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2008

WORKING PAPER SERIES 3

2008

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CNB CZECH NATIONAL BANK

WORKING PAPER SERIES

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3/2008

CNB WORKING PAPER SERIES

Printed and distributed by the Czech National Bank. Available at http://www.cnb.cz.

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Central Bank Losses and Economic Convergence

Martin Cincibuch, Tomáš Holub and Jaromír Hurník*

Abstract

This paper discusses the issue of central bank losses, developing a framework for assessing the ability of a central bank to keep its balance sheet sustainable without having to default on its policy objectives. Compared to the earlier literature, it analyses in more depth the consequences of economic convergence for the evolution of the central bank's balance sheet and the important role played in this process by the risk premium and equilibrium real exchange rate appreciation. A combination of a closed-form comparative-static analysis and numerical solutions of the future evolution of the central bank's own capital is used. Applying the framework to the Czech National Bank's case, the paper concludes that the CNB should be able to repay its accumulated loss in about 15 years without any transfer from public budgets.

JEL Codes: E52, E58.
Keywords: Balance sheet, central bank, economic convergence, monetary policy, real appreciation, risk premium, seigniorage, transition.

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This work was supported by the Czech National Bank.
We have benefited from valuable comments by Luděk Niedermayer, Jan Schmidt, Peter Stella, Zdeněk Tůma, and Eva Zamrazilová. We thank Jiří Beránek, Magda Gregorová, Miloslav Lorenc, Michal Koblas, Ladislav Mocháň, Ivona Nováčková, and Rimma Svobodová for helping us with the Czech National Bank trading and accounting data. All errors and omissions are ours. The views expressed in this paper are those of the authors and do not necessarily represent those of the Czech National Bank.

Nontechnical Summary

The motivation of this paper was the observation of systematic losses incurred by central banks of relatively low-inflation economies converging towards the developed world. Central bank losses and negative capital have become an important issue of policy debate, reflecting the experience of numerous central banks across the world. This issue is highly relevant to the CNB, because of the large accumulated loss in its balance sheet.

We analyse the economic sources of the central bank's losses while abstracting from the potential fiscal or quasi-fiscal reasons. In a consistent framework we discuss what real GDP growth, price level convergence, the risk premium and its trend decline, and disinflation mean for the central bank's balance sheet. We present a closed-form comparative-static analysis as well as numerical projections of the central bank's own capital. To do so, we link the balance-sheet model with the CNB's macroeconomic forecast published in its Inflation reports. Such an approach has not been used in earlier papers. Also, in comparison with earlier literature the present analysis is more in-depth as regards the consequences of economic convergence and the role played by the risk premium and equilibrium real exchange rate appreciation for central bank financial performance.

Our framework can be used for assessing the sustainability of the central bank's finances. In the Czech National Bank's case, we conclude that the CNB should be able to repay its accumulated loss without transfers from public budgets. This is important, because any government participation in central bank financing could constrain the bank's operational independence. In addition, we describe the historical experience of the CNB and compare the historical simulations based on our model with the actual history of the CNB's balance sheet.

While the CNB's case has many specific features and the conclusions reached in our paper may not be directly transferable to other central banks, the derived framework itself is fairly general and could be successfully applied to other countries' experience.

In a separate section of the article, we elaborate on the consequences of potential EMU membership for the entering bank's balance sheet. We separately discuss both the economic and institutional aspects. As regard the economic side, it is possible to amend our model using the restrictions on exchange rates, interest rates and the risk premium implied by EMU membership. On the other hand, the balance sheets of the participating National Central Banks are affected by ESCB monetary income redistribution rules. Overall for the CNB, the effect of euro adoption seems to be ambiguous. While the economic factors would imply faster repayment of the CNB's accumulated loss, the institutional factors are likely to push in the other direction. The actual outcome may depend on many assumptions, including the development of monetisation both in the Czech Republic and in the euro area, the number of countries in the euro area, etc. Some of the simulations that we carried out suggested that euro adoption would on balance speed up the repayment of the CNB's loss marginally, by about 2 years. Moreover, because of the elimination of the exchange rate risk the repayment would be more certain. We do not make any normative conclusions, however, because the better prospects for the CNB's loss repayment in the euro area partly stems from higher inflation.

1. Introduction

While under *standard* circumstances a central bank should operate at a profit, numerous central banks have faced substantial losses that have deteriorated their balance sheets and led to an accumulation of negative capital over recent decades. This has naturally raised the issue of whether a central bank can successfully conduct its monetary policy even with a negative level of its own capital.

This issue is highly relevant to the Czech National Bank (CNB), too, as it has incurred considerable losses since 2000, and it is currently operating with substantially negative own capital. At the end of 2007, its accumulated loss stood at CZK 200 bn., which is equivalent to 57% of the currency in circulation, or 6.7% of nominal GDP. Its negative own capital was only slightly lower, at CZK 176 bn.

The aim of this paper is to provide a practical framework for assessing the ability of a central bank to keep its balance sheet sustainable without having to default on its policy objectives given the current level of its own capital and the economic prospects. It builds on Holub (2001b), Bindseil, Manzanares and Weill (2004), and Ize (2005). While the basic rules that govern central bank financing are derived in those articles, the present paper avoids some simplifications of the central bank's balance sheet and the short cuts used in the macroeconomic context that may constrain the use of those earlier papers for practical analyses of a central bank's own capital.

In particular, the present paper discusses in more detail the consequences of economic convergence for the evolution of the central bank's balance sheet. Economic convergence typically includes some combination of GDP catch-up from an initially low level along with price level convergence, which means real exchange rate appreciation, a high – but gradually decreasing – risk premium on domestic assets, some progress with disinflation, relatively fast growth of currency in circulation supported by fast GDP growth and increasing monetisation of the economy, etc. All these factors have implications for the central bank's financial performance, but the present paper stresses above all the important role played by the risk premium and equilibrium real exchange rate appreciation. It also provides both a closed-form comparative-static analysis and numerical solutions of the future evolution of the central bank's own capital, exploiting some complementarities of the two approaches which have not been combined in earlier papers.

The paper applies the derived framework to the example of the CNB. We show that under most plausible scenarios the CNB will be able to repay its current losses at the horizon of approximately 15 years out of its future profits. While the CNB's case has many specific features, the framework itself is fairly general, and we thus believe it could be successfully applied to other countries' experience, too. We also show that our model was able to account well for the historical development of the CNB's actual balance sheet.

The rest of this text is organised as follows. Section 2 elaborates on the existing literature regarding central bank financing and discusses the extensions that are made in this paper. In section 3, we build a comprehensive model of a central bank's balance sheet, discuss the consequences of economic convergence and derive basic rules for the evolution of the central bank's own capital ratio. Section 4 is devoted to the specific case of the CNB. It describes the historical experience of the CNB and it compares the historical simulations based on our model with the actual history of the CNB's balance sheet. Furthermore, we attempt to find out how the CNB's own capital may evolve in the future. To do so, we link the balance-sheet model with the CNB's macroeconomic forecast published in its inflation reports. Then, in section 5, we elaborate on the consequences of potential EMU membership for the entering bank's balance sheet. Finally, section 6 concludes.

2. Existing Literature and New Developments

This section provides some references which may be useful for understanding the relationship of the present paper to earlier work. It does not, however, set out to provide a comprehensive summary of the existing literature on central bank capital, as this can be easily found, for example, in Bindseil, Manzanares and Weill (2004).

The economic literature has long discussed the potential sources of central bank losses and corresponding remedies. A classical reference as regards the quasi-fiscal origins of the losses is Fry (1993). Quasi-fiscal operations were also explored in Mackenzie and Stella (1996). Stella (1997) and Dalton and Dziobek (1999) concentrated on describing some particular cases and their particular solution, mainly by central bank re-capitalisation. Central bank quasi-fiscal operations in the case of transition economies were discussed, for example, in Markiewicz (2001).

Recently, the literature has started to focus more on the losses related to the high and growing foreign exchange reserves in many countries. Holub (2001a) decomposed central banks' profits/losses into seigniorage (monetary income), the costs associated with holding net foreign exchange assets, quasi-fiscal operations and operating costs, and applied this decomposition to the CNB's case. He concluded that the opportunity costs associated with foreign exchange reserves consumed about two thirds of the CNB's monetary income between 1993 and 1999. Hawkins (2003) mentioned sterilised foreign exchange interventions as a special case of quasi-fiscal activities by central banks that could lead to losses. Higgins and Klitgaard (2004) discussed the costs and risks of accumulating reserves, focusing mainly on Asian central banks. Exchange rate losses were also discussed in Frait (2005), Stella and Lönnberg (2008), and for some particular countries in Stella (2008).[1]

An important stream of literature has analysed the net present value of central banks (see Fry, 1993; Stella, 1997; Schmitt-Grohé and Uribe, 1999), thus de-emphasising their current profits and own capital and highlighting intertemporal solvency. A positive net present value in fact means that the central bank will generate sufficient profits from seigniorage in the future to repay current losses, and the negative own capital at present does not mean a solvency problem. Cincibuch and Vávra (2001) applied this concept to a transition economy, in particular to the Czech Republic, and concluded that the net present value of the CNB's monetary income was between CZK 360 bn. and 1800 bn. (i.e. between 16% and 82% of annual GDP in the year 2000), depending on the macroeconomic scenario chosen for the calculation.

While the net present value approach is theoretically appealing, it is too far from the actual accounting practices of central banks and does not explicitly analyse the development of their own capital over time. It also ignores the possible policy implications and credibility issues arising from the negative own capital of a central bank if there is no prospect of repayment in the foreseeable future. Stella (1997) discussed the need for central bank capital and articulated the possibility of inflation control being abandoned in reaction to the worsening of a central bank's balance sheet.[2] Holub (2001b) also dealt with the link between the evolution of a central bank's capital and its ability to perform its policy goals, analysing the sustainability of the

[1] See also *The Economist* (2005) for a popular discussion of these issues.
[2] More recent contributions include Stella (2005) and Stella (2008).

central bank's financial situation. Sims (2003) analysed some scenarios under which a central bank might lose control of inflation, and argued that the presence of such scenarios legitimises attention to the balance sheet by a central bank that does not have reliable fiscal backing. Stella and Lönnberg (2008) used the term "policy insolvency" to describe situations in which a central bank's policy decisions are affected by its financial condition.

Bindseil, Manzanares and Weill (2004) developed a model of central bank financing based on the evolution of a central bank's balance sheet in a basic macroeconomic context. Similarly, Ize (2005) sets a formal framework for the calculation of the minimum level of central bank capital needed to ensure the credibility of a central bank's inflation target. Frait (2005) discussed the consequences of negative central bank capital using the particular example of the CNB, concluding that its negative capital has so far not damaged monetary policy credibility in the Czech Republic and that it can be offset by future CNB profits.

In the present paper, we sum up the conclusions of Holub (2001b), Bindseil, Manzanares and Weill (2004) and Ize (2005) and use them to build up a more advanced framework for the modelling of the central bank balance sheet. We thus describe the approaches of these three papers in more detail here.

Bindseil, Manzanares and Weill (2004) pointed out that the connection between the level of a central bank's capital, its credibility and the possibility of abandonment of inflation control had not been well argued and formalised in the earlier literature. To overcome this problem they introduced a formal framework consisting of a simplified central bank balance sheet and a simple macroeconomic model based on the Wicksellian relationship between inflation and interest rates. The connection between the credibility of the central bank (i.e. its control over inflation) and its financing goes via the public's trust in the worth of money. It is argued that a loss-making central bank is simply not believed to ignore its balance sheet while conducting monetary policy. The danger of a deflationary trap is used as an example where the central bank may inflate deliberately. In addition, Bindseil, Manzanares and Weill (2004) argue that after a period of protracted losses, private perceptions of the risk of the central bank losing the right to issue legal tender may emerge.

Although the framework of Bindseil, Manzanares and Weill (2004) is theoretically useful, it is based on some assumptions that may be too strong to be applied for practical simulations. From a fundamental perspective, a striking constraint may be the assumed stability of the public's demand for legal tender. Indeed, it is hard to believe that higher inflation caused deliberately by the central bank to improve its financing would not lead to currency substitution and thus limit the increase in monetary income. From a practical perspective, the balance sheet and the macroeconomic model seem to be too simple to provide a reliable simulation of a central bank's balance sheet given its current state and the likely economic outlook. This holds especially in the case of an open economy, as Bindseil, Manzanares and Weill (2004) do not work explicitly with the exchange rate and the risk premium. It will become evident later that the extension of the analysis to economies with systematic negative pressure on the central bank's balance sheet, i.e. economies that face a non-zero risk premium or systematic changes in the real exchange rate, influences the results significantly.

In contrast with Bindseil, Manzanares and Weill (2004), Holub (2001b) and Ize (2005) in their analyses do give a prominent role to the risk premium (in combination with the structure of the central bank's balance sheet) as a key determinant of central bank profits. They do not, however, explicitly deal with the role of the real exchange rate trend. Unlike Bindseil, Manzanares and Weill (2004), they do not provide simulations of central bank capital. Instead, they concentrate on the analytical exposition of the evolution of central bank capital over time and its convergence to steady-state values. In doing so, they highlight the importance of the difference between the domestic interest rate and the growth rate of currency in circulation, as well as the level of central bank profits with zero own capital ("core profits" in the terminology of Ize, 2005).

Ize (2005), who formalises the policy implications of the model more explicitly than Holub (2001b), develops the concept of "core capital", i.e. the minimum capital needed by a central bank to ensure the credibility of its inflation target. Core capital is a function of the central bank's operating expenditures and the carrying cost of its international reserves. Although we build on this principle, there are simplifications that we aim to overcome. First, in addition to core capital, Ize (2005) introduces a variable called "core inflation", which serves as a link between core capital and the central bank's credibility. "Core inflation" plays the role of a policy variable that may be adjusted to keep the central bank's capital in positive values. The possibility of changes in foreign exchange reserves is not discussed, even though their ratio to currency in circulation is in fact treated as another policy variable that does not endogenously evolve over time. Second, similarly to Bindseil, Manzanares and Weill (2004), Ize (2005) assumes money demand to be stable over time, and even deliberately caused inflation does not violate this relationship. Third, it is assumed that in the long run the relative version of purchasing power parity holds. Thus, the risk premium is calculated as the difference between domestic and foreign real interest rates. This simplification, however, does not necessarily hold for a converging economy, where the real exchange rate may follow a trend. Fourth, the case where real growth of currency holdings exceeds the real interest rate is excluded from the analysis as unrealistic. Again, this may not hold for a converging economy, where appreciation of the real exchange rate may cause the real interest rate to fall well below the foreign real interest rate and the monetisation of the economy may be rising at the same time.

Building on Holub (2001b), Bindseil, Manzanares and Weill (2004) and Ize (2005), we extend the model in several aspects. First, we introduce a coherent open-economy framework and economic convergence issues into the analysis. These bring the links between the real exchange rate, domestic and foreign real interest rates and the risk premium into the game. Second, we work explicitly with monetary income, which allows for a structured economic discussion of all the particular factors that influence the central bank's balance sheet. Third, we add the sensitivity of money demand to inflation to the analysis. Fourth, we relax the assumption of a strictly exogenous, policy-determined ratio of foreign exchange reserves to currency in circulation. This is done by splitting the foreign exchange reserves into autonomous and discretionary parts. The autonomous part depends on the relationship between the return on the reserves and the growth of currency in circulation, whereas the discretionary part depends on the central bank's decision to make interventions in the foreign exchange market. On the one hand, this split enables us to work with the foreign exchange reserves ratio as another policy variable in addition to "core inflation", calculating a policy frontier of "core inflation" and foreign exchange reserves that must be respected by the central bank. The implication of this extension is straightforward: the central bank may adjust its profitability not only via inflation, but also via its foreign exchange reserves ratio. On the other hand, the autonomous development of the reserves ratio allows us to discuss if such an adjustment is achievable over time in a passive manner, or if it requires some active balance-sheet restructuring actions by the central bank.

All the adjustments mentioned above are made with the intention of providing a realistic model that can be used for analyses and dynamic simulations of central bank capital given the current structure of the central bank's balance sheet and a reasonably reliable long-term economic outlook. Knowledge of the future evolution of its own capital is crucial for any central bank operating in the real world. The simulation results show clearly how the structure of the balance sheet is going to evolve in the future and whether active adjustment is necessary for its sustainability. They may also help the central bank to adopt a proper public communication strategy and thus deal with the credibility challenges arising from its negative capital.

3. The Central Bank Balance Sheet in a Converging Country

This section discusses the conditions under which the future stream of gains will save the central bank from indefinite loss accumulation, and when eventually the central bank's loss may follow an explosive path.

We start our exposition with the balance-sheet model that is used later on for simulations. For a better understanding, however, we develop a detailed analytical framework, too. Both the balance-sheet model and the analytical framework incorporate important features of an open economy on a convergence path.

Let us begin with a schematic balance sheet of a central bank decomposed into its local currency and foreign exchange parts. Obviously, the value of the net foreign exchange assets (denoted by $NFXA_t$) is always financed by the net local currency liabilities (NCL_t) and own capital (OWN_t).

Denote the interest-bearing part of net local currency liabilities by $NIBL_t$. This consists of the reserve accounts of commercial banks with the central bank, the net liability stemming from open market operations, and the net local currency liabilities vis-à-vis the government and clients.

On the other hand, the non-interest-bearing liabilities consist mainly of the currency stock ($M0_t$). For the sake of simplicity, we assume that the other non-interest-bearing liabilities[3] may for practical purposes be subsumed into own capital OWN_t.

Consequently, we have the following stylised balance sheet of the central bank.

$$NFXA_t = NCL_t + OWN_t = NIBL_t + M0_t + OWN_t. \tag{3.1}$$

This means that the own capital in our definition is expressed as the difference between the bank's net foreign exchange assets and net local currency liabilities.

$$OWN_t = NFXA_t - NIBL_t - M0_t. \tag{3.2}$$

In order to predict the future path of own capital OWN one needs to make projections of the three components on the right-hand side of (3.2).

It is worth mentioning that the net foreign exchange assets and net local currency liabilities in the balance sheet (3.2) are separated, unless the bank carries out foreign exchange operations on its own account. This separation facilitates the linking of OWN_t to a macroeconomic projection.

[3] Depending on the local situation, banks' reserve accounts may be a part of non-interest-bearing liabilities, which could be treated as part of $M0_t$.

3.1 Net Local Currency Liabilities

Unless the central bank buys foreign exchange on its own account in amounts INT_t, the net local currency liabilities in the central bank's balance sheet can change between two periods only because of interest paid, operating outlays and dividend payments to the Treasury.

As regards the interest rate, we assume that the main open market operations, banks' current accounts and other remunerated claims on the central bank carry the same interest[4]. Let this prevailing local short-term interest rate be denoted by i_t.

Further, we denote by OL_t the operating outlays that are necessary to sustain the mere functioning of the central bank, and finally by DIV_t the dividend payments to the Treasury (or some quasi-fiscal operations of the central bank) in the period t. Summing up, one may write a recursive relation that governs this part of a central bank's balance sheet

$$NCL_{t+1} = NCL_t + NIBL_t i_t + OL_t + DIV_t + INT_t \tag{3.3}$$

At the same time, NCL_t consists of net interest-bearing liabilities $NIBL_t$ and $M0_t$. The demand for money links $M0_t$ to the volume of transactions in the economy and to the interest rate, while $NIBL_t$ becomes a residual item.

As usual, we approximate the transaction volume by the value of gross domestic product and we also assume that the demand for money is negatively related to the interest rate. If P_t is the price level then we write

$$M0_t = m_t P_t GDP_t. \tag{3.4}$$

where monetisation m_t is given by

$$m_t = ce^{-\alpha i_t}. \tag{3.5}$$

3.2 Net Foreign Exchange Assets

We assume that the international reserves of the central bank are invested in assets denominated in N different currencies. Let us denote by Q_t^i the size of the i-th currency portfolio and by S_t^i the exchange rate of the i-th currency vis-à-vis the local currency at time t. Therefore, the local currency value of the foreign reserves is given by

$$NFXA_t = \sum_{i=1}^{N} S_t^i Q_t^i \tag{3.6}$$

Assume that the currency allocation of the reserve assets is given exogenously by the reserves management policy. If x_t^i is the share of the i-th currency in the overall portfolio, then

$$S_t^i Q_t^i \;\; = \;\; x_t^i NFXA_t \tag{3.7}$$

[4] We thus assume away any implicit taxation on the banking sector due to unremunerated required reserves. Note that the required reserves, which are the bulk component of current accounts, are indeed remunerated at the main policy interest rate in the Czech Republic. This assumption also rules out any quasi-fiscal operations in the form of preferential loans to the government, banking sector, etc. This is justified given our focus on foreign exchange reserves-related losses, but may not be realistic for many countries. A generalisation would be straightforward, though (see e.g. Holub, 2001a).

The value of the net foreign exchange reserves $NFXA$ is affected by exchange rate changes and by the reserves' own return; let the net foreign currency return of the i-th portfolio be R_t^i. Then the local currency value of the foreign exchange reserves in the next period is given by

$$NFXA_{t+1} = \sum_{i=1}^{N} S_{t+1}^i Q_t^i + \sum_{i=1}^{N} S_{t+1}^i Q_t^i R_t^i + INT_t, \tag{3.8}$$

where INT_t indicates the amount of foreign exchange bought by the central bank on its own account in period t.

Taking into account (3.7) we may easily rewrite (3.8) as a law of motion for the local currency value of foreign exchange reserves

$$\begin{aligned} NFXA_{t+1} &= NFXA_t \sum_{i=1}^{N} \frac{S_{t+1}^i}{S_t^i} x_t^i \left(1 + R_t^i\right) + INT_t \\ &= NFXA_t \left(1 + y_t^*\right) + INT_t, \end{aligned} \tag{3.9}$$

where $y_t^* = \sum_{i=1}^{N} \frac{S_{t+1}^i}{S_t^i} x_t^i \left(1 + R_t^i\right) - 1$ is a total net local currency return on the foreign exchange reserves.

For analytical purposes it is also useful to express these relationships using a hypothetical basket currency. Let S_t is the exchange rate of this basket currency vis-à-vis local currency at time t and let Q_t is the size of the basket currency portfolio. Then we rewrite (3.6) as

$$NFXA_t = S_t Q_t, \tag{3.10}$$

and a relationship analogous to (3.8) can be used to define the net basket currency return R_t:

$$NFXA_{t+1} = S_{t+1} Q_t + S_{t+1} Q_t R_t + INT_t. \tag{3.11}$$

Taking into account (3.9), (3.10) and (3.11), one may algebraically solve for the basket-currency exchange rate change and for its return:

$$\frac{S_{t+1}}{S_t} = \sum_{i=1}^{N} \frac{S_{t+1}^i}{S_t^i} x_t^i \tag{3.12}$$

$$R_t = \frac{1}{\sum_{j=1}^{N} \frac{S_{t+1}^j}{S_t^j} x_t^j} \sum_{i=1}^{N} \frac{S_{t+1}^i}{S_t^i} x_t^i R_t^i \tag{3.13}$$

Note that the basket currency exchange rate level can be arbitrarily rebased and consequently the size of the currency portfolio is determined up to the multiplicative constant by (3.6) and (3.10)

3.3 The Dynamics of Own Capital

The dynamics of own capital are easily derived by substituting (3.3) and (3.9) into (3.2). It follows that

$$\begin{aligned} OWN_{t+1} &= NFXA_{t+1} - NCL_{t+1} \\ &= NFXA_t\,(1+y_t^*) + INT_t - NCL_t \\ &- NIBL_t i_t - OL_t - INT_t - DIV_t \\ &= OWN_t + NFXA_t y_t^* - NIBL_t i_t - OL_t - DIV_t \end{aligned} \tag{3.14}$$

In words, central bank losses may arise because of large net local currency interest-bearing liabilities (mainly open market operations to sterilise excess liquidity and current accounts of banks) that finance substantial parts of the foreign exchange assets in a situation where the total yield on foreign exchange assets is lower than the financing costs. Obviously, large operating costs also detract from the profits.

One may note that the variable INT_t, representing foreign exchange operations, cancels out and does not enter *directly* into the calculation of the central bank's profitability in equation 3.14. Therefore, one might in theory consider restructuring the balance sheet to diminish the holdings of foreign exchange assets and repaying the local currency interest-bearing liabilities. In practice, however, the feasibility of this solution could be limited in the short run because of the imperfect liquidity of the foreign exchange market and the related undesired consequences for the exchange rate.[5]

3.4 Real Appreciation, the Risk Premium and Central Bank Profits

The balance-sheet model derived above sets the stage for a discussion of the relationship between the convergence process and the emergence of central bank losses. To achieve this, one needs to invoke two basic equilibrium relationships of international macroeconomics, i.e. the relative version of purchasing power parity and uncovered interest rate parity.

It is a well-known fact that purchasing power parity does not hold empirically unless one allows for changes in the real exchange rate caused by the economic convergence process. We log-differentiate the definition of the (basket) real exchange rate and get

$$\Delta s_t = \Delta q_t + \pi_{t+1} - \pi_{t+1}^*, \tag{3.15}$$

where Δs_t represents the change in the nominal exchange rate of the basket currency, Δq_t the change in the real exchange rate of the basket currency, π_{t+1} domestic inflation and π_{t+1}^* foreign inflation. Indeed, for a converging (catching-up) economy, real appreciation ($\Delta q_t < 0$) is typically observed.

Similarly, we extend the uncovered interest parity condition to capture the existence of the risk premium that inevitably surrounds the convergence process of any less developed economy. As

[5] One possibility without such undesired consequences is to transfer the "excess" foreign exchange assets to the government, e.g. into a sovereign wealth fund, in exchange for domestic interest-bearing assets. This option has indeed been pursued in a few countries. Less ambitious operations aiming at reducing the foreign exchange assets of central banks have been undertaken in Chile and Mexico. The CNB's scheme of selling a portion of its earnings on foreign exchange reserves, which has been in place since 2004, also falls into this category of measures.

the existence of this risk premium is a well-known fact to all market participants it may also be called the predictable excess return. Equation (3.16) captures it.

$$\varphi_t = -\widehat{\Delta s_t} + i_t - i_t^*, \tag{3.16}$$

where φ_t represents the risk premium (predictable excess return), $\widehat{\Delta s_t}$ the expected change in the nominal exchange rate of the basket currency, i_t the domestic nominal interest rate, and i_t^* the foreign nominal interest rate.

In what follows we put

$$\widehat{\Delta s_t} = \Delta s_t, \tag{3.17}$$

which amounts to dealing with a perfect-foresight framework.[6]

The substitution of (3.15) and (3.17) into (3.16) gives for the interest rate

$$\begin{aligned} i_t &= \varphi_t + i_t^* + \Delta s_t \\ &= \varphi_t + i_t^* + \Delta q_t + \pi_{t+1} - \pi_{t+1}^*. \end{aligned} \tag{3.18}$$

For the sake of simplicity in the following text, we identify the money market rate i_t^* with the foreign portfolio return R_t defined in (3.13). With this simplification[7], the composite return derived within (3.9) can be (in a log-differencing approximation) rewritten as

$$y_t^* = \Delta s_t + i_t^*, \tag{3.19}$$

and further using (3.16) it may be rephrased as

$$y_t^* = i_t - \varphi_t. \tag{3.20}$$

Finally, the following expression for the profit and loss before distribution can be derived using the law of motion for the central bank's own capital (3.14), using the relationship (3.20) and the balance-sheet identity (3.2):

$$\begin{aligned} PL_{t+1} &= OWN_{t+1} - OWN_t + DIV_t \\ &= NFXA_t\,(i_t - \varphi_t) - NIBL_t i_t - OL_t \\ &= i_t(M0_t + OWN_t) - \varphi_t NFXA_t - OL_t \end{aligned} \tag{3.21}$$

This expression decomposes central bank profits into seigniorage (monetary income; $i_t M0_t$), earnings on the central bank's own capital ($i_t OWN_t$), losses on net foreign exchange assets due to the risk premium ($\varphi_t NFXA_t$) and operating outlays (OL_t).

Using the expression for the interest rate (3.18) we then arrive at

$$PL_{t+1} = (i_t^* - \pi_{t+1}^* + \Delta q_t + \varphi_t + \pi_{t+1})(M0_t + OWN_t) - \varphi_t NFXA_t - OL_t, \tag{3.22}$$

[6] A generalisation allowing for unsystematic errors in exchange rate expectations would be straightforward (see e.g. Holub, 2001a).

[7] Depending on its investment strategy, the central bank may, by taking on term or liquidity risk and appropriating the ensuing premium, achieve systematically higher returns.

which allows us to clarify the role of the main macroeconomic factors affecting central bank profitability.

The first term on the right-hand side of this equation shows the standard result that a central bank can (if $M0_t + OWN_t > 0$) improve its profitability by increasing domestic inflation[8], which raises its monetary income. However, the equation also shows that the central bank's profit is crucially affected by convergence-related variables in combination with the structure of the central bank's balance sheet. Since this is the primary focus of the present paper, let us elaborate on these issues in more detail.

Provided that $M0_t + OWN_t > 0$, this decomposition shows that appreciation of the real exchange rate (i.e. $\Delta q_t < 0$) reduces central bank profits by decreasing the equilibrium real interest rate in the domestic economy, and thus the seigniorage and earnings on the central bank's own capital.[9] Note that this effect takes place even if the central bank holds zero net foreign exchange assets, i.e. even if there can be no revaluation losses due to an appreciating nominal exchange rate.

It also implies that the trend real appreciation cannot be the sole source of central bank losses, as nominal interest rates cannot be negative. By reducing profits, it can nevertheless make the central bank more vulnerable to losses associated with net foreign exchange assets (or possibly other sources of loss, such as quasi-fiscal operations).

For $M0_t + OWN_t < 0$, i.e. in the case where the central bank is liable when it comes to net interest-bearing claims[10], the real appreciation helps, because it reduces the interest rate which the central bank pays for its net liabilities. However, in this dismal situation, and for $\varphi_t NFXA_t > 0$, it may help only to reduce, not to overturn, the inevitable losses.

Furthermore, equation (3.22) illustrates that the impact of the risk premium enters central bank profits through two channels. First, by increasing the domestic equilibrium interest rate it increases seigniorage and earnings on the central bank's own capital, and thus improves profits. Second, it leads to losses on net foreign exchange assets, thus depressing profits. The overall impact of the risk premium therefore depends on the sign of ($M0_t + OWN_t - NFXA_t$), i.e. whether the size of the central bank's non-interest-bearing liabilities is smaller or greater than its net foreign exchange assets. Note that the above expression is equal to $-NIBL_t$. Therefore, if the central bank has net local currency interest-bearing assets, the risk premium improves its profits. On the other hand, if the central bank has net local currency interest-bearing liabilities, the risk premium may lead to central bank losses. This is true especially if the net foreign exchange assets exceed currency in circulation and the central bank's own capital substantially, necessitating massive sterilisation of the liquidity issued.

3.5 Capital Ratio Dynamics

For a better understanding of the loss dynamics in relation to currency in circulation we derive a detailed analytical exposition, which can be used for a comparative-static discussion of a central bank's financial sustainability. We start with equation (3.14), which, using (3.2) and (3.20), can

[8] This is, of course, true only up to the point at which the increasing inflation leads to demonetisation of the economy strong enough to outweigh the positive direct effect. Holub (2001b) also discusses that this may actually not be true if a higher inflation rate increases the risk premium.

[9] There may be a partly offsetting effect of increased monetisation resulting from the lower opportunity costs of holding the domestic currency. This is, however, unlikely to fully compensate for the direct effect for countries with low inflation rates.

[10] Recall that $M0_t + OWN_t = NFXA_t - NIBL_t$.

be equivalently expressed as

$$OWN_{t+1} = (1 + i_t)OWN_t + i_t M0_t - \varphi_t NFXA_t - OL_t - DIV_t \tag{3.23}$$

Expressing central bank capital as a ratio to the currency stock, which properly reflects its relative importance in the balance sheet (see Holub, 2001b; and Ize, 2005), we get that

$$\frac{OWN_{t+1}}{M0_{t+1}} = \frac{(1 + i_t)}{1 + \mu_t}\frac{OWN_t}{M0_t} + \frac{i_t M0_t - \varphi_t NFXA_t - OL_t - DIV_t}{(1 + \mu_t)M0_t} \tag{3.24}$$

where μ_t is the growth rate of currency in circulation. Assuming that the dividend to the government is non-negative, i.e. that the central bank receives no capital injections from the government, this implies an inequality

$$\frac{OWN_{t+1}}{M0_{t+1}} \leq \frac{(1 + i_t)}{1 + \mu_t}\frac{OWN_t}{M0_t} + \frac{i_t M0_t - \varphi_t NFXA_t - OL_t}{(1 + \mu_t)M0_t}. \tag{3.25}$$

Note that this expression is analogous to the government debt equation when expressed as a ratio to GDP. The second term on the right-hand side is central bank profit if the central bank has zero own capital, which is analogous to the primary surplus of public budgets. Following Ize (2005), we will call this expression *core profits*[11]. The first term on the right-hand side reflects the dynamics of the ratio of capital to currency, which crucially depends on the relationship between the interest rate and currency growth, by analogy with the relationship of the interest rate and economic growth for the public debt-to-GDP ratio.

To assess whether the financial situation of a central bank is sustainable or not, one must evaluate inequality (3.25) for the given exogenous parameters and central bank policy goals. The policy goals naturally include the inflation rate (target), which also has implications for nominal currency growth.

Initially, we will also treat the *nfxa* ratio (i.e. $NFXA_t/MO_t$) as a fully autonomous policy decision of the central bank, which is in line with the approach taken by Holub (2001b) and Ize (2005). This in general implies that the central bank needs to intervene in the foreign exchange markets automatically to keep the *nfxa* ratio at a constant level. This assumption greatly simplifies the first exposition of the problem, as it allows us to treat core profits as a constant. The assumption is, however, not very realistic for most cases, and we relax it later on.

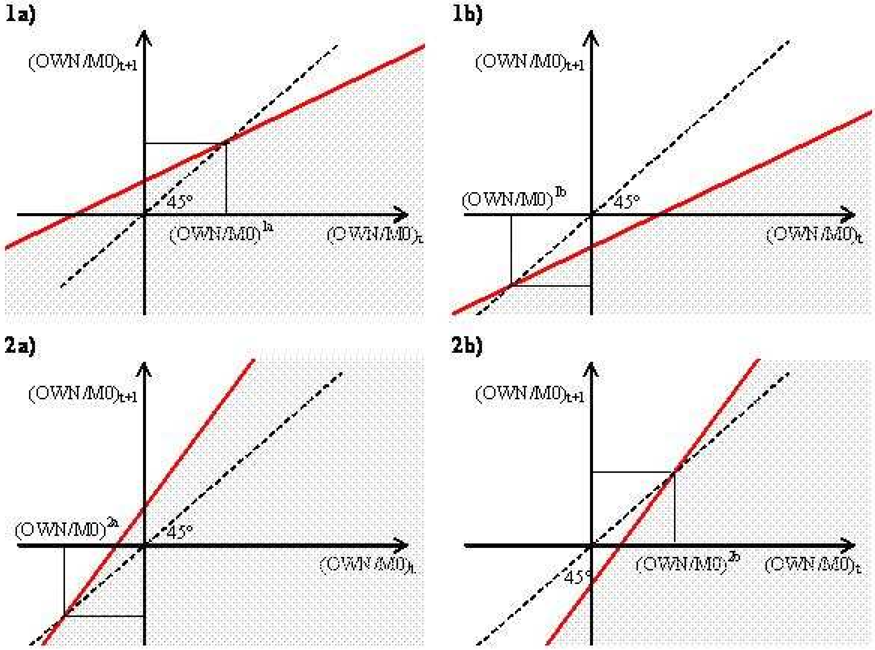
3.5.1 Constant Ratio of Net Foreign Exchange Assets

With this assumption, inequality (3.25) can be illustrated in a simple phase diagram, in which the ratio of central bank capital to currency at time t is put on the horizontal axis and the same ratio at time $t + 1$ is shown on the vertical axis. Inequality (3.25) is the shaded region below the straight red solid line with a slope of $(1 + i_t)/(1 + \mu_t)$ and an intercept given by *core profits*. Based on (3.25), we can differentiate between four cases:

- 1a) currency growth exceeds the nominal interest rate (or equivalently, real currency growth exceeds the real interest rate); "core profits" are positive.

[11] Ize (2005) derives his model in continuous time and in a log-linearised form, which leads to some minor differences compared with our expressions derived in discrete time.

Figure 3.1: Phase Diagram of the Central Bank's "Capital Ratio"



- 1b) currency growth exceeds the nominal interest rate; *core profits* are negative.
- 2a) currency growth is below the nominal interest rate; *core profits* are positive.
- 2b) currency growth is below the nominal interest rate; *core profits* are negative.

These cases are illustrated in the corresponding panels in Figure 3.1, which also include the dashed 45-degree lines representing steady-state points.

In cases 1a and 1b the capital ratio exhibits stable dynamics. The growth rate of currency is high, which means that the relative importance of the starting level of capital gets quickly "eroded" and the capital ratio eventually converges to a steady-state level $(OWN/M0)^{1a}$ or $(OWN/M0)^{1b}$, respectively. This is the maximum level that the capital ratio can achieve in the steady state; lower levels than that can of course be achieved by paying dividends to the government. With positive core profits, i.e. in case 1a, the steady-state level of capital is positive, implying no financial problems for the central bank[12]. With negative core profits, i.e. in case 1b, the situation is much more difficult. The central bank creates losses, which grow over time until the steady-state level of the negative capital ratio is reached. Moreover, a capital transfer to such a loss-making central bank is not a long-run solution, as the fast currency growth tends to decrease the ratio of capital to currency, and thus shifts the central bank back into losses towards the same negative steady-state level of capital.[13] Even with a negative level

[12] Problems could emerge, however, if a negative starting level of central bank capital caused distrust in the currency and thus led to a decline in the currency growth rate or to an increase in interest rates due to a rising risk premium. The situation could then change to case 2a (or even 2b). If the negative net capital of the central bank was below $(OWN/M0)^{2a}$ at that moment, the capital deficit would start to grow at an explosive pace. This would validate the initial distrust in the currency, creating scope for self-fulfilling problems.

[13] Stella (1997) writes that "recapitalization becomes necessary when losses turn chronic", but he also adds that "recapitalization makes sense only when government is committed to adopting other necessary supporting reforms".

of capital $(OWN/M0)^{1b}$ the central bank can function, but there is at least a theoretical danger of a self-fulfilling credibility crisis with a switch to case 2b. A financial collapse of the central bank would follow, or the central bank would have to abandon some of its policy goals. The only permanent solution is to make changes that shift central bank core profits into positive territory, i.e. to shift the situation to case 1a.

Ize (2005) disregards cases 1a and 1b as unrealistic in the long run, arguing that a dynamically efficient economy requires real interest rates above the GDP growth rate, which is likely to exceed the real growth rate of currency in circulation in the modern times of expanding electronic money. In other words, an inequality $(i - \pi) > g > (\mu - \pi)$ is assumed, where g is the real GDP growth rate. While this should be the case in the very long run, i.e. in the ultimate steady state of an economy, along the convergence path of a catching-up economy this need not hold. In a converging small open economy, the equilibrium real interest rate implied by the UIP condition is equal to the equilibrium foreign real interest rate minus the real appreciation trend plus the risk premium (3.18), i.e. to $(i^* - \pi^* + \Delta q + \varphi)$. Even if the foreign real interest rate exceeds the foreign economic growth rate, the domestic real interest rate may be smaller than the foreign one if the risk premium is sufficiently small and real appreciation relatively fast. Moreover, GDP growth is faster in a converging economy, making the inequality less likely to hold. Finally, the monetisation of the economy may be growing during a convergence process, in many cases supported by progress with disinflation, and with it currency growth may exceed the GDP growth rate. Putting all this together, an inverse inequality $(i - \pi) < g < (\mu - \pi)$ may actually hold for a relatively long period of time during the convergence process.

Proceeding to the other two cases, 2a and 2b, the capital ratio exhibits explosive dynamics. Interest rates are higher than currency growth, which means that the central bank profits/losses are more than sufficient to create additional positive/negative capital to *cover* the newly issued currency. This implies that the deviations of the capital ratio from its steady-state levels tend to magnify themselves over time. More precisely, this is true only for downward deviations, as higher-than-steady-state capital ratios can easily be solved by paying dividends to the government. Case 2a with positive core profits can be regarded as the standard profit-making central bank situation. The central bank can permanently maintain any capital ratio above a certain negative threshold level $(OWN/M0)^{2a}$. A problem arises only if a shock shifts the central bank capital below $(OWN/M0)^{2a}$. Then the situation becomes unstable. A recapitalisation of the central bank would be a permanent solution in this case, though.

With negative core profits, i.e. in case 2b, the critical level of capital is positive. The central bank generates core losses, which must be compensated by earnings on its own capital[14]. Otherwise, the losses start growing, the capital declines and eventually the central bank financially collapses, or is forced to give up its policy goals. The own capital thus must be above $(OWN/M0)^{2b}$ in this situation. An alternative, of course, is to reduce the central bank's costs in some way in order to achieve positive core profits and move to situation 2a.

The steady-state values of the capital ratio can be expressed from equation (3.24) as

$$own = \frac{i - \varphi nfxa - ol}{\mu - i} \tag{3.26}$$

In this case, "supporting reforms" can be interpreted as changes that shift the central bank to case 1a by raising its revenues or cutting its costs (e.g. avoiding quasi-fiscal operations and reducing the *nfxa* ratio over time in favour of domestic currency assets). Such a comprehensive recapitalisation would, of course, solve the problem.

[14] In this situation, the central bank in fact functions as a foundation that needs enough starting capital to receive sufficient interest earnings to cover its inherently loss-making activities.

where $i = i^* - \pi^* + \Delta q + \varphi + \pi$ and where own denotes the capital ratio, *nfxa* the ratio of net foreign exchange assets to currency, and *ol* the ratio of operating outlays to currency. This expression is equivalent to the concept of *core capital* in Ize (2005). It allows us to calculate in a closed form the capital ratio to which the central bank will be converging, given the exogenous factors and policy parameters.

3.5.2 Variable Ratio of Net Foreign Exchange Assets

Let us now drop the assumption that the *nfxa* ratio is a fully autonomous policy variable. Instead, we will start treating it as a path-dependent variable with its own endogenous dynamics. The endogenous dynamics may not always be resisted with central bank interventions, but may sometimes even be welcome if they help to achieve a desirable balance-sheet adjustment. In this regard, a key distinction that we are going to make is whether the balance-sheet adjustment can be achieved in a passive manner, i.e. with zero sales or purchases of foreign exchange reserves $(INT_t = 0)$, or whether an active adjustment of the balance sheet is needed. To answer this, we can use equation (3.9), describing the development of net foreign exchange assets over time, and rewrite it for the *nfxa* ratio using (3.20) as:

$$\begin{aligned} \frac{NFXA_{t+1}}{M0_{t+1}} &= \frac{1+y_t^*}{1+\mu_t}\frac{NFXA_t}{M0_t} + \frac{INT_t}{(1+\mu_t)M0_t} \\ &= \frac{1+i_t-\varphi_t}{1+\mu_t}\frac{NFXA_t}{M0_t} + \frac{INT_t}{(1+\mu_t)M0_t} \end{aligned} \tag{3.27}$$

For the passive adjustment scenario, the second term on the right-hand side is equal to zero. The development of the *nfxa* ratio over time then depends only on the relationship between the local currency return on foreign exchange assets and the currency growth rate. If the former is smaller than the latter, the *nfxa* ratio is going to decline over time and eventually converge towards zero. In other words, the relatively fast currency growth rate combined with relatively low earnings on foreign exchange assets is going to erode the importance of foreign exchange assets in the central bank's balance sheet. As a result, the source of central bank losses will disappear.

Note that the above condition will hold with certainty if there is a positive risk premium (which is the case we are interested in) and domestic interest rates are lower than the currency growth rate, as the inequality

$$y^* = (i - \varphi) < i < \mu \tag{3.28}$$

must hold in such a situation. In this optimistic case, the losses stemming from the risk premium in combination with a high *nfxa* ratio are thus a self-correcting problem under a passive adjustment scenario with relatively fast currency growth. Case 1b from Figure 3.1 eventually turns into case 1a.

A much less favourable situation would emerge if

$$i > y^* = (i - \varphi) > \mu. \tag{3.29}$$

In such a case the *nfxa* ratio would grow without limits and the passive adjustment scenario would not be plausible.

4. The CNB's Balance Sheet: From Deep Losses to Future Profitability

The CNB may serve well as an instructive example of a central bank in a converging economy. It started with a low initial level of foreign exchange reserves and chose the fixed exchange rate as a nominal anchor for the economy at the beginning of the economic transition. A period of extensive foreign exchange reserves accumulation followed due to an inflow of foreign investment. Finally, the exchange rate is now freely floating and the nominal exchange rate has been appreciating due to the real convergence process and the disinflation achieved.[15]

After the split of Czechoslovakia into the Czech and Slovak Republics on January 1, 1993 the initial level of the CNB's foreign exchange reserves was low at around 697 million euro. However, there was a steady rise in foreign exchange reserves in the subsequent years, both in absolute terms and relative to currency in circulation, as is well documented by Table 4.1. This increase in reserves reflected foreign capital inflows in combination with the monetary policy regime applied by the CNB.

The newly established CNB followed the de-facto fixed exchange rate regime that had been introduced by the State Bank of Czechoslovakia in 1990. Officially, the CNB also followed monetary aggregate targeting, with publicly revealed money growth targets. Although the exchange rate fluctuation band was rather narrow, at $\pm 0.5\%$, the CNB initially had little difficulty sterilising the effects of capital inflows to meet both the exchange rate and monetary targets.

Table 4.1: The CNB's Foreign Exchange Reserves (yearly averages in millions)

	CZK	Euro	ratio to currency
1993	65 462	1 930	1.17
1994	147 858	4 331	1.74
1995	269 092	7 840	2.54
1996	352 217	10 364	2.74
1997	350 250	9 727	2.55
1998	365 667	10 149	2.59
1999	424 683	11 518	2.65
2000	489 532	13 788	2.61
2001	511 725	15 092	2.62
2002	632 779	20 601	3.00
2003	708 712	22 225	3.03
2004	690 005	21 630	2.70
2005	696 780	23 402	2.53
2006	683 887	24 191	2.26
2007	652 158	23 511	1.94

Source: CNB

The inconsistency of the fixed exchange rate and monetary targets became more evident from 1994 onwards. The ongoing privatisation of the economy, the liberalisation of foreign capital

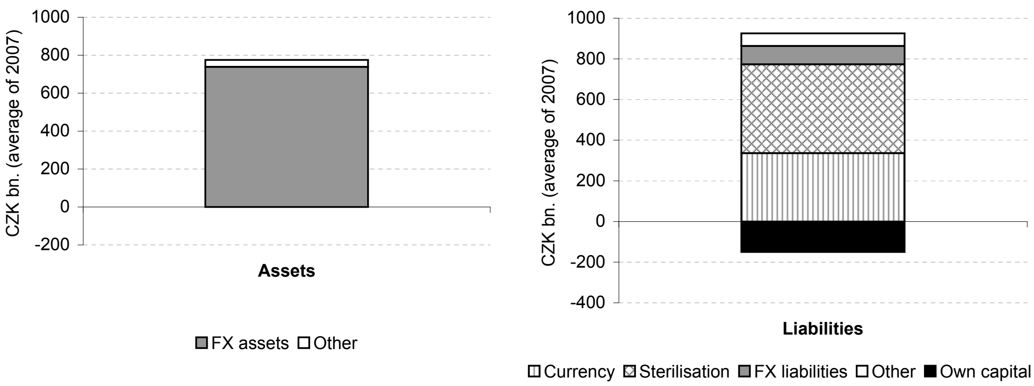
[15] The CNB is also an instructive example due to its transparent accounting practices, in particular the marking-to-market of its foreign exchange reserves. This means that the costs associated with its foreign exchange reserves are openly revealed in its books. At the same time, the CNB is allowed to retain its profits until its accumulated loss is fully repaid. The institutional set-up is thus in line with the assumptions that were used in the theoretical model. For countries with different accounting practices and institutional arrangements, one would of course need to modify the framework accordingly.

flows and the high domestic return on capital started to attract more and more foreign capital. In order to avoid nominal exchange rate appreciation the CNB was forced to purchase the inflowing capital and at the same time to sterilise the liquidity issued in order to avoid high monetary aggregate growth. This resulted in a rather quick rise in the foreign exchange reserves in 1995 and 1996, and at the same time in fast money supply growth exceeding the targets.

It can be seen from Table 4.1 that roughly half of the current foreign exchange reserves were accumulated under the fixed exchange rate regime that was in place until May 1997. Then the fixed exchange rate regime was abandoned and the exchange rate started to float. Table 4.1, however, also reveals that a substantial part of the foreign reserves has been acquired since 1997. This partly reflects three episodes of foreign exchange interventions in 1998, late-1999/early-2000 and 2001–2002, when the CNB was fighting strong appreciation tendencies, and partly also purchases of governmental privatisation revenues, again in order to avoid a rapid and strong appreciation of the currency.[16]

As a result, the CNB's balance sheet gradually evolved into the situation illustrated in Figure 4.1. The asset side is dominated by foreign exchange reserves, the volume of which is more than double that of currency in circulation. On the liability side, the main item besides currency in circulation is sterilisation of excess liquidity, i.e. CZK-denominated interest-bearing liabilities to the domestic banking sector, while the foreign exchange liabilities are quite small. The CNB's own capital is negative at almost 50% of the currency issued, due to the losses incurred by the CNB in recent years. The emergence of these losses is explained in the next subsection.

Figure 4.1: Graphical Exposition of the CNB's Balance Sheet



4.1 A Brief History of the Losses

Although a low-inflation environment had already been established by the fixed exchange rate regime at the beginning of the 1990s, Czech inflation can be viewed as having been low and rel-

[16] It is interesting to note that as its crucial part the CNB's agreement with the government on purchases of privatisation revenues included government participation in the expected sterilisation costs incurred by the CNB. This measure was taken to limit the negative consequences of further foreign exchange reserves accumulation on the CNB's financial performance. With the benefit of hindsight, however, the fees negotiated were insufficient to fully cover the CNB's costs associated with these purchases Earnings on the foreign exchange reserves naturally contributed to their accumulation as well, before the CNB started to sell a portion of these earnings in 2004.

atively stable only since 1999. Subsequently, the appreciation of the real exchange rate caused by the convergence process has proceeded mainly via appreciation of the nominal exchange rate, hitting the CNB's balance sheet substantially. Given the marking-to-market of the foreign exchange reserves, the main reason for the CNB's losses is nominal appreciation. This was combined with quasi-fiscal losses in the second half of 1990s related to banking sector rescue operations.

The period of persistent revaluation of the foreign exchange reserves begins in 2000. Table 4.2 captures the CNB's financing over the whole period in detail.[17] Although Table 4.2 shows that

Table 4.2: CNB Profits/Losses from Selected Operations (in CZK billion)

	Asset Revaluation Profits/Losses	Monetary Policy and Foreign Reserves Management Profits/Losses	Quasi Fiscal Operations Profits/Losses	Total Profits/Losses
1993	-1.86	0.38	0.0	-1.48
1994	1.54	-4.04	-2.88	-5.38
1995	1.00	7.3	-3.60	4.7
1996	-8.34	2.1	-1.45	-7.69
1997	44.65	0.79	-35.69	9.75
1998	-35.61	-6.39	-26.10	-68.1
1999	31.52	0.42	1.69	33.63
2000	-3.52	7.88	-1.58	2.78
2001	-40.12	12.7	1.05	-26.37
2002	-26.15	11.38	0.57	-14.2
2003	-29.77	12.84	0.76	-16.17
2004	-61.14	8.16	0.88	-52.1
2005	8.73	10.91	1.19	19.96
2006	-66.99	10.12	1.34	-56.39
2007	-47.67	13.97	0.02	-37.50

Source: CNB

the CNB faced revaluation losses also in 1993, 1996 and 1998, they were offset by gains in the preceding or subsequent years and hence they did not exhibit a systematic pattern. This is the case only from 2000 onwards, when the nominal exchange rate started to appreciate persistently. The year 2005 should be viewed as rather exceptional and compensating for the previous year 2004, when the loss was quite enormous due to strong nominal exchange rate appreciation. In addition, Table 4.2 provides evidence that the positive net gains arising from monetary policy implementation and foreign exchange reserves management have been able to compensate for the revaluation losses only partially.

The persistent revaluation losses naturally raise the question of the sustainability of the accumulated central bank loss. It is hard to expect that even a central bank can accumulate a loss indefinitely. Therefore, it is important to have tools for an empirical analysis of the central

[17] It is worth mentioning that Table 4.2 does not capture the CNB's financing completely. In fact, certain transactions with the government, operating costs and other items are omitted. For a complete and precise description of the CNB's financing, see the CNB's Financial Reports (available on the CNB website).

bank's balance-sheet sustainability along the convergence path. The theoretical framework derived in section 3 is suitable for such an analysis. To illustrate this, we apply the framework to the CNB's case. We first provide an analytical exposition of its balance-sheet sustainability along the lines presented in subsections 3.4 and 3.5, and then move to simulation exercises based on subsections 3.1 to 3.3. We believe that such an analysis could be applied to many central banks in transition and emerging market economies, even though one has to keep in mind country specifics in terms of economic development, central bank accounting practices and institutional set-up.

4.2 The CNB's Balance-Sheet Sustainability – Comparative-Static Exposition

In this section, we analyse the prospective dynamics of the CNB's capital ratio as suggested in subsections 3.4 and 3.5. To do this, we take the exogenous factors from the CNB's forecast (produced in October 2007), set the policy variables to their current values and assume long-run nominal currency growth equal to nominal GDP growth. Those values include an inflation target of 3% (to be lowered to 2% in 2010), a foreign equilibrium real interest rate of 1.8%, an equilibrium real exchange rate appreciation of 3.3%, a risk premium of 2.3%, an *nfxa* ratio of 2.00, an operating outlays ratio of 0.7% and a nominal currency growth rate of 8% (3% inflation plus 5% real growth).

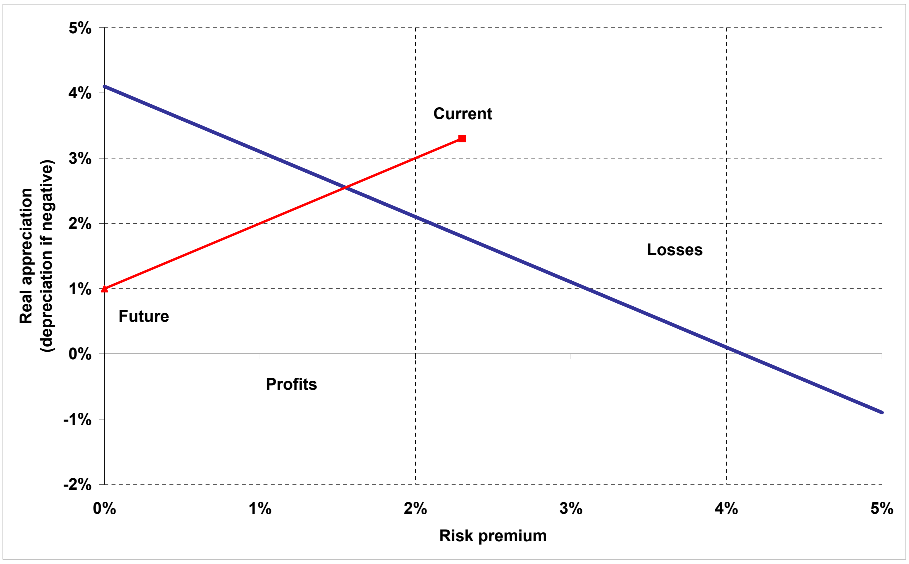
With these assumptions, the CNB currently finds itself in situation 1b described in subsection 3.5 (see Figure 3.1). The corresponding steady-state capital ratio is -0.36. This means that if nothing changes, the accumulated loss in the CNB's balance sheet would eventually be smaller than it is now relative to currency in circulation, but would remain negative. The factor that would prevent the loss from increasing explosively would be fast currency growth exceeding the assumed equilibrium nominal interest rate (equal to 3.8%).

The results are quite sensitive to the assumed values of the key parameters and policy variables. For example, should the risk premium be one percentage point higher than assumed and all other things remain unchanged, which is certainly not unrealistic given the past estimated values of the risk premium, the negative steady-state capital ratio would widen to -0.78, which exceeds the current level noticeably. Moreover, the announced reduction of the inflation target to 2%, all other things being the same as in the baseline scenario, also worsens the steady-state capital ratio to -0.60. Finally, if the nominal currency growth rate fell to 5%, perhaps due to a lower potential real GDP growth rate, which is quite likely in of the longer run, the negative steady-state capital ratio would deepen further to -1.14 with the new inflation target. In any case, these calculations do not paint a bright picture for the CNB.

Fortunately, though, the relevant parameters and variables are unlikely to stay at their current values forever. Focusing first on exogenous parameters, the CNB's forecasts assume that both the risk premium and the real exchange rate appreciation should be falling over time, towards 0% and 1% respectively. Such a change would improve the CNB's core profits to roughly 3.1% of currency in circulation (2.1% for the new inflation target), shifting it to case 1a from Figure 3.1. The steady-state capital ratio would reach +0.74 under these assumptions (0.50 with the lowered inflation target; 0.95 with the lower inflation target and 5% nominal currency growth).

In Figure 4.2 we plot the combinations of the risk premium and real exchange rate appreciation that would lead to zero core profits of the CNB, given the current policy parameters (with the 3% inflation target) and would thus gradually bring the capital ratio towards zero. The CNB's current situation lies above the zero profit line, which means that the core profits of the CNB are negative. It can be seen that with the current estimated level of the risk premium (2.3%), the equilibrium real exchange rate appreciation would have to fall to 1.8% a year to assure zero core profits. Or with the current pace of real appreciation (3.3%) the risk premium would have to decline to 0.8%. The long-run assumptions of the forecast for the future imply, however, that the CNB will shift to positive core profit territory.

Figure 4.2: Combinations of the Risk Premium and Real Appreciation Implying Zero Core Profits

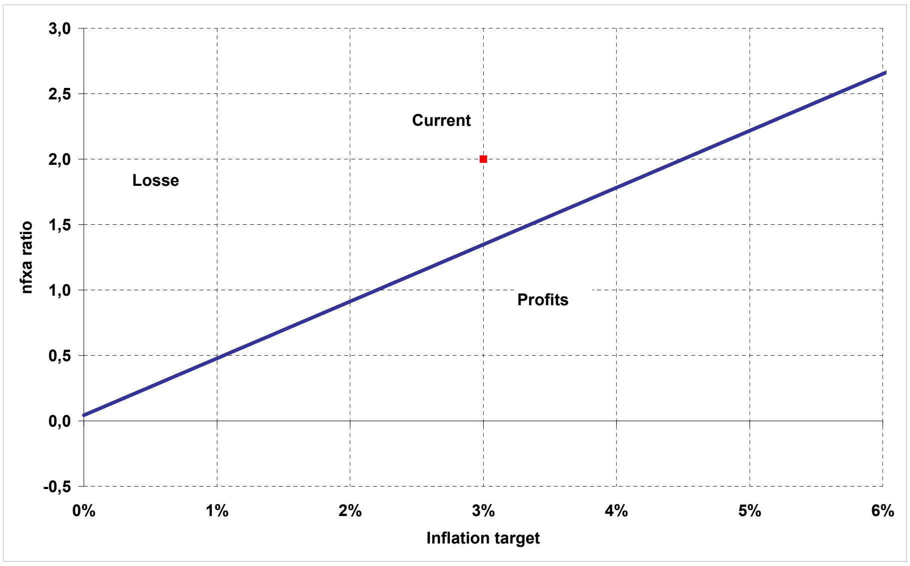


Another two margins of adjustment of core profits are the policy variables, i.e. the inflation target and the *nfxa* ratio. An increase in the inflation target and/or a reduction in the *nfxa* ratio would push the zero profit line in Figure 4.2 in the north-east direction. If the change was sufficiently strong, zero core profits could be reached even with the current exogenous variables. In Figure 4.3 we thus plot the combinations of the two policy variables that would lead to zero core profits for the current estimated risk premium (2.3%) and real equilibrium exchange rate appreciation (3.3%).[18] It can be seen that with the current *nfxa* ratio, the inflation target would have to be 4.5% to assure zero core profits. This contrasts with the existing 3% target (and even more so with the 2% target from January 2010). To make the 3% target sustainable with the current exogenous variables, the *nfxa* ratio would have to fall to 1.35 (0.91 for the new inflation target), i.e. by about 33% compared to its current level.

Such a change of the balance-sheet structure is hardly achievable in the short term. It would require massive sales of the CNB's foreign exchange reserves, most probably contributing to a huge exchange-rate appreciation, which would be in conflict with the CNB's policy goals and would, moreover, deepen the accumulated loss of the CNB even further by fostering exchange rate appreciation.

[18] Ize (2005) calculates the "core rate of inflation as the threshold rate of inflation that ensures zero core profitability". Such an approach has a shortcoming, though. It implicitly assumes that the inflation target is the only policy margin of adjustment, or that it is the first one to be used. However, as Ize (2005) shows, the core rate of inflation is a function of the nfxa ratio, i.e. another policy variable that can be influenced by central bank decisions. It is realistic to assume that most central banks would prefer to adjust their balance-sheet structures to achieve zero core profits before giving up their inflation goals. The two policy margins should thus be treated at least as equally important.

Figure 4.3: Combinations of the NFXA Ratio and Inflation Target Implying Zero Core Profits



In this paper, however, we are concerned mainly with the long-run sustainability of the central bank's balance sheet, and a balance-sheet adjustment may well be achievable in the long run. This is true especially in those cases where the starting *nfxa* ratio does not reflect true policy preferences such as maintaining international liquidity, but is rather a by-product of the past exchange rate regime or intervention decisions. We believe that this is the CNB's case. At the same time, the CNB's case is characterised by the optimistic scenario (3.28). The baseline of the CNB forecast (which includes the new 2% inflation target as a steady-state assumption) together with the assumptions about currency growth imply that the *nfxa* ratio is going to decline below 0.9 around the year 2020 if no interventions are carried out. Even though the exact date is, of course, dependent on the assumptions made, the CNB should eventually get into a profit-making situation.

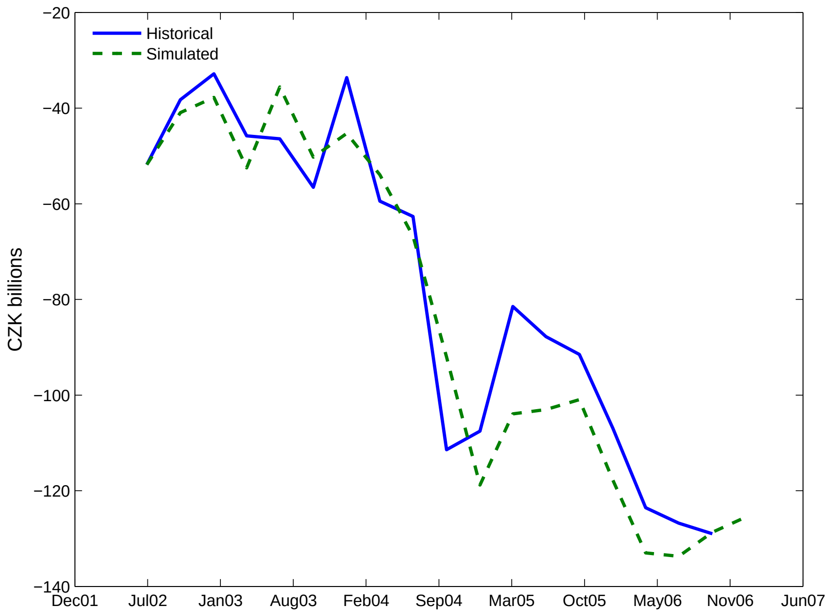
4.3 Historical Simulation

While the exposition of the CNB's accumulated loss dynamics provided in the previous subsection was based on a closed-form solution and allowed useful comparative-static exercises, it has its important limitations, too. In reality, most of the relevant variables (i.e. the risk premium, the equilibrium real exchange rate appreciation, the *nfxa* ratio, etc.) are likely to change over time simultaneously, which is hard to capture using the comparative-static approach. Moreover, the transitory dynamics, and not just the steady-state values captured by the analytical solution, are likely to be of interest to policy makers, too.

To overcome these shortcomings, the present section provides numerical simulations of the central bank's accumulated loss, using the model developed in subsections 3.1 to 3.3 and taking the CNB as an example. In order to test the robustness of our model we start with an out-of-sample historical forecast, before proceeding to the future forecast based on the recent situation and macroeconomic outlook.

To check the validity of our framework, we compare its predictions with the actual CNB balance-sheet developments. We take the actual balance sheet at a particular past date and conduct the model projection using the ex-post known development of the koruna exchange rate, local and foreign interest rates, gross domestic product, the consumer price level, the actual foreign exchange operations pursued by CNB on its own account, and the CNB's actual operating outlays.

Figure 4.4: The CNB's Actual Own Capital and Historical Projection



Source: Own calculations.

Figures (4.4) and (4.5) show that the projections follow the actual development quite closely. This corroborates that the model is internally consistent and has captured the most important factors affecting the CNB balance sheet. It shows that the balance sheet of the central bank may indeed be driven mainly by macroeconomic factors over which it can have no or very limited control.

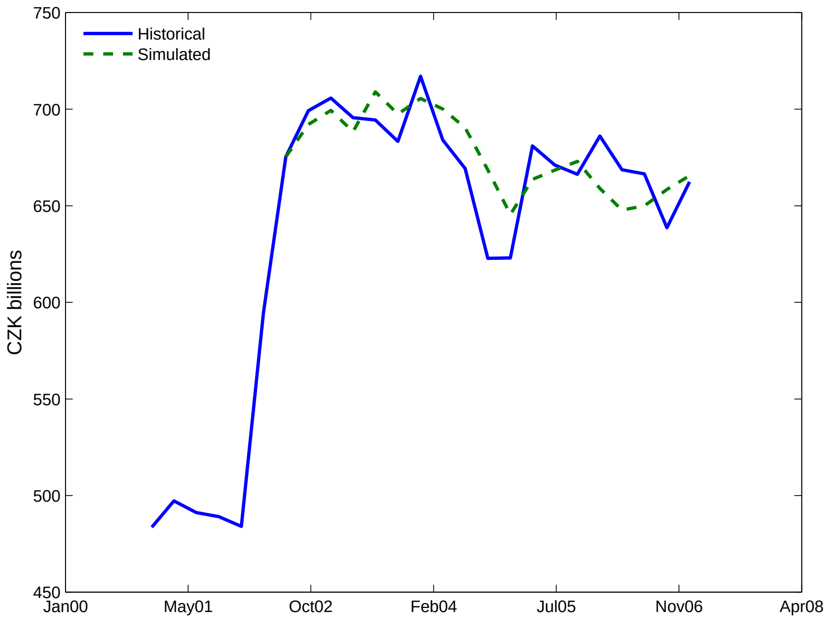
Although the actual dynamics of the explanatory factors listed above were utilised, the very good fit of the CNB own capital projection in Figure (4.4) is not necessarily automatic. Consider for example the projected and actual dynamics of net foreign exchange assets. While the model assumes that their yield is mechanically determined by the respective one-year interest rate swap rates, the actual duration or credit risk profile of the foreign exchange reserves portfolio, or active foreign exchange rate management thereof, may lead to higher or lower earnings. The correspondence between the projection and reality confirms that the foreign exchange assets were invested in a rather conservative manner in the past. The good fit also depends on the fact that the growth rates of $M0$ are modelled relatively precisely and that the bulk of the CNB's net local currency liabilities are remunerated at the monetary policy interest rate.[19]

4.4 Simulation into the Future

In order to use the model for simulating the future development of the central bank's balance sheet, one needs to make assumptions regarding the key macroeconomic variables. Importantly,

[19] For example that fixed assets or gold represent a very small proportion of total local currency liabilities.

Figure 4.5: The CNB's Actual Net Foreign Exchange Assets and Historical Projection



Source: Own calculations.

those assumptions should be internally consistent and should reflect some basic consensus concerning the long-run trends of the economy.

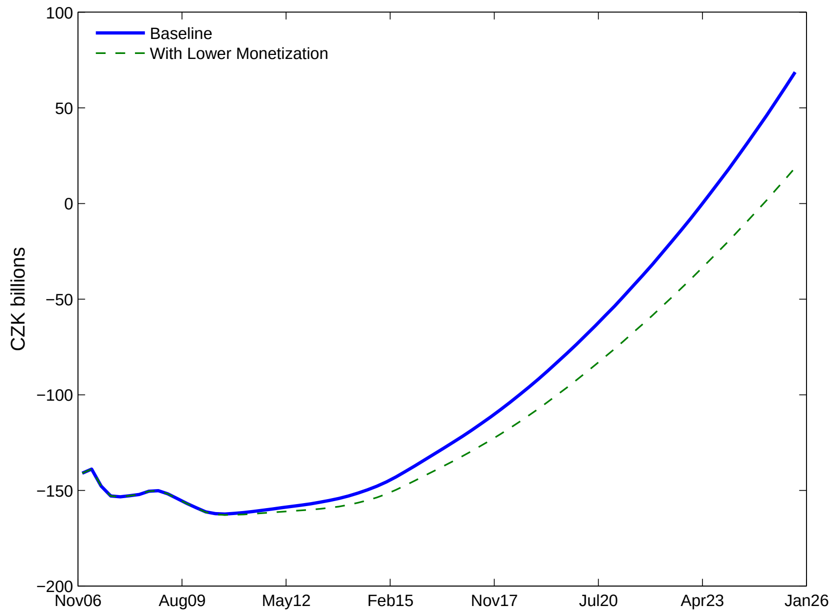
To fulfil the above requirements, the modelling of the balance sheet is based on the CNB's macroeconomic forecast as published in the CNB's Inflation Report. The CNB's forecast splits into two parts: business cycle fluctuations and underlying long-run trends. The business cycle is simulated using the CNB Quarterly Projection Model[20], and the long-run trends are chosen consistently with the model assumptions. For our long-term projection, the trends and equilibrium values underlying the forecast are, of course, more important than the business cycle dynamics.

Figure 4.6 depicts the projection based on the initial condition for the CNB's own capital in the first quarter of 2007 using the macroeconomic forecast from the fourth quarter of 2007, consistently with subsection 4.2. The long-run trends assumed in this CNB forecast were already mentioned in subsection 4.2. Long-run inflation is equal to the inflation target of 3% (2% with the new inflation target). This, together with the assumption of long-run potential output growth of 5% (assumed to decline gradually towards 3% in the simulations), governs nominal GDP growth, which is of primary importance for the expected growth of households' cash holdings. The ratio of cash holdings to nominal GDP (monetisation) has been growing in the Czech economy since 1993, and is about 9.5% of annual nominal GDP at present. The growth rate of cash holdings is currently roughly 10%, close to the average growth rate of 10.5% in the period from July 2002 to January 2007.

In order to model cash holdings properly one should of course also apply the elasticity of money demand to the nominal interest rate. In reality, however, the ratio of cash holdings depends on

[20] See Beneš, Vávra and Vlček (2002) for a detailed description.

Figure 4.6: Future Simulation of the CNB's Own Capital



Source: Own calculations.

interest rates only marginally, as estimated by Hanousek and Tůma (1995), and it is unlikely that the level of monetisation will grow further in the future. As a result, the level of monetisation remains roughly the same in our baseline simulation, causing the growth of cash holdings to converge towards the growth of nominal GDP.

The foreign equilibrium real interest rate is assumed to be currently around 1.8%. In addition, we assume that the foreign equilibrium interest rate will rise gradually towards 2%. In particular we deal with the US and Eurozone interest rates, as the CNB holds both the US dollar and the euro as its main reserve currencies. Long-run inflation is assumed to be 2% for both the Eurozone and the US. The risk premium is assumed to decline over time towards 0%. Finally, the current value of the trend real exchange rate appreciation is assumed to decline gradually towards 1%, reflecting the expected convergence slowdown. The real exchange rate appreciation in accordance with the assumed inflation differential consequently determines the expected path of the nominal exchange rate.

We assume that the foreign exchange reserves are invested in the euro or dollar money market with a one-year maturity. Future returns on these reserves are modelled using implied forward rates adjusted for the term premium. The term premium is positively related to the forward horizon, but the relationship is less than proportional. It was calibrated in such a way that at very long horizons the projected future one-year maturity rate coincides with the assumed equilibrium interest rate.

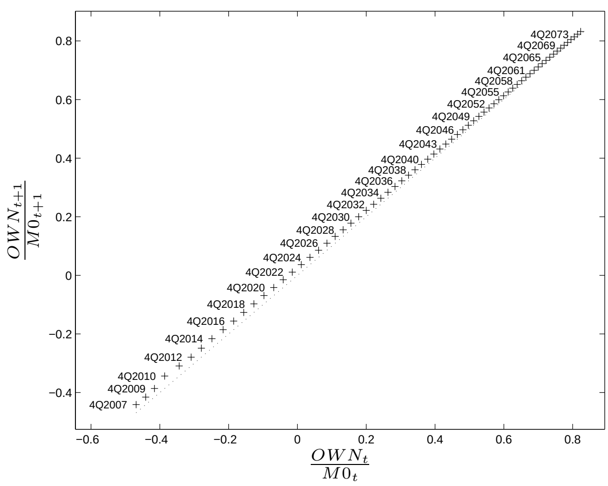
We assume that the return on the foreign exchange reserves is relatively conservative and that in reality it is possible to perform better. In fact, the actual duration of the CNB's portfolios is higher than one year. We also assume, in line with the current policy, that the CNB will sell the foreign currency interest (coupons) earned on its reserves in return for koruna. However, no other foreign exchange operations are taken into account in the simulation.

Table 4.3: CNB Balance-sheet Projections Based on the CNB's Macroeconomic Forecast from Q4 2007 (in CZK billion)

	OWN	$NFXA$	$M0$	$NIBL$	$OL(flow\ p.a.)$
2007	-148	650	326	472	1.9
2009	-154	630	370	415	2.1
2011	-161	605	455	310	2.2
2013	-155	581	542	195	2.3
2015	-140	562	625	77	2.4
2017	-115	549	704	-40	2.5
2019	-83	537	793	-173	2.6
2021	-43	526	890	-321	2.7
2023	5	516	993	-482	2.8
2030	245	480	1423	-1188	3.2

Source: Own calculations.

Figure 4.7: Phase Diagram of the Projected CNB Own Capital Ratio

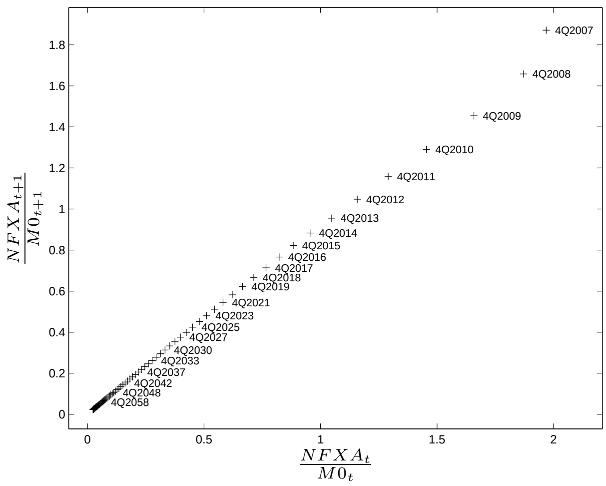


Source: Own calculations.

We further assume that the CNB neither pays dividends to the state budget nor receives any government support. Therefore, we assume that $DIV = 0$.

It follows from Figure 4.6 that the period of losses is not fully over yet. The baseline scenario predicts that the own capital becomes initially even more negative. Table 4.3 shows that despite the continued fast growth of cash holdings the central bank will remain a net borrower in the domestic currency for the next 10–11 years, which implies related costs for monetary policy conduct. The nominal GDP expansion, however, will lead to growth of the unremunerated liabilities represented by currency in circulation at the expense of costly sterilisations. This, together with the return on the foreign exchange reserves, becomes sufficient to eliminate the losses almost entirely at the horizon of seven years. The negative own capital then stops rising and later on starts to decline. The return of own capital to positive values becomes fast as soon as the growth of cash holdings eliminates the need to sterilise liquidity and the CNB becomes a net creditor in the domestic currency.

Figure 4.8: Phase Diagram of the Projected CNB's nfxa Ratio



Source: Own calculations.

It is evident that despite the initial worsening, the losses remain repayable by the stream of future profits in the baseline scenario. Time is on the CNB's side, and growth of currency in circulation does the trick. First, the liability side of the balance sheet becomes dominated by currency and at some moment in time the central bank may stop the costly withdrawal of liquidity from the banking sector altogether and start to provide liquidity to it. From this moment, the asset side also becomes more favourable. At the beginning the bulk of the assets were in foreign low-yielding currency, whereas with liquidity provisioning the asset composition will tilt towards the local currency.

Furthermore, it might be reasonable to expect, in line with the simulation's underlying assumptions, that the appreciation of the real exchange will decline and will be a smaller drag on profits. Moreover, the declining $NIBL$ will limit the negative influence of the declining, but still positive risk premium. Finally, once $NIBL$ turns negative the remaining risk premium will even support profitability. Thus, currency growth and the gradually dying out of the real exchange rate appreciation are the forces behind the return of own capital towards the positive values. As these factors are quite likely to happen in the future, similarly the accumulated loss is likely to be paid off.

One of course needs to keep in mind the importance of the underlying assumptions that lead to the repayment of the losses in the future. For some macroeconomic scenarios, the passive adjustment mechanism may not be viable. In subsection 4.2 we analysed in a comparative-static setting which values of the exogenous and policy variables would keep the central bank in core losses and thus prevent the future repayment of its current negative own capital. Similarly, one can run alternative or stress-test simulations to see if a particular mix of assumptions puts the central bank's balance sheet on a sustainable path.

We chose to illustrate this potential of the derived framework on a variable which did not receive so much attention in the comparative-static discussion of subsection 4.2, i.e. the nominal currency growth rate. In figure (4.6) above, we present an alternative simulation based on the assumption that the monetisation will gradually decline to 7% of annual nominal GDP, instead of remaining constant as in the baseline scenario. It turns out that although quantitatively important, the assumption of persistently high monetisation is not crucial for the result that the CNB should be able to generate enough future profits to reverse its negative own capital if the other assumptions of the baseline scenario remain unchanged. Significantly slower growth of cash holdings delays repayment of the accumulated loss by about 5 years, but does not change the position in a qualitative manner.

5. The Balance Sheet and Euro Adoption

Euro area membership would mean a significant change for the central bank balance sheet of a new member state. There are both economic and institutional reasons for this. Let us first concentrate on the economic aspect and then discuss the specific profit-sharing rules in the euro area.

5.1 Economic Considerations

First let us look at interest rates in the euro area case. Approximately speaking, the risk premium φ_t ceases to play a role for a union member. The euro will become its home currency and its remaining foreign exchange reserves will be held in dollars or in other world currencies. It seems to be a fair working assumption that the predictable excess returns for such currencies with respect to the euro will average to zero over the long run.

This allows us to simplify the balance-sheet model (3.21) to

$$PL'_t \;=\; i'_t(M0'_t + OWN'_t) - OL'_t, \tag{5.30}$$

where we denote by the accent the country's variables under the monetary union regime. For example, i'_t is the interest rate prevailing in the euro area after the entry of the new member state.

Without the risk premium, the profits of the central bank of a converging economy would not be depressed by those losses on the foreign exchange reserves. Yet in the context of the dual role of the risk premium in equation (3.21), one also needs to consider whether the interest rate under the euro will be higher or lower than in the other case.

If the new member state is small then $i'_t \approx i^*_t$, the interest rate in the union without the new entrant. Under this assumption, equation (3.18) shows two opposing factors that determine interest rates under euro area membership in comparison with the case of an independent currency. On the one hand, they will not contain the respective risk premium. But on the other hand, they will no longer be restricted by the inflation-targets-adjusted real appreciation.

The actual balance of these two factors is country specific. Traditionally, it has been assumed that new member states would benefit from the low inflation and credibility of the monetary union and therefore would enjoy lower interest rates after entry. However, this does not hold universally. For example, Czech interest rates have long been slightly below those in the euro area, because the real appreciation and relatively low inflation targets have outweighed the Czech risk premium. Therefore for the Czech case, we may conclude that interest rates in the euro adoption scenario would be marginally higher than otherwise.

Assuming $M0'_t + OWN'_t > 0$, the higher interest rates may affect profitability in two ways. They directly increase the return on the currency stock and own capital in (5.30), but they also negatively affect the demand for narrow money balances, as illustrated by (3.4) and (3.5). However, for small changes and low inflation levels the positive direct effect will be stronger.

Further, consider inflation and its influence on the currency stock. In general, whether inflation in a country is higher under euro area membership or with an independent monetary policy is again a country-specific matter. However, if the new member state has achieved low inflation and at the same time faces a real appreciation trend, inflation is very likely to increase after euro adoption. This is because euro area entry will not stop the real appreciation trend, which is a real-economy convergence phenomenon. With the nominal exchange rate fixed, the real appreciation $\Delta q'_t < 0$ will exclusively take the form of an inflation differential. In the Czech Republic, the inflation target of the independent Czech monetary policy has been set at 2% for the time period after January 2010, i.e. very close to that of the ECB. Therefore, the inflation differential vis-à-vis the euro area average caused by the real appreciation trend would imply higher inflation compared to the independent monetary policy scenario.

The higher inflation, *ceteris paribus*, means faster growth of $M0'_t$, as the following restatement of (3.4) and (3.5) shows:

$$M0'_t = m'_t P'_t GDP_t \quad (5.31)$$

$$m'_t = ce^{-\alpha i'_t}. \quad (5.32)$$

We assume here that real output growth and the structural parameters are not significantly affected by euro area membership, therefore $GDP'_t = GDP_t$, $c'_t = c_t$, and $\alpha'_t = \alpha_t$.

Summing up, we find that euro adoption would be unambiguously positive for the profit and loss of the CNB in the case of natural profit sharing, i.e. if we ignore the redistribution of monetary income in the euro area. This is because inflation will be higher, interest rates will be higher, albeit not too much to undermine the demand for currency, and the risk premium will not decrease the returns on the central bank's assets.

5.2 Euro-Area-Specific Institutional Features

The above economic considerations involve a significant simplification. The actual profit-sharing rule in the euro area is different from the natural one assumed in (5.30). In particular, monetary income is redistributed according to the countries' paid-up capital shares in the ECB, which are determined by equally weighted population and nominal GDP country shares in the EU. Moreover, 8% of the monetary income is allocated to the ECB to finance its operations. Formally, the share of the j-th country will be[21]

$$w_t^{EMU,j} = 0.92\frac{1}{2}\frac{N_t^j}{\sum_k N_t^k} + 0.92\frac{1}{2}\frac{P_t^j GDP_t^j}{\sum_k P_t^k GDP_t^k}. \quad (5.33)$$

In contrast to (5.33), the natural profit-sharing rule implied by (5.30), (5.31) and (5.32) reads

$$w_t^j = \frac{M0_t'^j}{M0'_t} = \frac{m_t'^j P_t'^j GDP_t^j}{\sum_k m_t'^k P_t'^k GDP_t^k}. \quad (5.34)$$

The euro area profit-sharing rule (5.33), which takes into account nominal GDP instead of the currency stock, penalises countries with highly monetised economies, i.e. those with high

[21] On a more detailed level of analysis, one would need to take into account that the countries' shares in the ECB's capital, defined in (5.33), are adjusted not continuously, but only once every five years. However, this does not have important qualitative consequences.

m^j in the demand for narrow money (5.31). On the other hand, because of its relation to the population, the profit-sharing rule is favourable to countries with relatively low nominal GDP per capita.

The redistributional aspects of the profit-sharing rule were firstly pointed out by Sinn and Feist (1997), who argued that Germany, for instance, could incur significant losses because the German mark's world currency role was not taken into account.[22] The same aspect and its implications for the prospective new euro area entrant were discussed by Gros (2004), who concluded that "that one would expect the new member countries to benefit from participating in the distribution of the profits of the ECB ... but this would not be the case for the Czech Republic, which neither gains nor loses seigniorage income".

In the Czech case the two factors affecting the direction of the redistribution work against each other. While the Czech economy is highly monetised, its nominal per capita income is low in comparison with the euro area average. The numerical evaluation shows, however, that the first factor is more influential. Therefore, the euro area profit-sharing rules would redistribute away from the CNB, at least in the initial period. For example, if the Czech Republic joined the current euro area immediately, its share in the monetary income would be roughly 1.8%, while the natural share would be around 2%. If entry came in about five years and the euro area in the meantime expanded to 22 countries, the Czech share in monetary income would be approximately 2%, but the natural share would at that time reach 2.2%.

Overall, the effect of euro adoption is ambiguous. While the economic factors would imply faster repayment of the CNB's accumulated loss, the institutional factors are likely to push in the other direction. The actual outcome may depend on many assumptions, including the development of monetisation both in the Czech Republic and in the euro area, the number of countries in the euro area, etc. Some of the simulations that we carried out suggested that euro adoption would on balance speed up the repayment of the CNB's loss marginally, by about 2 years.[23] In any case, future euro area membership does not change our conclusion that the CNB should be able to repay its loss out of future profits. Moreover, by eliminating the risk premium almost with certainty, euro adoption eliminates a major risk of this optimistic scenario.

One should emphasise, however, that the faster and more certain repayment of the CNB's loss in the euro area does not necessarily mean an unambiguous increase in Czech welfare. For example, the balance-sheet improvement partly stems from higher inflation, which is tantamount to a higher inflation tax and perhaps more nominal uncertainty. A welfare analysis, though, goes well beyond the scope of this paper.

6. Conclusions

Central bank losses and negative capital have become an important issue of policy debate, reflecting the experience of numerous central banks across the world. This issue is highly relevant to the CNB, too, given the huge accumulated loss in its balance sheet.

The source of the losses can differ substantially across countries and periods of time. While the earlier literature focused mainly on quasi-fiscal operations, more recent contributions have focused on the losses associated with high net foreign exchange reserves. The latter source

[22] In practice, this aspect was partly addressed by the phasing-in of the monetary income redistribution scheme during the first five years of operation of the euro area.

[23] These simulations are not presented here for the sake of brevity, but they are available from the authors upon request.

of losses is the focal point of the present paper, reflecting the CNB's experience since the year 2000. We have shown that central bank balance sheets in converging (emerging market) economies can be prone to systematic losses. This is especially true for countries that have achieved disinflation and at the same time have to sterilise liquidity issued in the past due to massive purchases of foreign exchange reserves. From the accounting point of view, the losses manifest themselves as revaluation of foreign exchange reserves. From the economic point of view, the decrease in seigniorage (monetary income) due to low nominal interest rates, combined with the risk-premium-related costs of holding large net foreign exchange reserves, is responsible for the losses.

Building on Holub (2001b), Bindseil, Manzanares and Weill (2004) and Ize (2005), our paper provides a practical framework for assessing the ability of a central bank to remain solvent given the current level of its own capital, the structure of its balance sheet and long-term economic prospects. To achieve this, we have developed a more comprehensive model of the central bank's balance sheet and its linkages to macroeconomic trends than the earlier literature. Most importantly, we have analysed in more depth the consequences of economic convergence for the evolution of the central bank's balance sheet and the important role played in this process by the risk premium and equilibrium real exchange rate appreciation. A combination of a closed-form comparative-static analysis and numerical solutions of the future evolution of the central bank's own capital has been used to expose the problem from different angles and exploit some complementarities of the two approaches which have not been combined in earlier papers.

The present paper applies the derived framework to the CNB's case. We show that if the risk premium, equilibrium real exchange rate appreciation and net foreign exchange reserves ratio remained at their current levels, the CNB would continue to record large "core losses" with its low inflation targets (2% from 2010). Given the fast growth rate of currency in circulation, the CNB's capital ratio would converge to a steady-state negative level of roughly -60%. Moreover, one cannot exclude even more pessimistic outcomes for plausible variations in the underlying assumptions.

This is not, however, a realistic long-term scenario. As economic convergence progresses, the risk premium is likely to fade away, as is the real exchange rate appreciation trend. Moreover, the net foreign exchange reserves ratio will gradually fall if the CNB engages in no future foreign exchange interventions. Taking the long-run trends from the CNB's forecasts and assuming no interventions, our simulations show that the CNB will be able to repay its current accumulated loss out of future profits. The most plausible scenarios suggest that the loss will take roughly 15 years to repay. Given this prospect, we believe that the accumulated loss can be kept in the CNB's books without damaging monetary policy credibility and without recourse to public budgets to cover the loss. One should always keep in mind that any such government participation in central bank financing could constrain the bank's operational independence, making such participation less attractive than the repayment strategy based on the central bank's future profits. This strategy should be openly communicated to the public and political representatives to address the credibility challenges arising from the central bank's negative capital.

While the CNB's case has many specific features and the conclusions reached in our paper may not be directly transferable to other central banks, the derived framework itself is fairly general and could be successfully applied to other countries' experience. We leave this as a challenge for future research.

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ISSN 1803-7070