Monetary policy, banking, and systemic risk in open economies

Jaromír Beneš†
International Monetary Fund

Andrea Gerali
Bank of Italy

David Vávra
Czech National Bank

Unfinished draft
October 26, 2009

Abstract

We build an extension of a small open economy DSGE model to incorporate in policy simulations and forecasts a feedback loop between a banking sector, bank capital, and default risk on the one hand, and real activity on the other hand in economies exposed to currency and maturity mismatches. The framework can be used to address the following four broad categories of issues: (I) the effect of the state of the banking sector (especially its capitalisation) on the predictions of macroeconomic indicators, (II) assessing the risks of large balance sheet effects vis-à-vis large financial shocks and devaluations or depreciations, (III) using time-varying capital requirements as a complementary policy instrument, and (IV) providing basic macroeconomic and dynamic consistency in systemic risk simulations and early warning exercises.

†Corresponding author: jbenes@imf.org.
# Contents

1 **Introduction** 3

2 **The model** 5  
  2.1 Real economy 5  
  2.2 Financial intermediation 7  
  2.3 Monetary policy 13

3 **Model calibration** 13  
  3.1 Steady-state parameters 13  
  3.2 Transitory parameters 13  
  3.3 Duration of loans 13  
  3.4 Bank cost function 13  
  3.5 Non-performing loans 13

4 **Simulation experiments** 13  
  4.1 Country premium shock 13  
  4.2 Housing boom and bust 13

5 **Concluding remarks** 13

A **Optimal behaviour of the model’s agents** 15  
  A.1 The consumer 15  
  A.2 The firm 15  
  A.3 The bank’s wholesale branch 15  
  A.4 The bank’s retail branch 16  
  A.5 Central bank 16

B **The bank’s loan-to-equity cost function** 16

C **The non-performing loans** 16

D **The solution algorithm** 17

E **Simulation graphs** 19
1 Introduction

We build a relatively simple extension of a small open economy DSGE model to incorporate in policy simulations and forecasts a feedback loop between a banking sector, bank capital, and default risk on the one hand, and real activity on the other hand, in economies exposed to currency and maturity mismatches. The framework is meant to address the following four broad categories of issues:

1. Evaluating the implications of the state of the banking sector, especially its capitalisation, for the predictions of the main macroeconomic variables.

2. Assessing the options monetary policy makers have in open economies when faced with large financial distress (such as the one induced by the current global financial crisis) with potentially fatal implications for the bank and non-bank balance sheets.

3. Using time-varying bank capital requirements as a complementary tool to accompany more traditional monetary policy based on controlling the short term rates or the nominal exchange rate, and contain some of the systemic risk.

4. Providing general-equilibrium consistency and a time dimension to systemic risk simulations and early warning exercises based (usually) on static balance-sheet models.

We find a number of features critical in building such a framework. First, the banks are modelled as agents with their own net worth, i.e. bank capital. This is not only because bank capital is subject to regulation, but also because the state of the banking sector and the indicators relating to bank capitalisation may improve on the analytical power and story-telling capacity of macro models at times. We build on some of the existing literature that has bank capital as another state of the economy, such as Markovic (2006) or de Walque et al. (2008), but deviate from these in the way the capital is given a non-trivial role in general equilibrium.

Second, the banks bear some of the aggregate risk. We emphasise this feature because it fundamentally differs from a large amount of the literature on financial frictions built around the accelerator of Bernanke et al. (1999). The debt contracts therein are, in fact, one-period loans contingent upon macroeconomic outcomes. The financial intermediaries can, therefore, adjust the interest rates \textit{ex post} to compensate for any losses unforeseen at the time the contract was signed. However,
ex-post bank losses caused by adverse macroeconomic shocks, increases in non-performing loans, and mismatches on the banks’ balance sheets can be an important propagation mechanism in the real world. To this end we introduce two sources of ex-post risks on the banks’ side:

- We introduce non-performing loans, and link them to aggregate macroeconomic outcomes in a rather ad-hoc way. This is a very stylised simplification motivated by practical considerations, with no underlying microeconomic foundations. As such, it will be subject of our future research.

- We expose the banking sector to maturity mismatches, letting them provide multi-period loans to the consumers and refinance these with short-term debt. As we argue, the inclusion of long-term maturities has no first-order effects on the ex-ante choices of the consumers and banks, but can significantly influence the balance sheets and the rest of the economy ex post, in the presence of unforeseen shocks.

- We expose either the banks, or the households, or both, to currency mismatches.

Third, we believe macroeconomic systems tend to display discontinuous behaviour when exposed to very large shocks, with the basic elasticities and multipliers changing sizeably beyond a certain point. We choose some of the functional forms so to capture such non-linearities, and demonstrate their effect in our simulations. To this end, we also develop a simple and fast solution method handling a small number of non-linearities while resorting the usual first-order approximation elsewhere.

The paper is organised as follows. In Section 2, we flesh out the model’s two sectors: the real sector and the financial sector. In Section 3 we conduct several simulation and policy experiments to illustrate the properties of our framework and its usefulness for structuring policy debates, and summarise the major policy implications. Section 4 concludes. There are a number of technical appendices. Appendix A derives the optimality conditions for the model’s individual agents. Appendices B and C explain the reasons and the way the banks’ cost function and the non-performing loans are introduced. Appendix D details the solution method used to handle the non-linearities.
2 The model

To strike a balance between the real and financial aspects of the model, we keep the structure of the real economy relatively simple. It features one production sector that uses three types of inputs, namely capital (in fixed supply at the aggregate level) and domestically produced intermediates, and imported inputs, to produce domestic consumer goods and exports. We add the usual real and nominal rigidities to obtain realistic business-cycle dynamics.

Financially, the country as a whole is a net debtor by assumption, owing to the consumers’ time preferences relative to the rest of the world. The consumers borrow from banks; these, in turn, combine foreign funds and their own equity (bank capital), to make the loans.

For ease of notation, we describe the agents’ problems assuming that all assets and liabilities, except the banks’ foreign borrowing, are denominated in local currency. It is then straightforward to extend the model to cover more general currency structure, and expose some of the agents to currency mismatches. We discuss these modifications in Appendix A. Also, we do not explicitly introduce the usual Dixit and Stiglitz (1977) monopolistically competitive markets when they are necessary (for costly price adjustments), but rather impose downward-sloping demand curves on representative agents instead, consistent with the implications of such market structures. To this end, quantities and prices taken as given are denoted by a bar.

2.1 Real economy

Consumers. The representative consumer demands domestically produced consumer goods, $C_{H,t}$, and imports, $C_{M,t}$, trades in physical capital, $K_t$ (which is rented out to the firms), takes multi-period bank loans, $L_t$, described later in this section, and receives profits from the firms, dividends for the banks, and the operating surpluse of the central bank. The consumer chooses $C_{H,t}$, $C_{M,t}$, $K_t$, and $L_{n,t}$ to maximise

$$E_0 \sum_{t=0}^{\infty} \beta^t \log(C_t - \theta \tilde{C}_{t-1}),$$

subject to a budget constaint,

$$L_t = J_{t-1} - [R_{K,t}K_t + P_{K,t}(K_t - K_{t-1}) + \Pi_t - P_{H,t}C_{H,t} - P_{M,t}C_{M,t}], \quad (1)$$
where $J_{t-1}$ is the sum of all repayments payable at time $t$ associated with all loans taken in the past that have not matured yet and defined later on (in the special case with only one-period loans existing, obviously $J_{t-1} = L_{t-1}R_{Lt-1}$). $R_{K,t}$ is the rental price of capital, $\Pi_t := \Pi_{F,t} + \Pi_{B,t} + \Pi_{CB,t}$ is the sum of the firms’ profits, the banks’ dividends, and the central bank’s surpluses. The total consumption index, $C_t$, is given by Leontieff preferences over the domestically produced goods and imported goods,

$$C_t := \min \left\{ \frac{C_{H,t}}{1 - \omega}, \frac{C_{M,t}}{\omega} \right\}.$$

For future reference, we denote the consumer’s net current income (excluding debt service) by $\Theta_t$,

$$\Theta_t := R_{K,t}K_t + P_{K,t}(K_t - K_{t-1}) + \Pi_t - P_{H,t}C_{H,t} - P_{M,t}C_{M,t}.$$ 

We show later in this section that the consumer’s problem with a multitude of maturities can be kept analytically tractable and with a very small number of new state variables needed while preserving the main implications of multi-period nominal debt provided.

**Production.** The representative firm uses a capital rented from the consumer, domestically produced intermediates, $N_{H,t}$, and imports, $N_{M,t}$, to produce output, $Y_t + X_t$, sold in two segmented markets: a domestic market (to the consumer, and to other firms as intermediates) and an export market (to the rest of the world),

$$Y_t + X_t = K_t^{1 - \gamma_H - \gamma_M}N_{H,t}^{\gamma_H}N_{M,t}^{\gamma_M}.$$

Because of the design of the production function, the firm’s marginal cost is independent of scale of output, and we can split the its decision-making into two stages. First, the input factors are demanded in proportions given by their relative prices. The factor prices also determine the marginal cost,

$$\Phi_t \propto R_{K,t}^{1 - \gamma_H - \gamma_M}P_{H,t}^{\gamma_H}P_{M,t}^{\gamma_M}.$$

Second, the firm maximises the present value of its domestic sales and that of its export sales, both corrected for the cost of price adjustments,

$$E_0 \sum_{t=1}^{\infty} \beta^t A_t \left[ P_{H,t}Y_t (1 - h_{H,t}) - \Phi_tY_{H,t} \right],$$

$$E_0 \sum_{t=1}^{\infty} \beta^t A_t \left[ P_{X,t}X_t (1 - h_{X,t}) - \Phi_tX_t \right],$$
subject to downward-sloping demand curves,

\[ Y_t = \left( \frac{P_{H,t}}{\bar{P}_{H,t}} \right)^{-\varepsilon_c} \tilde{Y}_t, \]
\[ X_t = \left( \frac{P_{X,t}}{\bar{P}_{X,t}} \right)^{-\varepsilon_x} \tilde{X}_t, \]

where \( h_{H,t} \) and \( h_{X,t} \) are quadratic costs associated with domestic price and export price adjustments.

\[ h_{H,t} := \xi_c \left[ \Delta \log P_{H,t} - \Delta \log \bar{P}_{H,t-1} \right]^2, \]
\[ h_{X,t} := \xi_c \left[ \log \left( \frac{P_{X,t}}{S_t} \right) - \log \bar{P}_{W,t} \right]^2. \]

### 2.2 Financial intermediation

The country as a whole is a net debtor. Intermediation of foreign funds follows in two stages. First, a representative, locally owned bank obtains foreign funds. Second, these funds are combined with the bank’s own equity (bank capital), and lent to the consumer in different maturities. The bank, is therefore, exposed to maturity mismatches, with short-term debt on its liabilities, and multi-period loans on its assets.

We first explain how to make the consumer’s and bank’s problem with multi-period loans tractable while preserving the stylised effects of exposure to maturity mismatches. Then, we describe the behaviour of the banking sector with bank capital introduced as an indispensable factor in financial intermediation.

To keep the analysis tractable, we split the representative bank into its wholesale and retail branches, both of which behave competitively. The wholesale branch borrows from abroad, combine the foreign funds with the bank’s equity, purchases central bank bills, and extends short-term loans to the retail branch. Furthermore, wholesale banking is subject to convex costs increasing in the loan-to-equity ratio. This cost function guarantees that bank capital is an indispensable factor, an assumption discussed in more detail at the end of this section.

The retail branch arranges swaps between the wholesale branch and the consumer. It offers the consumer a complete range of maturities refinanced by the short-term funds from the wholesale branch. The loans extended to the consumer are risky in the sense that in each period, a certain portion of the existing loan contracts disappear and pose a real cost to the economy’s overall resources. This assumption is to mimic the fact that there non-performing loans, without actually deriving that process from microeconomic foundations. The default rate is an ad-hoc function of overall macroeconomic conditions.
The wholesale and retail branches externalise the other’s decisions in our current framework. However, at the end of the day, they combine the net worth of each into the bank’s total equity, which is what determines the costs associated with the bank’s leverage. Such a set-up obviously distorts the pricing of the loans. We will examine this inconsistency more carefully and remove it in the future development.

Multi-period loans in the consumer’s problem. In this section, we modify an otherwise standard consumer problem to incorporate the effects of the existence of multi-period debt with fixed repayments. Our aim is not to address the consumer’s portfolio choice between various options (such as multi-period, fixed-rate loans versus one-period or variable-rate loans), but rather to draw the implications of the existence of long-term debt while keeping the framework as analytically tractable as possible.

The consumer, a net debtor at all times, can only take a loan that is repaid in an infinite number of geometrically decaying repayments, starting from next period. The repayments are determined at the time the loan is granted, and cannot be renegotiated. The declining repayments mimic the fact there are typically all possible maturities existing at an aggregate level, with the effect of each cohort of loans (i.e. the loans with different maturities taken at a particular time) decaying over time, as more and more loans mature and the amount being repaid on that cohort decreases. We can easily characterise the “average” time until maturity of such a geometric loan by Macaulay’s duration,¹ and match this with the aggregate duration of loans existing in the real world (or other forms of debt, for that matter). We discuss the duration in more detail in Section 3.3. Moreover, the declining repayments do not contradict our effort to model fixed-rate loans: It is the fact that the repayment scheme is set (fixed) at time $t$ and cannot be changed at any later time that matters.

Introducing an infinitely long loan with geometric repayments has two major practical advantages over a more common loan with a fixed, finite maturity and flat repayments throughout. First, the geometric distribution allows us to write all the summations involved in describing the problem in recursive form. In other words, it does not entail a (possibly very large) number of new state variables in models with very long maturities.² Second, the average maturity can be calibrated using just one parameter, namely the rate at which the repayments decay, without changing the model’s structure in any other way.

¹ See Bierwag and Fooladi (2006) for an overview of duration analysis.
² For example, 80 new state variables would be needed in a quarterly model with 20-year debt.
We now describe the problem formally. A loan $L_t$ taken at time $t$ is paid back in repayments proportional to the amount borrowed and decaying at a fixed rate $\phi \in (0, 1)$:

- repayment due at $t+1$: $Q_t L_t$,
- repayment due at $t+2$: $\phi Q_t L_t$,
- \ldots
- repayment due at $t+k$: $\phi^{k-1} Q_t L_t$, etc.

The consumer’s otherwise standard budget constraint can be now written as

$$L_t = J_{t-1} + \Delta_t,$$

where $L_t$ is the amount currently borrowed, $J_{t-1}$ is the sum of all repayments due at $t$ associated with all past loans,

$$J_{t-1} = \sum_{k=1}^{\infty} \phi^{k-1} Q_{t-k} L_{t-k},$$

and $\Delta_t$ is the consumer’s current income less current expenditures (not including debt service). Note first that $J_t$ can be written recursively as

$$J_t = \phi J_{t-1} + Q_t L_t,$$  \hspace{1cm} (2)

and that setting $\phi = 0$ exactly reproduces the standard problem with one-period debt.

Then, assigning the $t+k$ budget constraint a Lagrange multiplier $\beta^{t+k} \Lambda_{t+k}$, and the law of motion for $J_{t+k}$ a Lagrange multiplier $\beta^{t+k} \Lambda_{t+k} \Psi_{t+k}$, we can work out the first-order conditions w.r.t. to $L_t$ and $J_t$, respectively:

$$L_t : 1 = \Psi_t Q_t,$$  \hspace{1cm} (3)

$$J_t : \Psi_t = E_t \left[ \frac{\beta \Lambda_{t+1}}{\Lambda_t} (1 + \phi \Psi_{t+1}) \right].$$  \hspace{1cm} (4)

To understand these two conditions, we will now turn to how the repayments are determined. Let’s suppose there is a risk-neutral agent who supplies the multi-period loans while refinancing herself through short-term (one-period) debt, and bearing all the maturity mismatch risk. In a competitive market, the present value
of the repayments discounted by the short-term rate \( R_t \) will equal the amount borrowed,

\[
1 = Q_t \sum_{k=1}^{\infty} \phi^{k-1} E_t \left[ \frac{1}{R_t \cdots R_{t+k-1}} \right].
\]

Expressing this condition recursively,

\[
1 = \Omega_t Q_t, \quad (5) \\
\Omega_t = \frac{1}{R_t} [1 + \phi \Omega_{t+1}], \quad (6)
\]

and comparing Eqs. (5)–(6) with Eqs. (3)–(4), we can observe that \( \Phi_t = \Omega_t \) at all times, and

\[
E_t \left[ \frac{\beta \Lambda_{t+1}}{\Lambda_t} \right] = \frac{1}{R_t}.
\]

In other words, the usual one-period Euler consumption equation holds, and is based on a one-period rate (i.e. the rate used to construct the price of the multi-period loan).

We can now summarise the two most important implications:

1. The consumer’s ex-ante decisions are identical to those that would prevail in an economy where only one-period debt exists. The existence of multi-period loans does not alter the way the consumer wishes to substitute intertemporally; the intertemporal substitution between \( t \) and \( t+1 \) is still determined by the underlying one-period rate. Nor does it change the ex-ante path for the consumer’s shadow value of wealth.

2. The existence of multi-period loans matters for the consumer’s outcomes ex post, through valuation effects, to the extent the economy is hit by unforeseen shocks. This can be seen from the budget constraint, Eq. 2, where only a small proportion of future repayments is affected by today’s conditions, as opposed to a one-period loan case for which the \( t+1 \) repayment would be entirely determined by today’s short-term rate.

Notice the implication 1 is not specific to the design of our geometric loan. It is more general. Imagine a more realistic example where the consumer can choose any combination of all possible maturities between one and infinity. Although we would not be able to determine the individual amounts borrowed (without adding some more assumptions), the first-order conditions, which would effectively give rise to an expectations-based term structure of interest rates, would still include the intertemporal condition relating consumption at \( t \) and \( t+1 \) to a one-period rate.
**Wholesale banking.** The bank as a whole is owned by the consumer, and is required to follow a fixed dividend plan. Namely, it must pay the dividends out in fixed proportion, \( \delta \), to its gross revenues, \( V_t \). The assumption of an exogenous (i.e. non-optimised dividend policy) is critical for giving the bank capital, or a non-consumer agent’s net worth in general, a non-trivial role. It is used in similar context e.g. by Aoki et al. (2004).

The wholesale branch of the bank maximises the present value of these dividends

\[
E_0 \sum_{t=0}^{\infty} \beta^t \Lambda_t \delta V_t,
\]

subject to a balance sheet identity

\[
H_t + B_t = F^*_t S_t + E_t,
\]

and the law of motion for equity,

\[
E_t = (1 - \delta) V_t,
\]

where \( H_t \) are a wholesale loan extended the retail branch, \( B_t \) is the purchases of central bank bills, \( F^*_t \) is foreign borrowing, and \( E_t \) is the bank’s capital (equity or net worth). The bank takes the interest rates, i.e. \( R^H_t, R^B_t, \) and \( R^*_F \), as given.

The gross revenue is the amount the bank receives at the beginning of the next period in wholesale loan repayments plus the gross return on the government bonds, minus the amount to be repaid on the foreign funds, and adjusted for a convex cost increasing in the bank’s loan-to-equity (LTE) ratio, \( \lambda_t \equiv H_t/E_t \),

\[
V_t := R^H_{t-1} H_{t-1} + R^B_{t-1} B_{t-1} - R^*_F_{t-1} F^*_{t-1} S_{t-1} - E_{t-1} f(\lambda_t) + e_t,
\]

where \( e_t \) is the net worth of the retail branch taken as given. We discuss the details of the \( f \) function in Appendix B. Structural interpretation of it can be based on both reputational and regulatory costs associated with low levels of capitalisation. Moreover, the fact that we impose a smooth function rather than an inequality constraint can be thought of as an analogy to inventory models and the expected costs of stocking out, such as Blanchard (1983): The mere approaching of the bank’s conditions to a critical threshold (such as a minimum regulatory requirement), and hence an increased probability of hitting it in the near future, is costly.

The most important result (derived in Appendix A) is that the optimal wholesale lending rate is set independent of the shadow value of the bank’s equity, as a
mark-up over the policy rate, $R_{B,t}$.

$$R_{H,t} = R_{B,T} + f' (\lambda_t),$$

increasing in the LTE ratio.

**Retail banking.** The retail branch receives short-term wholesale loans, $H_t$, from the wholesale branch, and extends a total amount of $L_t$ in multi-period loans to the consumer. At the same time, it receives repayments for all the existing loans. Recall that these repayments are always pre-determined at the time of granting the respective loan, and cannot be changed or re-negotiated at a later time.

Every period, a certain fraction, $g_t$, of all existing loans turn non-performing, with the share of non-performers cumulating throughout the term of the loan. In our model, *non-performing* means that the loan is still being repaid by the consumer, but the repayments never reaches the bank. There is a very important reason for such an, at first sight rather peculiar, assumption: We want the bank to face losses from the non-performing loans (and hence increase the lending rates vis-à-vis expected increases in the non-performing loans) but, at the same time, we do *not* want the representative consumer to be relieved from the costs of intertemporal substitution. We will return to this point after showing how the retail lending rate is set by the branch.

Under these conditions, the law of motion for the retail branch’s short-term debt is given by

$$H_t = R_{H,t-1} H_{t-1} + L_t - j_{t-1},$$

where $j_t$ is the sum of all repayments received at $t$ adjusted for the past and current defaults. Using the assumption of a geometrically decaying sum of repayments associated with each cohort of loans, the receipts of the retail branch evolve as follows:

$$j_t = (1 - g_t) [\phi j_{t-1} + Q_t L_t],$$

where $Q_t$ is the initial repayment rate of a hypothetical geometric loan.

The retail branch equates the cost of refinancing, determined by $R_{H,t}$, and the expected revenues from providing the loans. The one-period lending rate, $R_{L,t}$ is, therefore, given by

$$E_t [1 - g_{t+1}] R_{L,t} = R_{H,t}.$$

Finally, we need to evaluate the net worth of the retail branch, $e_t$, included in the bank’s total equity. It is given by the present value of the expected repayments
to be received by the branch, discounted by its refinancing rate,

\[ e_t := j_{t+1} \sum_{\tau=1}^{\infty} \phi^{\tau-1} E_t \left[ \frac{(1 - g_{t+1}) \cdots (1 - g_{t+\tau})}{R_{H,t} \cdots R_{H,t+\tau-1}} \right]. \]

### 2.3 Monetary policy

We show in Appendix A that the balance sheet of the central bank is, absent portfolio balance channels, irrelevant for the general equilibrium outcomes. We can, therefore, assume, with no harm, that \( B \rightarrow 0 \), while letting the central bank control the policy rate, \( R_{B,t} \).

Monetary policy is, in general, conducted through a combined reaction function based on an inflation-targeting rule and exchange rate management. The two objectives, the inflation target and the central parity, are always set consistent with each other ex ante.

### 3 Model calibration

#### 3.1 Steady-state parameters

#### 3.2 Transitory parameters

#### 3.3 Duration of loans

#### 3.4 Bank cost function

#### 3.5 Non-performing loans

### 4 Simulation experiments

#### 4.1 Country premium shock

#### 4.2 Housing boom and bust

### 5 Concluding remarks
References


A Optimal behaviour of the model’s agents

A.1 The consumer

A.2 The firm

A.3 The bank’s wholesale branch

First, we can use the balance sheet identity,
\[ H_t + B_t = F_t^* S_t + E_t \]
to substitute the central bank bills away,
\[ V_t = (R_{H,t-1} - R_{B,t-1}) H_{t-1} \\
    - (R_{F,t-1} S_t - R_{B,t-1} S_{t-1}) F_{t-1} + R_{B,t-1} E_{t-1} - E_{t-1} f(\lambda_{t-1}) + e_t. \]

The wholesale branch’s Lagrangian is then as follows:
\[ \mathcal{H} = E_0 \sum_{t=0}^{\infty} \beta^t \Lambda_t \left\{ \delta V_t + \Phi_t \left[ (1 - \delta) V_t - E_t \right] \right\}, \]

The first-order necessary conditions then are as follows:
\[ H_t : \quad V_{H,t} [\delta + (1 - \delta) \Phi_t] = 0, \quad (7) \]
\[ F_t : \quad R_{F,t} E_t \left[ \frac{S_{t+1}}{\lambda_{t+1}} \right] = R_{B,t}, \quad (8) \]
\[ E_t : \quad \Phi_t = V_{E,t} E_t \left\{ \frac{\beta \Lambda_{t+1}}{\lambda_{t+1}} \left[ \delta + (1 - \delta) \Phi_{t+1} \right] \right\}, \quad (9) \]
where the derivatives of the gross revenue with respect to \( H_t \) and \( E_t \), respectively, are given by
\[ V_{H,t} \equiv R_{H,t} - R_{B,t} - f'(\lambda_t), \]
\[ V_{E,t} \equiv R_{B,t} + \lambda_t f'(\lambda_t) - f(\lambda_t). \]

Unless \( \delta + (1 - \delta) \Phi_t = 0 \), or \( \Phi_t \) grows unbounded, condition (7) reduces to \( V_{H,t} = 0 \). In other words, the optimal wholesale lending rate setting reduces to a mark-up over the central bank bill rate increasing in the current LTE ratio.

Note that the shadow value of bank capital is not effectively needed to determine the bank’s equilibrium any longer; below we discuss the conditions under which this statement is valid in.
Denoting by $R_{E,t} = V_{E,t}/E_{t-1}$ the gross return on equity, we can now summarise the bank’s optimal plan as follows:

$$\lambda_t = H_t/E_t,$$  \hspace{1cm} (10)

$$E_t = (1 - \delta)R_{E,t-1}E_{t-1},$$  \hspace{1cm} (11)

$$R_{E,t} = R_{B,t} + \lambda_t f'(\lambda_t) - f(\lambda_t) + r_{E,t},$$  \hspace{1cm} (12)

$$R_{H,t} = R_{B,t} + f'(\lambda_t),$$  \hspace{1cm} (13)

$$R_{E,t}^e E_t \left[ \frac{S_{t+1}}{S_t} \right] = R_{B,t},$$  \hspace{1cm} (14)

$$H_t + B_t = F_t + E_t,$$  \hspace{1cm} (15)

$$r_{E,t} = v_t/E_{t-1}.$$  \hspace{1cm} (16)

A.4 The bank’s retail branch

A.5 Central bank

The central bank’s balance sheet has foreign exchange reserves (denominated and expressed in foreign currency), $FX^*_t$, on the assets, and the central bank bills issued, $B_t$, on the liabilities,

$$S_t FX^*_t = B_t.$$  

The operating surpluses, given by the ex-post differences in the interest revenues and costs,

$$\Pi_{CB,t} := FX^*_{t-1} R^*_{E,t-1} \frac{S_{t-1}}{S_t} - B_{t-1} R_{B,t-1},$$

are lump-summed to the consumer.

However, absent any portfolio balance channels, the path for $B_t$ is irrelevant for the macroeconomic outcomes. Any increase in $B_t$ will, ceteris paribus, raise not only the foreign exchange reserves, $F^*_t$, but also the financing needs of the wholesale bank, $F^*_t$, and hence we can keep it zero at all times, allowing the bank still to control the policy rate, $B_t$.

B The bank’s loan-to-equity cost function

C The non-performing loans

We experiment with a number of non-performing-loan functions, each of them being a non-linear, sigmoid function increasing in a particular macroeconomic indicator. The two basic cases are:
an aggregate loan-to-value ratio, measured by the present value of the consumer’s current debt divided by the value of the consumer’s claims to physical productive capital (a hypothetical collateral),

\[ g_t := g \left( \frac{PV_t}{(1 - \kappa)P_{A,t}} \right), \]

where the present value given by the discounted stream of future to-be-paid instalments associated with the loans existing today,

\[ PV_t = J_t \sum_{\tau=1}^{\infty} E_t \left[ \phi^{-1} \beta^\tau \Lambda_{t+\tau} \right] = \frac{J_t}{Q_t}; \]

or a similar loan-to-current-income ratio, with current income

\[ g_t := g \left( \frac{PV_t}{CI_t} \right), \]

where the aggregate current income, \( CI_t \), is

\[ CI_t := R_{K,t} 1 + \Pi_t, \]

see also Eq. 1.

D The solution algorithm
E Simulation graphs

Small-sized shock to country risk premium: 100 bp
Inflation targeting vs Exchange rate peg
Large-sized shock to country risk premium: 1,000 bp
Inflation targeting vs Exchange rate peg
Large-sized shock to country risk premium: 1,000 bp
Exchange rate peg vs Devaluation