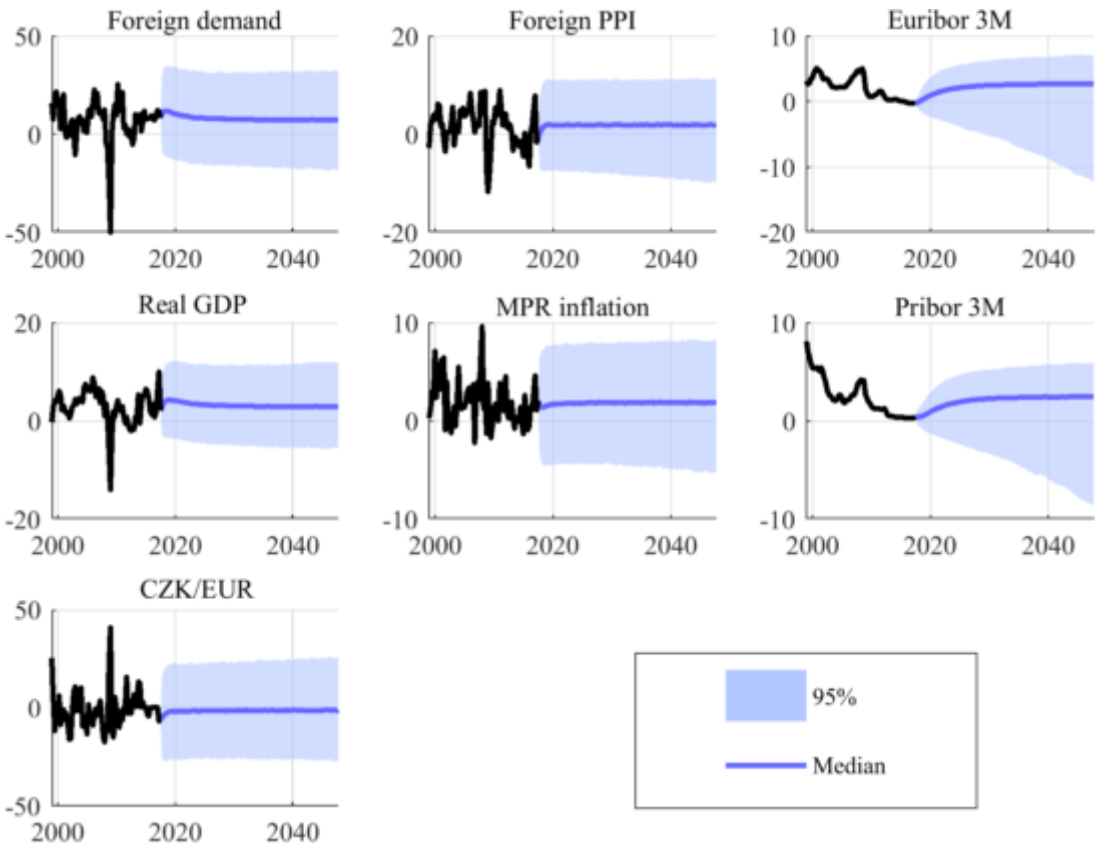
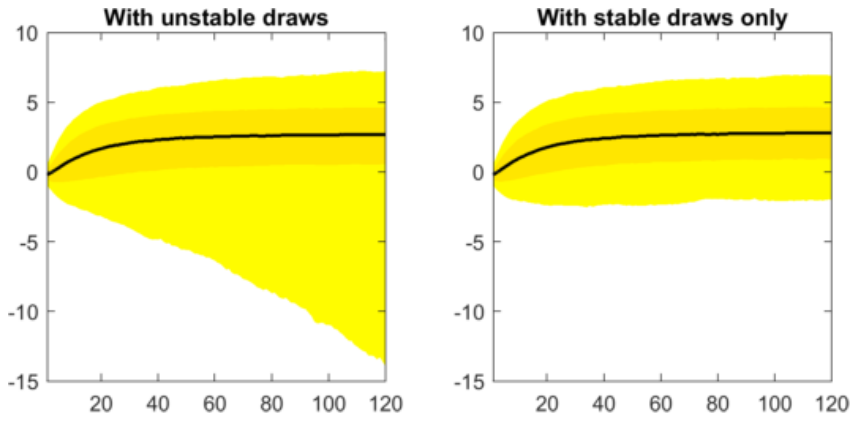


Figure A2: Distribution of Foreign Interest Rate Forecasts: The Effect of Excluding Unstable Paths



Note: 95% and 68% confidence bands are indicated by the shaded areas.

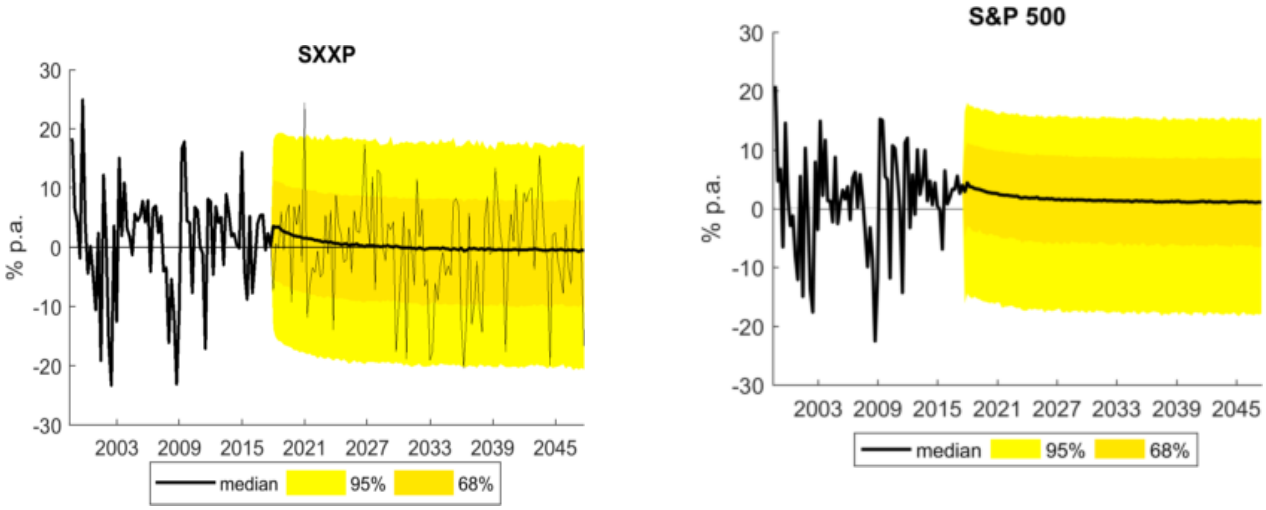
In addition to the BVAR model, a battery of models is used to generate forecast paths of EUR and USD stock returns and CZK/USD exchange rate appreciation/depreciation. We omit stock prices and the CZK/USD exchange rate from the BVAR model to keep the set of parameters manageable.

To obtain the forecast paths of USD and EUR stock returns, a simple bivariate vector autoregression consisting of stock returns and short-term interest rates is estimated separately for USD and EUR. The STOXX Europe 600 (SXXP) and the 3M Euribor are used in the model for stock returns for the euro area and the S&P 500 and the 3M USD Libor in that for the US.[27] Based on the estimated model, the path of stock returns is computed for each forecast path of the short-term interest rate obtained from the main model. A randomly drawn historical residual estimated within the satellite model is added in each forecasting period to simulate the effect of upcoming shocks and uncertainty in the relationship between stock returns and short-term interest rates.[28] The resulting distributions of the stock return outlook are reported in Figure A3.

[27] The number of lags is selected based on the AIC criterion and equals two for both the EUR model and the USD model. The models are estimated on quarterly data over the period 1998Q4–2017Q4 and the resulting forecast paths are then averaged into yearly projections.

[28] Generating a forecast path of stock returns for a given path of the interest rate is basically hard-conditioning. However, we stick to the simpler procedure described in the text. Our approach ignores the estimated covariance between the residuals.

Figure A3: Distribution of Stock Return Forecasts



Note: The thin black line depicts a randomly drawn forecast path.

The motivation for modelling stock returns based on the interest rate outlook is twofold. First, such a model set-up – even though very simplistic – can capture a negative short-run relationship between interest rates and stock returns. Second, the wider confidence bands for stock returns in comparison to interest rates (see Figure A5) hint at the higher riskiness associated with stock holdings. Stochastic simulations allow us to introduce the possibility of substantial losses on stock holdings. A randomly drawn forecast path for the SXXP stock return in Figure A3 (the thin black line) shows that the stochastic framework allows for a situation of negative returns lasting several years, as observed, for example, during the Great Recession of 2008.

Similarly to stock returns, a bivariate VAR is used to generate forecast paths of the CZK/USD exchange rate. The CZK/USD exchange rate is not included in the core model because the model is not intended to model the world economy. On the other hand, a bivariate model consisting of the CZK/EUR and CZK/USD rates can to some extent capture the high correlation between the two, and the close relationship is thus transferred into the stochastic simulations.[29] The resulting distribution of the CZK/USD exchange rate appreciation/depreciation outlook is reported in Figure A4.

[29] The number of lags is selected based on the AIC criterion and equals two lags. The exchange rate enters the model in annualised quarter-on-quarter changes, consistently with the form of the CZK/EUR rate in the main BVAR model. The models are estimated on quarterly data over the period 1998Q1–2017Q4 and the resulting forecast paths are then averaged into yearly projections.

Figure A4: Distribution of CZK/USD Exchange Rate Growth Forecasts

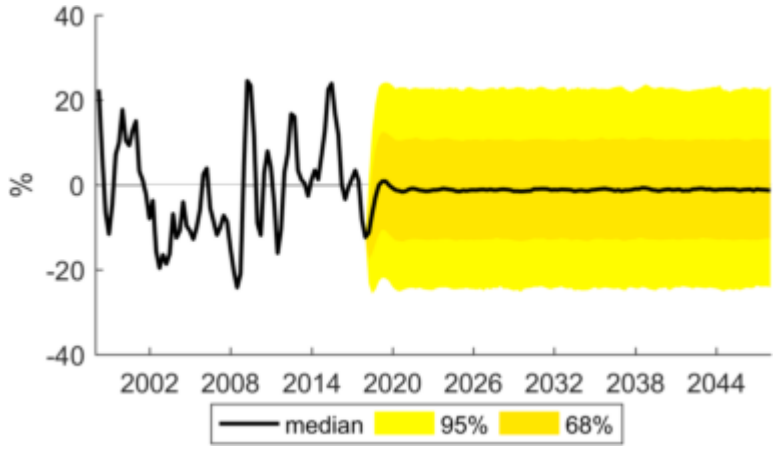


Figure A5 shows the projected distributions of the macroeconomic variables that serve as an input into the simulation of the balance sheet. They combine the deterministic path described in the main text and the forecast paths generated by the BVAR and satellite models. Regarding the forecast paths, some issues are worth noting.

The forecast paths for one-year foreign interest rates are taken from the model with the three-month rate. The use of the forecast paths of the three-month rate includes the assumption that the three-month and one-year rates experience similar shocks and transmission, i.e. that the difference between the two is constant. The demeaning procedure then produces the forecast path applicable to interest rates for one-year government bonds. Next, the underlying macroeconomic model includes only the Euribor and not the US dollar interest rate. The simulated distribution of the Euribor is applied to the USD rate as well. The same path as for the Euribor is taken for the US interest rate in the benchmark specification. As a robustness check, a randomly drawn forecast path of the Euribor is taken as the forecast path for the US interest rate. The results are almost unaffected.

Figure A5: Projected Distributions of Macroeconomic Variables

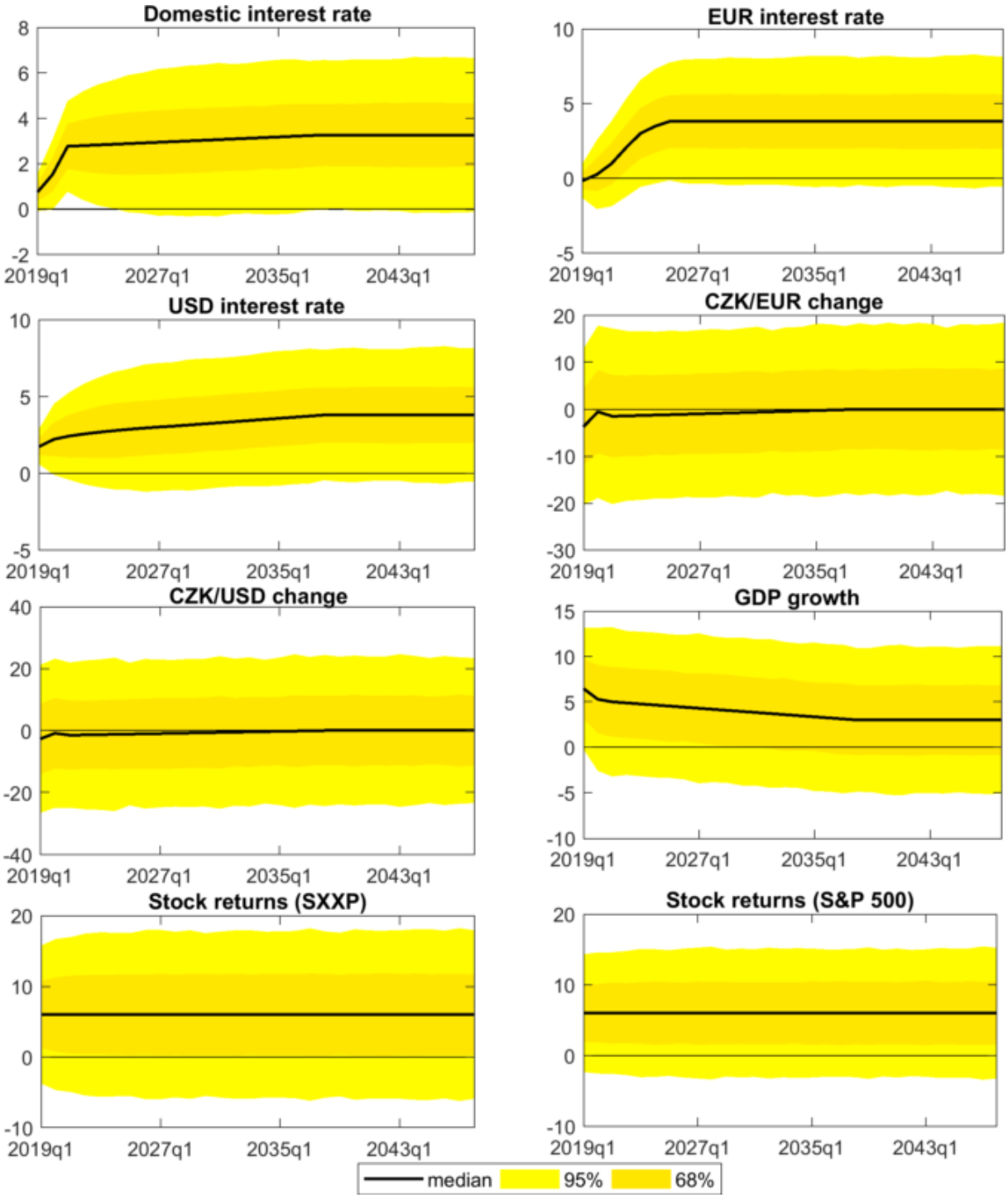


Figure A5 also demonstrates that the effective lower bound on the nominal interest rate is ignored. Combining the forecast paths with the deterministic path defined outside the model precludes sensible treatment of the bound. The interest rates are crucial for the projections, as both income and expenses are directly linked to them. To get some idea of the effect of ignoring the bound, a robustness check is done below in Appendix C by imposing the zero bound for all parts of the interest rate forecast path that lies in negative territory. Note, however, that this adjustment

ignores the impact of changes in the interest rate from negative to zero on other macroeconomic variables and as such can be considered illustrative only.

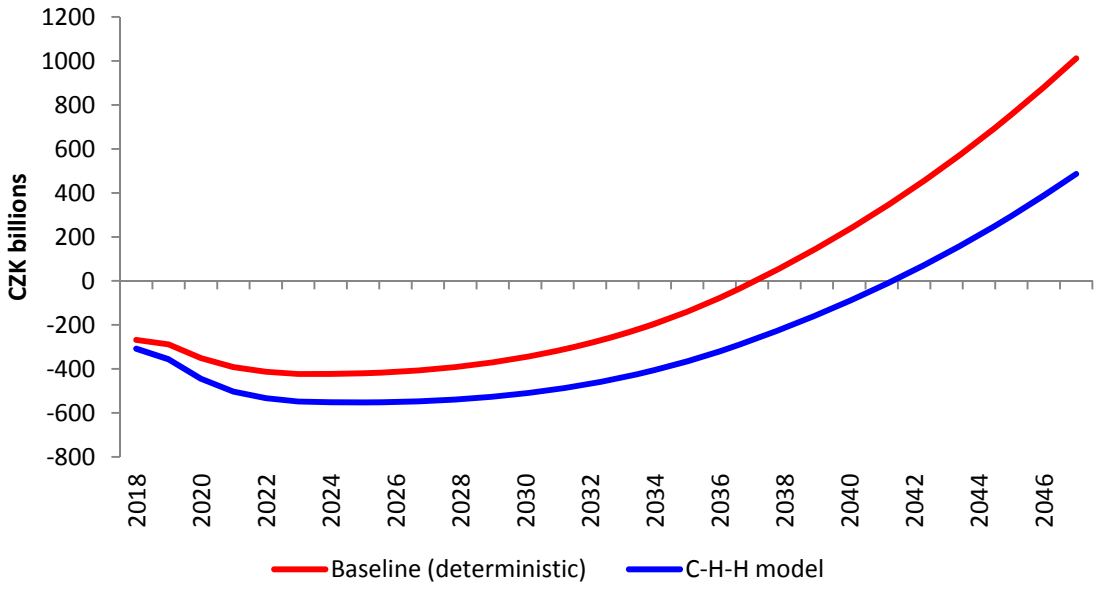
Appendix B: Comparison of the Baseline Simulation with Cincibuch et al. (2009)

In this appendix, we present a comparison of our baseline simulations of the CNB's equity (in the deterministic version) with simulations based on the model from Cincibuch et al. (2009) (referred to as the "C-H-H model"). This exercise serves: (i) as a robustness check of our simulations; (ii) to illustrate the importance of modelling the yields on foreign exchange reserves in a more comprehensive way compared to the C-H-H model.

For the sake of comparability, the C-H-H model was rewritten from quarterly to annual frequency. At the same time, we used the same macroeconomic assumptions as in our baseline simulations wherever relevant. The main difference thus consists in: (i) no distinction between the EUR and USD part of the FX reserves in the C-H-H model; (ii) no reflection of the investment in stock indexes in that model.

As shown in Figure B1, the two models provide a similar time profile for the equity of the CNB, including the peaks in 2023–2025 followed by a gradual return to positive territory. Quantitatively, though, the C-H-H model is somewhat less optimistic than our baseline simulation, with the negative equity peaking at around 8% of annual GDP. This is due to more conservative modelling of the yields on FX reserves in the C-H-H model. However, the projected year of full elimination of the CNB's negative equity differs only slightly: 2038 in our deterministic setting of the baseline simulation and 2042 according to the C-H-H approach. Overall, the differences due to the different modelling approaches seem relatively small compared to the uncertainties related to the underlying macroeconomic assumptions, as highlighted in section 4.

Figure B1: Equity of the CNB – Baseline Simulation vs. Cincibuch et al. (2009) Model

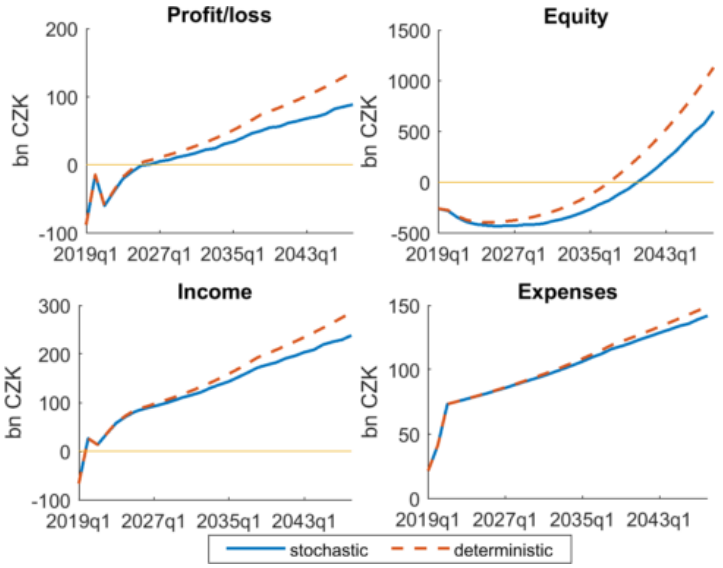


Appendix C: Additional Results

This appendix presents several sensitivity checks. The first check concerns the difference between the deterministic and stochastic simulations. The deterministic simulation implicitly assumes that the macroeconomic outlook underlying the balance sheet simulation is known with certainty. Importantly, as the system of accounting identities is nonlinear, the deterministic path and the median of the stochastic projection need not be equal. The nonlinearity of the system (see, for example, the equation for the evolution of money in circulation) in general implies skewness of the distributions of income statement and balance sheet items. And for skewed distributions some basic identities with medians cease to hold. For example, in the defining relationship of equity as the difference between assets and liabilities, the median of the equity distribution does not have to correspond to the difference in the medians of the distribution of assets and liabilities. The equity projection in the deterministic setting can thus differ from the median equity projection in the stochastic setting.

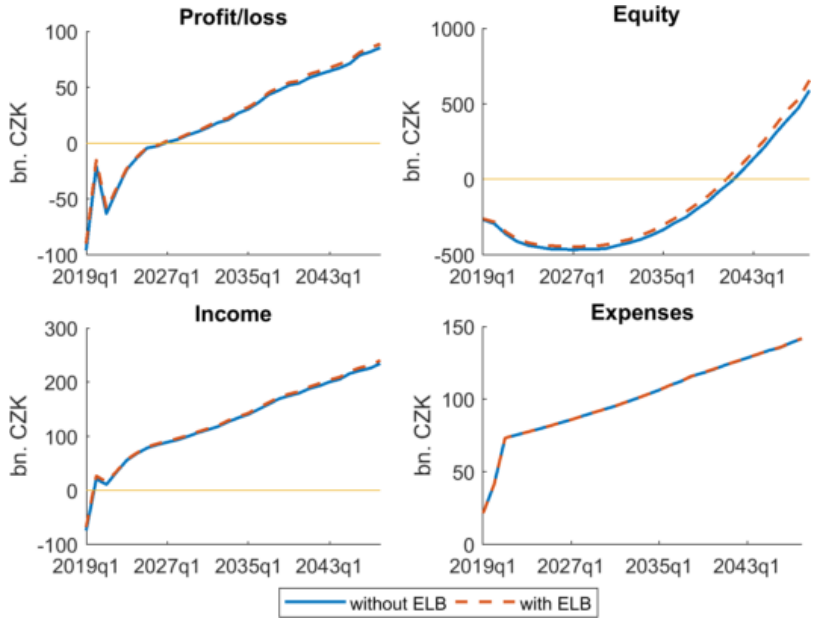
Figure C1 shows the medians of CNB balance sheet and income statement items in the stochastic setting and their deterministic counterparts and demonstrates that relying on deterministic simulation could underestimate the duration of the negative equity period for this specific exercise.

Figure C1: Deterministic and Stochastic (median) Simulations



The second check relates to the zero lower bound on the nominal interest rate (ZLB). As shown in Figure A5, a portion of the possible realisations of future interest rate paths attain negative values. The following figure demonstrates that accounting straightforwardly for the ZLB by imposing zero whenever the outlook is negative does not have a substantial effect on the projected variables. The fact that the ZLB is not accounted for in the main text is therefore not an important issue.

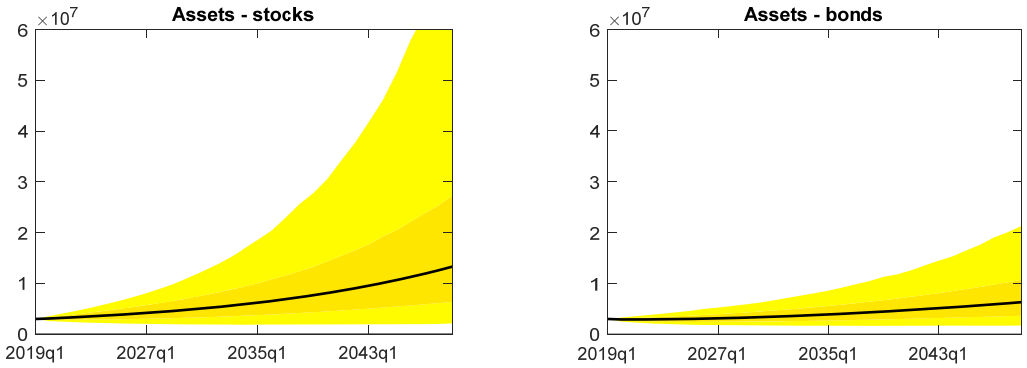
Figure C2: Simulations without and with the ZLB



Appendix D: Notes on the Composition of the FX Reserves

Stochastic simulations of the balance sheet can be employed to contribute to the discussion of the composition of the asset side of the balance sheet. All the simulations presented in the main text are based on the assumption that foreign government bonds comprise 90% of assets and the rest is invested in a stock portfolio. Comparing the projections for different stock-bond ratios can help to frame the discussion underlying the asset management. Note, however, that the satellite model for stock returns employed by the simulation tool is very simple, so a more detailed quantitative analysis of the stock-bond composition is not pursued in this paper.

Figure D1: Stochastic Projections of the Asset Side

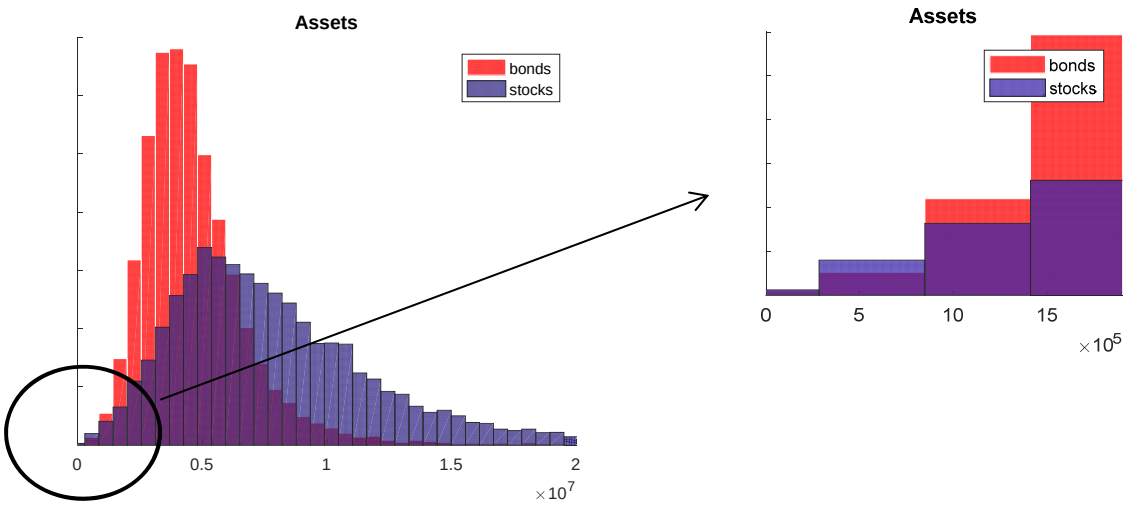


Note: The median (black line) and the 68% and 95% confidence intervals (shades of yellow) are presented.

To shed some light on the effect of various FX reserves compositions, two extreme cases are examined – the situation where assets consist of stocks only and that where they are made up

solely of foreign government bonds. Figure D1 reports the stochastic projections of the asset side in the two cases. It turns out that the median projection is higher in the case of FX reserves fully invested in stocks. On the other hand, wider confidence bands can be observed, as holding stocks is a more risky option.

Figure D2: Distribution of the FX Reserves in 20 Years



To directly compare the two cases, Figure D2 shows the simulated distributions of FX reserves after 20 years in the cases where the CNB holds stocks only and foreign bonds only. Holding stocks only, there would be higher probability of a higher CZK value of FX reserves holdings (left panel). Furthermore, a slightly higher probability of a very low value of FX reserves is estimated in the same situation (right panel).

The difference in the probability of a very low value of FX reserves for stocks and for bonds is not substantial. This observation is a consequence of an important channel that should be taken into account when considering the optimal stock-bond ratio. Assuming a negative relationship between stock returns and bond yields, lower stock returns are associated through higher foreign bond returns and the UIP condition with depreciation of the domestic currency and thus with higher returns on the asset side of the central bank balance sheet. The exchange rate thus moderates the central bank loss associated with a decrease in stock returns.[30]

[30] Other links affect the central bank balance sheet in the case of a fall in stock returns. For example, the open economy IS curve suggests that an increase in the foreign interest rate leads to a fall in domestic output gap, which negatively affects seigniorage revenues and consequently leads to lower central bank profit. The estimated model, however, suggests that the link implying higher profits due to exchange rate depreciation dominates.

CNB WORKING PAPER SERIES (SINCE 2017)		
10/2018	Michal Franta Tomáš Holub Branislav Saxa	*Balance sheet implications of the Czech National Bank's exchange rate commitment*
9/2018	Dominika Kolcunová Tomáš Havránek	*Estimating the effective lower bound for the Czech National Bank's policy rate*
8/2018	Volha Audzei Sergey Slobodyan	*Sparse restricted perception equilibrium*
7/2018	Tibor Hlédik Jan Vlček	*Quantifying the natural rate of interest in a small open economy – The Czech case*
6/2018	Václav Brož Michal Hlaváček	*What drives distributional dynamics of client interest rates on consumer loans in the Czech Republic? A bank-level analysis*
5/2018	Lukáš Pfeifer Martin Hodula	*Profit-to-provisioning approach for setting the countercyclical capital buffer: The Czech example*
4/2018	Ivan Sutóris	*Asset prices in a production economy with long run and idiosyncratic risk*
3/2018	Michal Franta	*The likelihood of effective lower bound events*
2/2018	Soňa Benecká Ludmila Fadejeva Martin Feldkircher	*Spillovers from euro area monetary policy: A focus on emerging Europe*
1/2018	Jan Babecký Clémence Berson Ludmila Fadejeva Ana Lamo Petra Marotzke Fernando Martins Pawel Strzelecki	*Non-base wage components as a source of wage adaptability to shocks: Evidence from European firms, 2010-2013*
16/2017	Oxana Babecká Kucharčuková Renata Pašalićová	*Firm investment, financial constraints and monetary transmission: An investigation with Czech firm-level data*
15/2017	Václav Brož Lukáš Pfeifer Dominika Kolcunová	*Are the risk weights of banks in the Czech Republic procyclical? Evidence from wavelet analysis*
14/2017	Jan Babecký Kamil Galuščák Diana Žigraiová	*Wage dynamics and financial performance: Evidence from Czech firms*
13/2017	Peter Claeys Bořek Vašíček	*Transmission of uncertainty shocks: Learning from heterogeneous responses on a panel of EU countries*
12/2017	Michal Dvořák Luboš Komárek Zlatuše Komárková Adam Kučera	*Longer-term yield decomposition: An analysis of the Czech government yield curve*
11/2017	Jan Brůha Michal Hlaváček Luboš Komárek	*House prices and household consumption: The case of the Czech Republic*
10/2017	Jan Brůha Oxana Babecká Kucharčuková	*An empirical analysis of macroeconomic resilience: The case of the great recession in the European Union*
9/2017	Simona Malovaná	*Does monetary policy influence banks' perception of risks?*

	Dominika Kolcunová Václav Brož	
8/2017	Simona Malovaná	*Banks' capital surplus and the impact of additional capital requirements*
7/2017	František Brázdik Michal Franta	*A BVAR model for forecasting of Czech inflation*
6/2017	Jan Brůha Moritz Karber Beatrice Pierluigi Ralph Setzer	*Understanding rating movements in euro area countries*
5/2017	Jan Hájek Roman Horváth	*International spillovers of (un)conventional monetary policy: The effect of the ECB and US Fed on non-Euro EU countries*
4/2017	Jan Brůha Jaromír Tonner	*An exchange rate floor as an instrument of monetary policy: An ex-post assessment of the Czech experience*
3/2017	Diana Žigraiová Petr Jakubík	*Updating the ultimate forward rate over time: A possible approach*
2/2017	Mirko Djukić Tibor Hlédik Jiří Polanský Ljubica Trajčev Jan Vlček	*A DSGE model with financial dollarization – the case of Serbia*
1/2017	Michal Andrle Miroslav Plašil	*System priors for econometric time series*

CNB RESEARCH AND POLICY NOTES (SINCE 2017)

1/2017	Mojmír Hampl Tomáš Havránek	*Should inflation measures used by central banks incorporate house prices? The Czech National Bank's approach*
2/2017	Róbert Ambriško Vilma Dingová Michal Dvořák Dana Hájková Eva Hromádková Kamila Kulhavá Radka Štiková	*Assessing the fiscal sustainability of the Czech Republic*

CNB ECONOMIC RESEARCH BULLETIN (SINCE 2017)

May 2018	*Risk-sensitive capital regulation*
November 2017	*Effects of monetary policy*
May 2017	*Trade and external relations*

Czech National Bank
Economic Research Division
Na Příkopě 28, 115 03 Praha 1
Czech Republic
phone: +420 2 244 12 321
fax: +420 2 244 12 329
http://www.cnb.cz
e-mail: research@cnb.cz
ISSN 1803-7070