

Central Bank Losses and Economic Convergence^{*}

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Abstract

This paper discusses central bank losses and develops a formal framework for assessing the sustainability of its balance sheet. Analyzing the consequences of economic convergence in depth, it emphasizes the role played by the risk premium and equilibrium real exchange rate appreciation. A closed-form comparative-static analysis and also numerical solutions of the future evolution of the central bank's own capital are presented. Applying this framework to an example of a converging economy, namely the Czech Republic, we find that the Czech National Bank should be able to repay its accumulated loss in about 15 years without any transfer from public budgets.

1. Introduction

While under *standard* circumstances a central bank should operate with profit, numerous central banks have faced substantial losses that have led over time to an accumulation of negative capital. 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.

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 et al. (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.¹ 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,² a high – but gradually decreasing – risk premium on domestic as-

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¹ The central bank's balance sheet has been discussed recently also in relation to the ongoing financial and economic crisis (Stella, 2009). It applies, however, that any losses in this case are rather of a “quasi-fiscal” type and are not of primary interest here.

² See Čihák and Holub (2005); Cincibuch and Podpiera (2006); Égert, Halpern, and MacDonald (2006).

sets, some progress with disinflation, relatively fast growth of currency in circulation supported by fast GDP growth, and increasing monetization of the economy. 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.

This framework is applied to the example of the Czech National Bank (CNB), which has incurred considerable losses since 2000, and which is currently operating with substantially negative own capital.³ 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. 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. 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.

The rest of this text is organized 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. Finally, section 5 concludes.

2. Existing Literature and New Developments

The economic literature has long discussed the sources of central bank losses and their possible remedies. While the quasi-fiscal origins of the losses and the potential need for central bank re-capitalization were explored by Fry (1993), Mackenzie and Stella (1996), and Dalton and Dziobek (1999), there is also a literature which focuses on losses related to high foreign exchange reserves. It includes Holub (2001a) and Higgins and Klitgaard (2004). Interestingly, Hawkins (2003) mentioned sterilized foreign exchange interventions as a special case of loss-making quasi-fiscal activities. Exchange rate losses were also discussed by Stella and Lönnberg (2008) and Stella (2008).⁴

³ There are many central banks in emerging economies that face repeated losses, namely the central banks of Romania and Slovakia in the Central European region, Thailand and Indonesia in Asia, and Chile in South America. While the framework developed here applies to all those central banks in general, the practical application of comparative-static analysis or dynamic simulation of future losses/profits is extremely difficult for non-insiders due to different accounting standards and procedures as well as to different levels of publication openness when it comes to the balance sheet of the central bank.

⁴ See also The Economist (2005) for a popular discussion.

This paper deals with the formal link between the central bank's balance sheet and its macroeconomic context. It adds to a stream of the literature represented mainly by Holub (2001b), Bindseil et al. (2004), and Ize (2005). Bindseil et al. (2004) introduced a theoretically useful formal framework consisting in a simplified central bank balance sheet and a simple macroeconomic model based on the Wicksellian relationship between inflation and interest rates, and provided simulations of central bank capital. However, some of their model assumptions were too strong from a practical perspective. Especially for open economies, a non-zero risk premium or systematic changes in the real exchange rate may play a significant role, but the model of Bindseil et al. (2004) does not deal explicitly with those phenomena.

Holub (2001b) and Ize (2005) in their analyses give a prominent role to the risk premium as a key determinant of central bank profits. Both papers provide an analytical exposition of central bank capital 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). However, significant simplifications are still present in these models. First, they do not explicitly deal with the real exchange rate trend, which is a salient feature of many converging economies. On the contrary, Ize (2005) assumes that in the long run the relative version of purchasing power parity holds and, consequently, the risk premium is calculated as the difference between domestic and foreign real interest rates. Second, the possibility that the real growth of currency holdings exceeds the real interest rate is excluded in Ize (2005). Nevertheless, in a converging economy, appreciation of the real exchange rate may cause the real interest rate to fall below the foreign real interest rate, but the monetization of the economy may be rising at the same time.

Besides modeling issues, the emergence of the losses and negative own capital of some central banks has stimulated a debate of what policy implications this may have. Already, Fry (2003) has articulated the possibility of inflation control being abandoned in reaction to the worsening of a central bank's balance sheet. More recent contributions dealing with the link between sustainability of the central bank's financial situation and its ability to perform its policy goals include Holub (2001b), Sims (2003), Bindseil et al. (2004), Ize (2005), Stella (2005), and Stella and Lönnberg (2008).

Bindseil et al. (2004) focused on credibility issues and argued that a loss-making central bank is simply not believed to ignore its balance sheet while conducting monetary policy. Moreover, they raised the possibility that after a period of protracted losses, the public may begin to worry that the central bank will lose its right to issue legal tender. Stella and Lönnberg (2008) coined the term "policy insolvency" to describe situations in which a central bank's policy decisions are affected by its financial condition.

Ize (2005) 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. In addition to core capital, a policy variable called "core inflation" is introduced. It links core capital and the central bank's credibility. "Core inflation" may be adjusted to keep the central bank's capital in positive values. However, Ize (2005) does not discuss the possibility of changes in foreign exchange

reserves, even though their ratio to currency in circulation is in fact treated as another potential policy variable that does not endogenously evolve.

However, the inflation risk might be overemphasized by the model of Bindseil et al. (2004) and Ize (2005). They assume stability of the public's demand for currency, but higher inflation induced by the central bank to improve its finances would lead to currency substitution and thus limit the central bank's incentive to resort to such a solution.

Building mainly on Holub (2001b), Bindseil et al. (2004), and Ize (2005), we refine the discussion 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 discussion of factors influencing 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. This split facilitates modeling of the foreign exchange reserves ratio as another policy variable in addition to "core inflation," by means of which the central bank may adjust its profitability. Moreover, 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.

We intend to provide a realistic and pragmatic approach that can be used for analyses and dynamic simulations of the central bank balance sheet given its current structure and a reasonably reliable long-term economic outlook. Such simulations should show whether active adjustment of the balance-sheet structure is necessary. In effect, they may help the central bank to adopt a proper 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 the 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 liabilities⁵ may for practical purposes be subsumed into own capital OWN_t .

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

$$NFXA_t = NCL_t + OWN_t = NIBL_t + M0_t + OWN_t \quad (1)$$

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.

$$OWN_t = NFXA_t - NIBL_t - M0_t \quad (2)$$

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 (2).

It is worth mentioning that the net foreign exchange assets and net local currency liabilities in the balance sheet (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.

3.1 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.⁶ 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

$$NCL_{t+1} = NCL_t + NIBL_t i_t + OL_t + DIV_t + INT_t \quad (3)$$

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.

⁵ Depending on the local situation, banks' reserve accounts may be a part of non-interest-bearing liabilities, which could be treated as part of $M0_t$.

⁶ 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 generalization would be straightforward, though (see e.g. Holub, 2001a).

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

$$M0_t = m_t P_t GDP_t \quad (4)$$

where monetization m_t is given by

$$m_t = ce^{-\alpha i_t} \quad (5)$$

3.2 Net Foreign Exchange Assets

The international reserves of the central bank may be invested in various currencies. Let S_t be the exchange rate of the basket currency⁷ representing the reserve portfolio at time t . Let us denote by Q_t the size of the international reserves in terms of this basket currency. Therefore, the value of the reserves is given by

$$NFXA_t = S_t Q_t \quad (6)$$

The value of the reserves is affected by exchange rate changes, by the reserves' own return R_t , and by the central bank's foreign exchange operations. Then the local currency value of the international reserves in the next period is given by

$$NFXA_{t+1} = S_{t+1} Q_t + S_{t+1} Q_t R_t + INT_t \quad (7)$$

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

We may easily rewrite (7) as a law of motion for the foreign exchange reserves

$$\begin{aligned} NFXA_{t+1} &= NFXA_t \frac{S_{t+1}}{S_t} (1 + R_t) + INT_t \\ &= NFXA_t (1 + y_t^*) + INT_t \end{aligned} \quad (8)$$

Using logarithmic approximation and denoting $\Delta s_t = s_{t+1} - s_t = \ln(S_{t+1}) - \ln(S_t)$ we may express y_t^* , which is the net total return on the foreign exchange reserves, as

$$y_t^* \approx \Delta s_t + R_t \quad (9)$$

3.3 The Dynamics of Own Capital

The dynamics of own capital are easily derived by substituting (3) and (8) into (2). It follows that

⁷ We assume that the currency allocation of the reserve assets is given exogenously by the reserve management policy. If x^i_t is the share of the i -th currency in the overall portfolio, if S^i_t stands for the exchange rate of the i -th currency, and if R^i_t is the net foreign currency return of the i -th portfolio, then one may algebraically solve for the basket-currency exchange rate change:

$\frac{S_{t+1}}{S_t} = \sum_i \frac{S_{t+1}^i x^i_t}{S_t^i x^i_t}$, and for its return: $R_t = \left(\sum_i \frac{S_{t+1}^i x^i_t}{S_t^i x^i_t} \right)^{-1} \sum_i \frac{S_{t+1}^i x^i_t R^i_t}{S_t^i x^i_t}$. 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.

$$\begin{aligned}
OWN_{t+1} &= NFXA_{t+1} - NCL_{t+1} \\
&= NFXA_t (1 + y_t^*) + INT_t - NCL_t - NIBL_t i_t - OL_t - INT_t - DIV_t \\
&= OWN_t + NFXA_t y_t^* - NIBL_t i_t - OL_t - DIV_t
\end{aligned} \tag{10}$$

In words, central bank losses may arise because of large net local currency interest-bearing liabilities (mainly open market operations to sterilize 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, 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 (10). 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. For further discussion on restructuring the central bank's balance sheet see section 2.

To sum up, the path for the accumulated profit or loss is calculated from (2) as a sum of the components $NFXA_t$ and $-NCL_t$ related by the foreign exchange operations. The trajectory of $NFXA_t$ is calculated using the difference equation (8). Similarly for NCL_t one uses (3), in which the currency stock is substituted from (4).

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

$$\Delta s_t = \Delta q_t + \pi_{t+1} - \pi_{t+1}^* \tag{11}$$

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 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 (12) captures it.

$$\phi_t = -\Delta\hat{s}_t + i_t - i_t^* \quad (12)$$

where ϕ_t represents the risk premium (predictable excess return), $\Delta\hat{s}_t$ 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

$$\Delta\hat{s}_t = \Delta s_t \quad (13)$$

which amounts to dealing with a perfect-foresight framework.⁸

The substitution of (11) and (13) into (12) gives for the interest rate

$$i_t = \phi_t + i_t^* + \Delta s_t = \phi_t + i_t^* + \Delta q_t + \pi_{t+1} - \pi_{t+1}^* \quad (14)$$

In the following text, we identify the money market rate i_t^* with the foreign portfolio return R_t . With this simplification,⁹ the composite return y_t^* from (9) can be rewritten as

$$y_t^* = \Delta s_t + i_t^* \quad (15)$$

and further using (12) it may be rephrased as

$$y_t^* = i_t - \phi_t \quad (16)$$

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 (10), using the relationship (16) and the balance-sheet identity (2):

$$\begin{aligned} PL_{t+1} &= OWN_{t+1} - OWN_t + DIV_t \\ &= NFXA_t (i_t - \phi_t) - NIBL_t i_t - OL_t \\ &= i_t (M0_t + OWN_t) - \phi_t NFXA_t - OL_t \end{aligned} \quad (17)$$

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 ($\phi_t NFXA_t$), and operating outlays (OL_t).

Using the expression for the interest rate (14) we then arrive at

$$PL_{t+1} = (i_t^* - \pi_{t+1} + \Delta q_t + \phi_t + \pi_{t+1})(M0_t + OWN_t) - \phi_t NFXA_t - OL_t \quad (18)$$

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,¹⁰ which raises its monetary income. However, the equation also

⁸ A generalization allowing for unsystematic errors in exchange rate expectations would be straightforward (see e.g. Holub, 2001a).

⁹ 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.

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.¹¹ 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,¹² 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 $\phi_t NFXA_t > 0$, it may help only to reduce, not to overturn, the inevitable losses.

Furthermore, equation (18) 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 sterilization 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 com-

¹⁰ This is, of course, true only up to the point at which the increasing inflation leads to demonetization 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.

¹¹ There may be a partly offsetting effect of increased monetization 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.

¹² Recall that $M0_t + OWN_t = NFXA_t - NIBL_t$.

parative-static discussion of a central bank's financial sustainability. We start with equation (10), which, using (2) and (16), can be equivalently expressed as

$$OWN_{t+1} = (1 + i_t)OWN_t + i_tM0_t - \phi_tNFXA_t - OL_t - DIV_t \quad (19)$$

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

$$\frac{OWN_{t+1}}{M0_{t+1}} = \frac{(1 + i_t)}{1 + \mu_t} \frac{OWN_t}{M0_t} + \frac{i_tM0_t - \phi_tNFXA_t - OL_t - DIV_t}{(1 + \mu_t)M0_t} \quad (20)$$

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

$$\frac{OWN_{t+1}}{M0_{t+1}} \leq \frac{(1 + i_t)}{1 + \mu_t} \frac{OWN_t}{M0_t} + \frac{i_tM0_t - \phi_tNFXA_t - OL_t}{(1 + \mu_t)M0_t} \quad (21)$$

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*.¹³ 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 (21) 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.

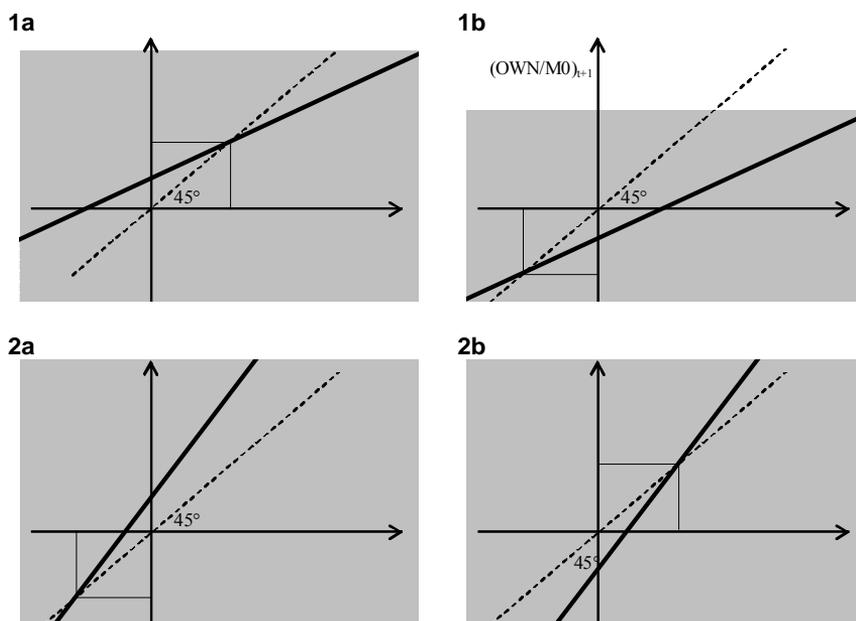
Initially, we will also treat the *nfxa* ratio (i.e., $NFXA_t/M0_t$) as a fully autonomous policy decision of the central bank, which is in line with the approach taken by Holub (2001b) and Ize (2005). This in general implies that the central bank needs to intervene in the foreign exchange markets automatically 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 (21) 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 (21) is the shaded region below the straight solid line with a slope of $(1 + i_t)/(1 + \mu_t)$ and an intercept given by *core profits*.

¹³ Ize (2005) derives his model in continuous time and in a log-linearized form, which leads to some minor differences compared with our expressions derived in discrete time.

Figure 1 Phase Diagram of the Central Bank’s “Capital Ratio”



Based on (21), 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;
- 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 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.¹⁴ With negative core profits, i.e., in case 1b, the situation is much more difficult. The central bank creates losses, which grow over time

¹⁴ 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.

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 toward the same negative steady-state level of capital.¹⁵ Even with a negative level 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 (14), i.e., to $(i^* - \pi^* + \Delta q + \phi)$. 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 monetization 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 recapitalization of the central bank would be a permanent solution in this case, though.

¹⁵ 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”. 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 favor of domestic currency assets). Such a comprehensive recapitalization would, of course, solve the problem.

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.¹⁶ 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 $(OWN/MO)^{2b}$ 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 (20) as

$$own = \frac{i - \phi nfxa - ol}{\mu - i} \quad (22)$$

where $i = i^* - \pi^* + \Delta q + \phi + \pi$ 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 (8), describing the development of net foreign exchange assets over time, and rewrite it for the *nfxa* ratio using (16) as:

$$\begin{aligned} \frac{NFXA_{t+1}}{MO_{t+1}} &= \frac{1 + y_t^*}{1 + \mu_t} \frac{NFXA_t}{MO_t} + \frac{INT_t}{(1 + \mu_t)MO_t} \\ &= \frac{1 + i_t - \phi_t}{1 + \mu_t} \frac{NFXA_t}{MO_t} + \frac{INT_t}{(1 + \mu_t)MO_t} \end{aligned} \quad (23)$$

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 toward 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.

¹⁶ 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.

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

$$y^* = (i - \phi) < i < \mu \quad (24)$$

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 1* eventually turns into case 1a.

A much less favorable situation would emerge if

$$i > y^* = (i - \phi) > \mu \quad (25)$$

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

The active balance sheet adjustment involves selling the foreign exchange assets of central banks. In practice, it has been undertaken for example in Chile and Mexico. This option is limited by the possible undesired consequences it may have for the exchange rate. A way of active adjustment without such fallout 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 strategy has indeed been pursued in some countries. Furthermore, there have been proposals that the central bank may opportunistically sell to the market when there are depreciation pressures. However, such leaning-against-the-wind can create the perception that the central bank will insure speculators and that currency is a safe one-way bet. Therefore, it seems that there might be a case for preannounced automatic measures designed to minimize the interference of balance-sheet management with monetary policy. The CNB’s scheme of selling a portion of its earnings on foreign exchange reserves, which has been in place since 2004, falls into this category.

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

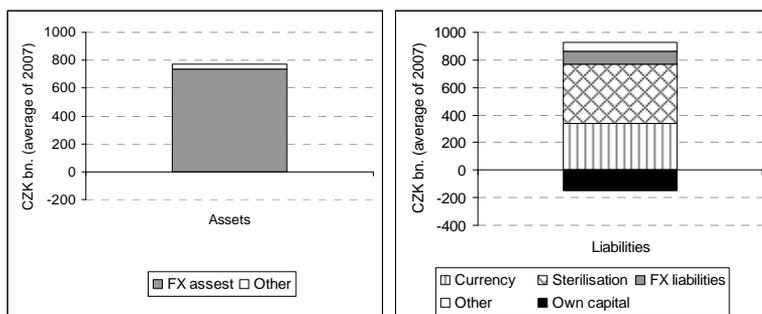
The Czech National Bank is an example of a central bank facing economic convergence challenges.¹⁷ It is illustrated in *Figure 2* that as of 2007, the CNB’s assets were dominated by foreign exchange reserves, the volume of which was more than double that of currency in circulation.

The large stock of foreign reserves was mirrored on the liability side by items stemming from sterilization of excess liquidity (i.e., CZK-denominated interest-bearing liabilities to the domestic banking sector), which was created by purchases of foreign currency assets. The sterilization is necessary to keep short-term interest rates at the desired level from the monetary policy point of view.

The stock of foreign reserves has risen from a relatively modest initial level equivalent to 1.9 bn. euro in 1993¹⁸ more than tenfold to above 23 bn. euro in 2007.

¹⁷ 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.

Figure 2 Graphical Exposition of the CNB's Balance Sheet



Source: CNB

Table 1 shows that the foreign reserves have grown large not only in absolute terms, but also relatively with respect to currency in circulation.

Roughly half of the current foreign exchange reserves were accumulated before May 1997. In that period, CNB followed a de facto fixed exchange rate regime and over time it had to purchase more and more of the foreign capital attracted by privatization and gradual liberalization of capital flows. But even though in 1997 the exchange rate was allowed to float, a significant amount of foreign reserves has been acquired since that time. This reflects three episodes of foreign exchange market interventions¹⁹ and also direct purchases of government privatization revenues.²⁰ By these measures, in effect by adding liquidity to the foreign exchange market, the CNB attempted to avoid disorderly nominal appreciation of the currency.

4.1 A Brief History of the Losses

Figure 2 also indicates that in 2007 the CNB's own capital was negative at almost 50% of the currency issued. Even though quasi-fiscal losses related to banking sector rescue were incurred in the second half of the 1990s, the bulk of the accumulated loss stems from appreciation of Czech koruna and marking-to-market of the foreign exchange reserves, as Table 2 illustrates.

In the table, 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).

The macroeconomic reasons for this loss can be directly mapped to the factors listed in the discussion in section 4 after equation (18): real appreciation, disinflation and inflation targets that have been gradually lowered, and also the risk premium of the Czech economy systematically contributed to the CNB's negative P/L.

We applied the framework developed in sections 1 to 3 to the historical data and compared it with the CNB's actual accounting data. Specifically, we took the ac-

¹⁸ When Czechoslovakia was split into the Czech and Slovak Republics.

¹⁹ In 1998, late-1999/early-2000, and 2001–2002.

²⁰ It is interesting to note that the CNB's agreement with the government on purchases of privatization revenues included government participation in the expected sterilization 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.

Table 1 The CNB's Foreign Exchange Reserves (yearly averages in millions)

Year	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

Table 2 CNB Profits/Losses from Selected Operations (in CZK billion)

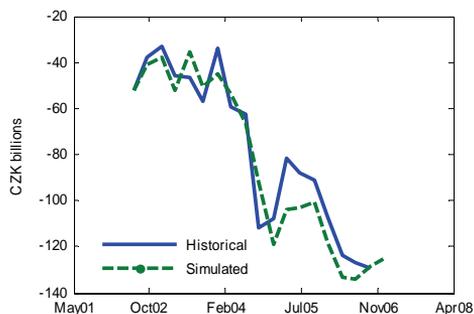
Year	Asset Revaluation Profits/Losses	Monetary Policy and Foreign Reserves Management Profits/Losses	Quasi Fiscal Operations Profits/Losses	Total Profits/Losses
1993	-1.86	0.38	0.00	-1.48
1994	1.54	-4.04	-2.88	-5.38
1995	1.00	7.30	-3.60	4.70
1996	-8.34	2.10	-1.45	-7.69
1997	44.65	0.79	-35.69	9.75
1998	-35.61	-6.39	-26.10	-68.10
1999	31.52	0.42	1.69	33.63
2000	-3.52	7.88	-1.58	2.78
2001	-40.12	12.70	1.05	-26.37
2002	-26.15	11.38	0.57	-14.20
2003	-29.77	12.84	0.76	-16.17
2004	-61.14	8.16	0.88	-52.10
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

tual balance sheet at a particular past date and conducted 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 conducted by the CNB on its own account, and the CNB's actual operating outlays.

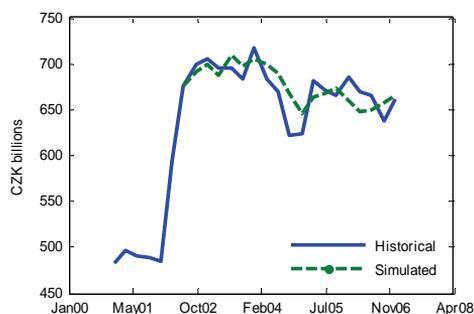
Figures 3 and 4 show that the projections follow the actual development quite closely. This corroborates that the model is internally consistent and has captured the most important factors affecting the CNB balance sheet. It shows that the balance sheet of the central bank may indeed be driven mainly by macroeconomic factors over which it can have no or very limited control.

Figure 3 The CNB's Actual Own Capital and Historical Projection



Source: The authors' calculations.

Figure 4 The CNB's Actual Net Foreign Exchange Assets and Historical Projection



Source: The authors' calculations.

Although the actual dynamics of the explanatory factors listed above were utilized, the very good fit of the CNB own capital projection in *Figure 3* is not 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 modeled well enough and that the bulk of the CNB's net local currency liabilities are remunerated at the monetary policy interest rate.²¹

4.2 The CNB's Balance-Sheet Sustainability

The framework derived in section 3 is suitable for assessing whether a central bank's balance sheet is sustainable along the convergence path. As an illustration, we apply the framework to the CNB's case. We first provide an analytical exposition of

²¹ For example that fixed assets or gold represent a very small proportion of total local currency liabilities.

its balance-sheet sustainability using analytical comparative-statics and then move to direct simulation exercises.

In order to use the model, one needs to make assumptions regarding the key macroeconomic variables. Importantly, those assumptions should be internally consistent and should reflect some basic consensus concerning the long-run trends of the economy. Therefore, the modeling of the balance sheet is based on the CNB's macroeconomic forecast as published in the CNB's Inflation Report.²² 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,²³ and the long-run trends are chosen consistently with the model assumptions. For our long-term balance-sheet projections, the trends and equilibrium values underlying the forecast are, of course, more important than the business cycle dynamics.

4.2.1 Comparative-Static Exposition

The comparative statics of the CNB's capital ratio as suggested in subsections 4 and 5 are based on the long-term assumptions underlying the CNB's macroeconomic forecast (produced in October 2007). Specifically, 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, and an operating outlays ratio of 0.7%. We assume long-run nominal currency growth equal to 8%. The stock variables are set to their current values.

With these assumptions, the CNB currently finds itself in situation 1b described in subsection 3.5.1 (see *Figure 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%).

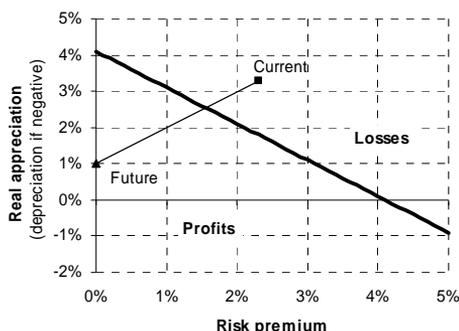
The results are sensitive to the assumed values of the key parameters and policy variables. For example, should the risk premium be one percentage point higher than assumed and all other things remain unchanged, which is certainly not unrealistic given the past estimated values of the risk premium, the 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 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

²² The central CNB macroeconomic forecast is used. Its risks are not quantified in full; nevertheless, distributions derived from past forecasting errors are provided. Alternative scenarios are employed to tackle uncertainty.

²³ See Beneš et al. (2002) for a detailed description. Used until mid-2008.

Figure 5 Combinations of the Risk Premium and Real Appreciation Implying Zero Core Profits



Source: The authors' calculations.

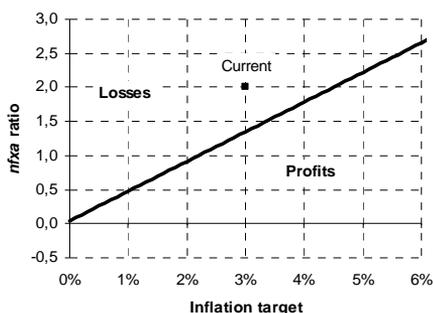
forecasts assume that both the risk premium and the real exchange rate appreciation should be falling over time, toward 0% and 1% respectively. Such a change would improve the CNB's core profits to roughly 3.1% of currency in circulation (2.1% for the new inflation target), shifting it to case 1a from *Figure 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 5* 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 toward 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 ensure 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.

Another two margins of adjustment of core profits are the policy variables, i.e., the inflation target and the $\eta f x a$ ratio. An increase in the inflation target and/or a reduction in the $\eta f x a$ ratio would push the zero profit line in *Figure 5* 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 6* 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%).²⁴ It can be seen that with the current $\eta f x a$ 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

²⁴ 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 $\eta f x a$ 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 6 Combinations of the NFXA Ratio and Inflation Target Implying Zero Core Profits



Source: The authors' calculations.

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.

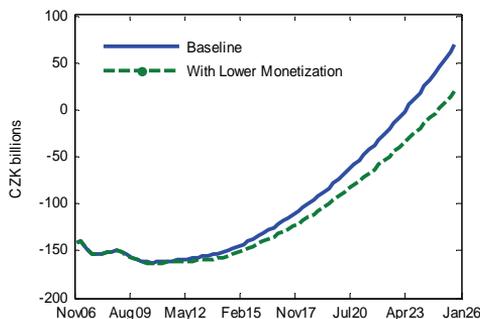
In this paper, however, we are concerned mainly with the long-run sustainability of the central bank's balance sheet, and a balance-sheet adjustment may well be achievable in the long run. This is true especially in those cases where the starting $nfxa$ ratio does not reflect true policy preferences 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 characterized by the optimistic scenario (24). 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.

4.2.2 Simulation into the Future

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.

Figure 7 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

Figure 7 Future Simulation of the CNB's Own Capital



Source: The authors' calculations.

quarter of 2007, consistently with the long-term values in section 4.2.1. Additionally, it is assumed that long-run potential output growth will decline gradually from 5% toward 3% in the simulations. It 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 (monetization) 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 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 interest rates only marginally, as estimated by Hanousek and Tůma (1995), and it is unlikely that the level of monetization will grow further in the future. As a result, the level of monetization remains roughly the same in our baseline simulation, causing the growth of cash holdings to converge toward the growth of nominal GDP.

In addition, we assume that the foreign equilibrium real interest rate will rise gradually toward 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. Also, the risk premium is assumed to decline over time toward 0%. Finally, the current value of the trend real exchange rate appreciation is assumed to decline gradually toward 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 modeled 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

Table 3 CNB Balance-Sheet Projections Based on the CNB's Macroeconomic Forecast From Q4 2007 (in CZK billion)

Year	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: The authors' calculations.

its reserves in return for koruna. However, no other foreign exchange operations are taken into account in the simulation.

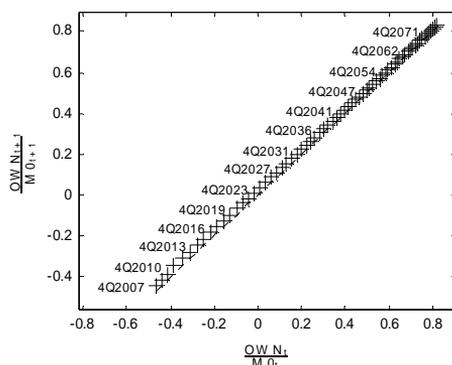
We further assume that the CNB neither pays dividends to the state budget nor receives any government support. Therefore, we assume that $DIV = 0$.

It follows from *Figure 7* that the period of losses is not fully over yet. The baseline scenario predicts that the own capital becomes initially even more negative. *Table 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 sterilizations. 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 sterilize liquidity and the CNB becomes a net creditor in the domestic currency.

The evolution of the CNB's balance sheet structure in relative terms is illustrated in *Figures 8* and *9*, which show the phase diagrams of projected own capital ratio and the *nfxa* ratio. It is evident that despite the initial worsening, the losses remain repayable by the stream of future profits in the baseline scenario and the capital ratio may eventually grow to substantially positive levels (*Figure 8*). 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 favorable. At the beginning the bulk of the assets were in foreign low-yielding currency, whereas with liquidity provisioning the asset composition will tilt toward the local currency.

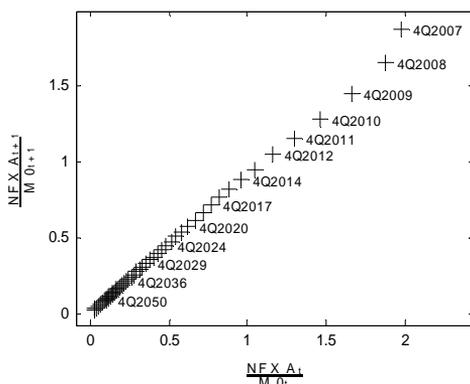
Furthermore, it might be reasonable to expect, in line with the simulation's underlying assumptions, that the appreciation of the real exchange will decline and will be a smaller drag on profits. Moreover, the declining *NIBL*, and with it a falling *nfxa* ratio (*Figure 9*), will limit the negative influence of the declining, but still posi-

Figure 8 Phase Diagram of the Projected CNB Own Capital Ratio



Source: The authors' calculations.

Figure 9 Phase Diagram of the Projected CNB's NFXA Ratio



Source: The authors' calculations.

tive, 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 toward positive values. As these factors are quite likely to happen in the future, the accumulated loss is similarly 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 4.2.1 we analyzed 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 4.2.1, i.e., the nominal currency growth rate. In *Figure 7* above, we pre-

sent an alternative simulation based on the assumption that the monetization 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 monetization 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. 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. 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 of losses is the focal point of the present paper. 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 sterilize 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 et al. (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 macro-economic trends than the earlier literature. Most importantly, we have analyzed 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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