# Monetary Policy and Financial Stability in Emerging-Market Economies: An Operational Framework*

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**Abstract**

We develop a simple model that integrates monetary and macroprudential policy transmission, with special reference to emerging-market economies. We illustrate the use of the model by developing a number of hypothetical scenarios that simulate various sources of risk in a typical emerging-market economy: shocks to the country spread, terms-of-trade shocks, and asset price bubbles.

*The views expressed herein are those of the authors and do not reflect the views of any of the affiliate institutions.

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# 1 Introduction

In this paper we develop a simple model that incorporates interactions between monetary business cycles and macro-financial cycles, meaning fluctuations in risk on the balance sheets of financial institutions. The model can be used to quantify the basic channels of both monetary and macroprudential policy transmission, with special reference to emerging-market economies. Models of this kind are useful to regulators and policymakers to lay foundations for an operational framework upon which practical macroprudential policy making could be based. We see the model's role as a platform upon which a broader amount of information, including not only the model's assumptions but also other off-model evidence and expert judgment, can be combined to produce and coordinate sensible policy advice.[1]

The model incorporates several features that we find crucial for modelling the interplay between the real and financial sectors, and some of these features are new in monetary macro models. First, bank lending is modeled as a deposit- and equity-funded nominal debt contract, rather than as deposit-funded investment in risky equity, the latter being the avenue chosen by a number of recent papers on this topic including Gertler and Karadi (2010) and Angeloni and Faia (2009). The model is therefore one of commercial lending banks, rather than of investment banks or equity mutual funds. Second, Bank lending takes place in an environment where lending is risky, and where aggregate, non-diversifiable risk affects the profits not only of borrowers but also of banks, which distinguishes the model from traditional treatments of banks under costly state verification, such as Carlstrom and Fuerst (1997) and Bernanke et al. (1999). Banks therefore need to have their own net worth to absorb risk, and this net worth plays a non-trivial role in determining the banks' lending policy. Third, bank capital is subject to regulation, but this regulation is not "hard-wired" as a binding constraint on banks' decision-making, as in Angeloni and Faia (2009) and a number of other papers in this literature. The regulation is rather a system of penalties that creates incentives for bank behavior, as suggested by Milne (2002). This way, the model creates endogenous regulatory capital buffers, which are an important empirical regularity in all banking systems (Jokipii and Milne (2008)), and are able to interpret the responses of such capital buffers to various shocks using value-at-risk (or capital-at-risk) types of conditions, such those derived by Estrella (2004) or Peura and Jokivuolle (2004). A necessary condition for the existence of the capital buffers is that acquiring fresh capital is subject to frictions,

[1] This is the best practice of the world's leading central banks in practical monetary policy making and forecasting.

rigidities, costs, or delays, as emphasized by many authors, including Van den Heuvel (2002), Estrella (2004), or Peura and Keppo (2006). Our model incorporates such frictions.

We illustrate the use of the model in a series of policy experiments and simulations. We explain the potential macroprudential consequences of some of the major shocks that may pose systemic risk in a typical emerging-market economy: a country spread shock, a terms of trade shock, and an asset price bubble. Although we show the implications of various combinations of macroprudential and monetary policy responses, we do not, in this paper, provide a formal metric to evaluate their welfare consequences. The main two reasons are as follows. First, while it is relatively easy to evaluate the *costs* of capital requirements, such as lower output because of a higher cost of borrowing as in Estrella (2004), redirection of credit away from riskier but more productive projects as in Tchana (2009), or reductions in liquidity services provided by bank liabilities as in Van den Heuvel (2008), it is more difficult to model the *benefits* thereof, such as curbing excessive risk taking and excessive leverage. We believe that proper evaluation of such benefits will also involve policymakers' judgment (Tucker (2009), Saporta (2009)). Second, the outcomes of policies aimed at financial stability are heavily affected by nonlinearities arising during less likely but more damaging episodes of systemic tail-risk shocks. Evaluating such policies cannot be therefore based on the traditional linear-quadratic control framework, as is most of the optimal monetary policy literature. Instead it must adopt more global numerical methods, or at least higher order approximations. We do intend to return to the question of welfare in the near future, using higher order approximations, but ignoring the steady state effects of different coefficients characterizing macroprudential policies, and instead focusing on their potential for successful counter-cyclical policies around a given steady state.

The paper is organized as follows. In Section 2 we set forth the financial sector and its interactions with the household sector. In Section 3 we detail the rest of the model. We then design and conduct our policy experiments and simulations in Section 4. Section 5 concludes. Technical details are provided in Appendices A and B.

## 2 Financial Structure of the Model

In this section, we describe financial interactions and frictions between households and banks. These are then incorporated into a simple general equilibrium macroeconomic model of a small open economy in the next section.

Our aim is to create a feedback loop between the real economy and the financial sector, and to incorporate financial institutions that are subject to capital regulation. To that end, we find the following three elements critical: (i) There exist endogenous stochastic defaults on bank loans in equilibrium. (ii) At least some of the credit risk cannot be diversified by financial institutions, in other words, banks bear some of the aggregate risk, and their net worth can be hit by unexpected shocks. (iii) The Modigliani-Miller equivalence between debt financing and capital breaks down so that the terms of bank lending are affected by the level of bank capitalization.

In our model, we introduce these three key elements through the following structure. Households borrow from banks to finance their current and capital expenditures. The contract between the two parties is affected by financial frictions arising because of limited enforcement. Specifically, a borrower may choose to default on his or her obligations, in which case the lender can only seize the borrower's assets that collateralize the loan (here: productive capital), and recover the market value less a liquidation cost. The resulting risk premium charged by the lender affects not only capital purchases (and hence aggregate investment), but also consumption. This is attractive for models of small open economies for it has the power to induce a stable long-run distribution of the consumption-to-wealth ratio in a theory-consistent way.[2]

The debt contracts in our model are not contingent on future outcomes, so that lending rates are fixed at the beginning of the contract and cannot be adjusted later on, which corresponds closely to how bank lending contracts work in the real world. This distinguishes our model from the financial accelerator of Bernanke et al. (1999), where lending rates are state-contingent so that banks can make zero profits not just ex-ante but also ex-post. The main implication is that lenders are now exposed to non-diversifiable aggregate risk, on top of the usual diversifiable idiosyncratic risk.

Finally, the banks are subject to an *ex-post* capital requirement, in the form of a penalty payable whenever a bank's net worth, calculated *after* the returns on assets and the costs of liabilities are realized, falls below a regulatory minimum. We adopt this type of incentive-based model of capital regulation from the bank portfolio choice literature, for instance Milne

[1] See e.g. Alburquerque and Hopenhayn (2004), Lorenzoni and Walentin (2007), or Gerlter and Karadi (2010) for examples of other macro models with limited or costly enforcement.

[2] See Schmitt-Grohé and Uribe (2003) for an overview of alternative mechanisms.

[2] The idea of non-contingent contracts in a macro-prudential model is also found in Zhang (2009) who, unlike this paper, fixes the cut-off idiosyncratic productivity ex ante, not the lending rate.

(2002). As emphasized by many authors (Peura and Keppo (2006), Van den Heuvel (2002)), capital adequacy requirements will only play a non-trivial role in the bank portfolio choice if recapitalization is costly or associated with some kind of market imperfection. Our model includes two such imperfections, ex-post regulation and a cost to shareholders of injecting or withdrawing capital to or from the banks after the return on equity is realized. In the extreme case, with the cost made infinitely large, bank capital can only be accumulated from retained earnings – an assumption made quite frequently in models with financial frictions.

To keep the exposition of the basic problems simple, we derive our results under the following two simplifying assumptions. First, all financial assets and liabilities, including foreign borrowing (introduced in the next subsection) are denominated in local currency. It is, though, relatively straightforward to adapt the equations for any currency structure. Second, we note that the bank makes two basic types of choices in our model. It needs to specify the terms of the debt (loan) contract with the household, and to find an optimal structure of its liabilities, that is a split between capital (equity) and foreign borrowing to finance its loans, given the capital requirements in place. We separate these two decisions from each other, and think of the bank as consisting of two branches, a wholesale branch, managing liabilities, and a retail lending branch, screening customers and signing loan contracts with them. Each branch then takes the other's decisions as given.

## 2.1 Contract between Bank and Household

There a single representative household that consists of a large number of members indexed by $j \in (0, 1)$. While consumption decisions are made by the household as a whole (and will be described in the next section), capital purchases and bank loans are chosen by each member individually taking the household's shadow value of wealth as given. This assumption provides full risk sharing to the household members, and makes them all identical at the time they make their decisions despite the fact that they face idiosyncratic uncertainty afterwards.

At time $t$, member $j$ purchases $P_{K,t}K_t^j$ worth of capital, and contracts a loan $L_t^j$ by signing a debt contract collateralized by the capital and the future returns thereon. The loan contract specifies a non-contingent gross interest rate $R_{L,t}^j$. At the beginning of time $t+1$, the capital becomes worth $R_{K,t+1}^j P_{K,t}K_t^j$, where $R_{K,t+1}^j$ is the individual return to capital, including a rental price received from producers, capital gains, and depreciation.

The return has two components, an aggregate one, $R_{K,t+1}$, and an idiosyncratic one, $\omega^j_{t+1}$,

$$R^j_{K,t+1} = R_{K,t+1}\omega^j_{t+1},$$

and $\omega^j_{t+1} \in (0,\, \infty)$ is a random variable with a known c.d.f. identical across all household members and denoted by $\Phi(\cdot)$, and normalized relative to $R_{K,t+1}$ so that $\mathbb{E}_t[\omega^j_{t+1}] = 1$.

At time $t+1$ the household's repayment $R^j_{L,t}L^j_t$ falls due. If the return to capital falls below the amount due, she defaults on the loan and lets the bank seize the capital. Given the aggregate return to capital, $R_{K,t+1}$, the cut-off level of idiosyncratic productivity for a default is given by

$$\bar{\omega}^j_{t+1} := \frac{R^j_{L,t}L^j_t}{R_{K,t+1}P_{K,t}K^j_t} = \frac{R_{L,t}}{R_{K,t+1}}\ell_t. \tag{1}$$

where $\ell_t := L_t/(P_{K,t}K_t)$ is a loan-to-value ratio. The bank seizes and sells the capital of the defaulting household in the market, receiving the market value, $R_{K,t+1}\omega^j_{t+1}P_{K,t}K^j_t$, less a liquidation cost, which is a fraction $\nu \in (0,\, 1)$ of the market value.

We write the effective loan repayment expected to be made by household member $j$ as $\mathbb{E}_t[R^j_{L,t}L_t\, g(\omega^j_{t+1})]$, and the loan repayment expected to be received by the bank as $\mathbb{E}_t[R^j_{L,t}L^j_t\, h(\omega^j_{t+1})]$. It follows that

$$g(\bar{\omega}) = 1 - \Phi(\bar{\omega}) + \frac{1}{\bar{\omega}}\int_0^{\bar{\omega}} \omega \,\mathrm{d}\,\Phi(\omega) = \frac{1}{\bar{\omega}}G(\bar{\omega}), \tag{2}$$

$$h(\bar{\omega}) = 1 - \Phi(\bar{\omega}) + (1-\nu)\frac{1}{\bar{\omega}}\int_0^{\bar{\omega}} \omega \,\mathrm{d}\,\Phi(\omega) = \frac{1}{\bar{\omega}}H(\bar{\omega}). \tag{3}$$

We are now ready to work out the terms of the optimal debt contract between the bank and household member $j$. To that end, we need to find $L^j_t$, $K^j_t$, and $R^j_{L,t}$ to maximize the household's expected value

$$\max_{L^j_t,K^j_t,R^j_{L,t}} \Lambda_t\left[L^j_t - P_{K,t}K^j_t\right] + \beta\,\mathbb{E}_t\,\Lambda_{t+1}\left[-R^j_{L,t}L^j_t\, g(\omega^j_{t+1}) + R_{K,t+1}P_{K,t}K^j_t\right] \tag{4}$$

where $\Lambda_t$ is the household's shadow value of nominal wealth[3], subject to an ex-ante zero profit condition requiring that the bank receive a return from lending equal to its opportunity cost. As the contract is non-contingent, the zero profit condition can only hold in expectations,

$$\mathbb{E}_t\left[\frac{R^j_{L,t}L^j_t\, h(\omega^j_{t+1})}{R_{E,t+1}}\right] = r_tL^j_t, \tag{5}$$

[3]That is, a current-dated Langrange multiplier associated with the household's budget constraint

where $R_{E,t+1}$ is the future aggregate return on equity. The opportunity cost, $r_t$, is determined by the wholesale branch, and is derived in the next subsection. After substituting the Lagrange multiplier on (5) out of the three first-order conditions, we obtain the following optimality conditions:

$$\mathbb{E}_t\left[\frac{\beta\Lambda_{t+1}}{\Lambda_t} R_{K,t+1}\, G'(\bar{\omega}^j_{t+1})\right] = \frac{1}{r_t}\,\mathbb{E}_t\left[\frac{R_{K,t+1}}{R_{E,t+1}} H'(\bar{\omega}^j_{t+1})\right], \tag{6}$$

$$\mathbb{E}_t\left[\frac{\beta\Lambda_{t+1}}{\Lambda_t} R_{K,t+1}\left(1 - G(\bar{\omega}^j_{t+1})\right)\right] = \ell^j_t - 1, \tag{7}$$

and the zero profit condition (5). Equation (6) equates the marginal benefits of capital investment between households and banks. Equation (7) determines the optimal loan volume.

Because the ex-ante distributions of the idiosyncratic components of the returns on capital, $\omega^j_{t+1}$, are identical across all members of the household, the contractual terms will be the same, and all members will choose the same loan-to-capital ratio under the same lending rate. The aggregate levels of loans and capital are defined as $L_t := \int_0^1 L^j_t \mathrm{d}\, j$ and $K_t := \int_0^1 K^j_t \mathrm{d}\, j$. Finally, the expressions for $G(\omega)$, $G'(\omega)$, $H(\omega)$, and $H'(\omega)$ when the idiosyncratic component is distributed log-normally can be found in Bernanke et al. (1999). We list the first-order conditions with these expressions in the appendices.

## 2.2 Bank Capital Choice

We now turn to determining how much capital the bank will hold and how much foreign funding it will obtain to finance its lending, and how the required return in the zero profit condition is determined. We first exposit the basic trade-off facing the bank. Foreign borrowing is a cheaper source of funds than capital[4], therefore absent capital regulation the bank would always choose to avoid capital funding. However, it is subject to *ex-post* capital requirements obligating the bank to have sufficient equity after the returns on its assets and the costs of its liabilities are realized, or face a penalty proportional to its assets:

$$R_{t+1}L_t - R_{F,t}F_t < \gamma R_{t+1}L_t \Rightarrow \text{penalty } \upsilon L_t. \tag{8}$$

The condition, similar to Milne (2002), formalizes the fact that we think of capital regulation as an incentive-based mechanism affecting the bank's optimal portfolio choice, rather than

[4]The result that the interest rate on foreign funds, $R_{F,t}$, is lower than the expected return on equity, $R_{E,t+1}$, is explained later.

an inequality binding at all times. The distinction between the incentive-based model and a hard-wired restriction only arises when the world is uncertain. Were the return on loans, $R_{t+1}$, known in advance and free of risk, a bank faced with (8) would simply maintain capital and loans in fixed proportion provided the two regulation parameters, $\gamma$ and $\upsilon$, are restrictive enough.

The bank behaves competitively taking as given the distribution of the total return on its assets, $R_{t+1}$, received from the retail branch,

$$R_{t+1} := \frac{\int_0^1 R^j_{L,t} L^j_t \, h(\bar{\omega}^j_{t+1}) \, \mathrm{d}\, j}{L_t} \quad , \tag{9}$$

as well as the costs of its liabilities, $R_{F,t}$ and $R_{E,t+1}$. It chooses the volume of loans, $L_t$, foreign funding, $F_t$, and capital (equity), $E_t$, to maximize the shareholders' value,

$$\max_{L_t, F_t, E_t} \; \mathbb{E}_t \left[ \frac{R_{t+1} L_t - R_{F,t} F_t - \upsilon L_t \Psi(\widetilde{R}_{t+1})}{R_{E,t+1}} \right] - E_t \tag{10}$$

subject to a balance sheet identity, $L_t = F_t + E_t$. As explained earlier, we abstract from limited liability and allow for possible $t+1$ states with the negative bank equity (making the shareholders liable). The $t+1$ cash flows are discounted by the shareholders' opportunity cost, that is by the aggregate expected return to equity. The last term in the numerator is the expected cost of the regulatory penalty weighted by the probability of the bank's falling below the regulatory minimum, where $\Psi(\cdot)$ denotes the c.d.f. of the return on loans. The cut-off return on loans, $\widetilde{R}_{t+1}$, which will push the bank right to the edge of capital adequacy at the beginning of time $t+1$, is given by (8),

$$\widetilde{R}_{t+1} := \frac{R_{F,t} F_t}{(1-\gamma) L_t} = \frac{R_{F,t}}{1-\gamma} (1 - e_t),$$

where $e_t := E_t / L_t$ is the equity-to-loans ratio. Note that $\widetilde{R}_{t+1}$ is known at time $t$ and fixed (non-stochastic).

[4] We could alternatively assume that shareholders' liability is limited but that they lose the bank's franchise, or charter, value upon its liquidation as in Estrella (2004). Making the franchise value equal to the regulatory penalty would reproduce the results.

Substituting for $F_t$ from the balance sheet, we solve for the optimal $L_t$ and $E_t$. The first-order conditions for $L_t$ and $E_t$ are, respectively, as follows:

$$\mathbb{E}_t\left[\frac{R_{t+1}}{R_{E,t+1}}\right]=\mathbb{E}_t\left[\frac{1}{R_{E,t+1}}\right]\left[R_{F,t}+\upsilon\Psi(\widetilde{R}_{t+1})+\upsilon\,\psi(\widetilde{R}_{t+1})\frac{R_{F,t}}{1-\gamma}\,(1-e_t)\right], \tag{11}$$

$$R_{F,t}\left[1+\frac{\upsilon\,\psi(\widetilde{R}_{t+1})}{1-\gamma}\right]=\frac{1}{\mathbb{E}_t[1/R_{E,t+1}]}. \tag{12}$$

where $\psi(\cdot)$ is the p.d.f. corresponding to $\Psi(\cdot)$.

Equation (11) says that the lending spread will, *ceteris paribus*, increase in response to reductions in the equity-to-loans ratio (or, equivalently, increases in leverage). This is a very intuitive result since low capital is associated with a higher probability of the bank's falling below the regulatory minimum and incurring a penalty. We illustrate the shape of such a "wholesale" lending function in Figure 1. The two curves are computed around the model's steady state for two different standard deviations of the idiosyncratic component of the return on capital: 0.35 (actual calibration) and 0.25. In fact, some other authors, including Furfine (2001), Gerali et al. (2010), or Angelini et al. (2010), take a more direct shortcut subjecting the banks to a reduced-form convex cost determined by the distance from a regulatory minimum. Furthermore, equation (12) equates the cost of debt liabilities (foreign borrowing) and the cost of bank capital adjusted for the effect the capital has on the expected cost of the regulatory penalty. Also note that the two conditions do not pin down the scale of the bank's business, that is the levels of $L_t$ or $E_t$, only its leverage.

When substituted back into equation (10), the two conditions give rise to zero *expected* economic profits, owing to the fact that the expected cost of the regulatory penalty is linearly homogenous in $L_t$ and $E_t$. This is consistent with our competitive market assumption made initially.

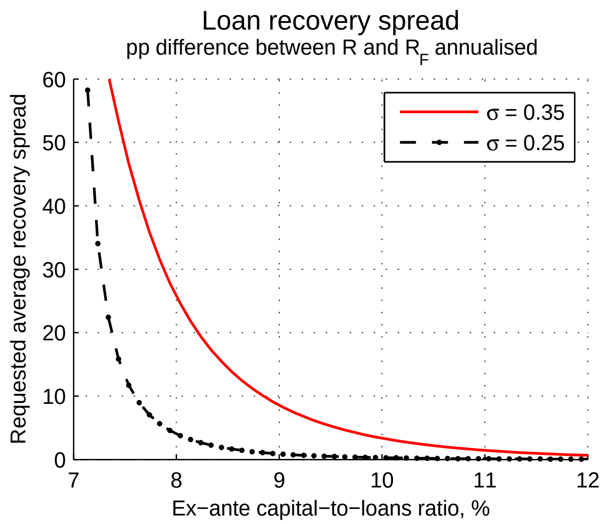
Finally, we use equation (11) to define the required expected return on loans used in the zero profit constraint, equation (5), based on the contractual problem above. Because we cannot express the expected return on the assets directly we must derive the required return on loans relative to the aggregate return on bank capital

$$\mathbb{E}_t\left[\frac{R_{t+1}L_t}{R_{E,t+1}}\right]=r_tL_t, \tag{13}$$

where $r_t$ follows from equation (11),

$$r_t:=\mathbb{E}_t\left[\frac{1}{R_{E,t+1}}\right]\left[R_{F,t}+\upsilon\Psi(\widetilde{R}_{t+1})+\upsilon\psi(\widetilde{R}_{t+1})\frac{R_{F,t}}{1-\gamma}\,(1-e_t)\right]. \tag{14}$$

Figure 1: "Wholesale" Lending Supply Curve



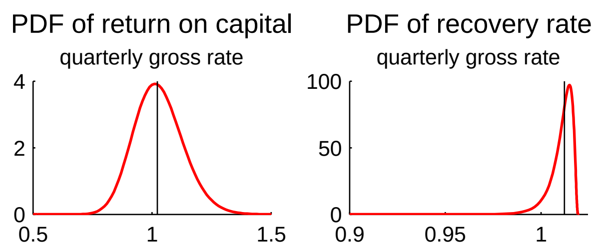

The fact that equation (13) refers to the total volume (integral) of loans whereas (5) is a constraint associated with a loan to an individual is irrelevant because differentiating either expression w.r.t. $L_t^j$ or $R_{L,t}^j$ yields the same results.

## 2.3 Return on Loans

To complete the specification of the financial interactions, we need to relate the conditional distribution of the return on loans, $R_{t+1|t}$, taken as given in the previous subsection, to the relevant source of aggregate uncertainty, that is to the conditional distribution of the household's return on productive capital, $R_{K,t+1|t}$ and. Recall that the c.d.f. and p.d.f. of the return on loans is necessary for us to evaluate expressions (11), (12), and (14).

We first derive a functional mapping between $R_{t+1}$ and aggregate $R_{K,t+1}$. Then, we use this mapping to express the distribution of $R_{t+1|t}$ as a function of $R_{K,t+1|t}$, and re-write the bank's first-order conditions in these terms. Last, we deal with the endogeneity problem arising between the return on capital, $R_{K,t+1}$, and the optimal behavior of the bank. The distribution of $R_{K,t+1|t}$ must be known at the time of quantifying the bank's behavior. However, the distribution of $R_{K,t+1|t}$ depends, in general, on the model as a whole, and hence also on the banks. We explain possible ways to approach this kind of problem.

Figure 2: Distribution of Return on Loans.




For given $R_{L,t}$ and $\ell_t$, we get the following mapping from a particular value $R_{K,t+1}$ to the bank's return on loans, $R_{t+1} = \rho(R_{K,t+1})$:

$$\rho(R_{K,t+1}) := R_{L,t+1} h(\widetilde{\omega}_{t+1}) = \frac{1}{\ell_t} R_{K,t+1} H(\widetilde{\omega}_{t+1}),$$

where $\widetilde{\omega}_{t+1} := R_{L,t}\ell_t / R_{K,t+1}$, and the functions $h(\cdot)$ and $H(\cdot)$ are defined by (2). Note that the function $\rho(\cdot)$ maps $(0,\infty)$ onto $(0, R_{L,t}]$ by design. In other words, the actual return on loans can only reach $R_{L,t}$ at maximum, which case would obviously occur only if no-one defaulted. With $\rho(\cdot)$ at hand, we can now calculate the c.d.f. and p.d.f. for $R_{t+1}$ (denoted earlier by $\Psi(\cdot)$ and $\psi(\cdot)$, respectively) based on the c.d.f. and p.d.f. for $R_{K,t+1}$, which we denote by $F(\cdot)$ and $f(\cdot)$, respectively:

$$\Psi = F\left(\rho^{-1}\right),$$

$$\psi = f\left(\rho^{-1}\right) \cdot (\rho^{-1})' = f\left(\rho^{-1}\right) \cdot \left(\rho'\right)^{-1},$$

where the first derivative is given by

$$\rho'(R_{K,t+1}) = \frac{1}{\ell_t}\left[H(\widetilde{\omega}_{t+1}) - H'(\widetilde{\omega}_{t+1})\,\widetilde{\omega}_{t+1}\right].$$

More specifically, to evaluate these functions at the cut-off return $\widetilde{R}_{t+1}$, we proceed as follows. We first find $\widetilde{R}_{K,t+1} := \rho^{-1}(R_{t+1})$, and set $\Phi(\widetilde{R}_{t+1}) = F(\widetilde{R}_{K,t+1})$. Then, we find $\widetilde{\omega}_{t+1} := R_{L,t}L_t/(\widetilde{R}_{K,t+1}P_{K,t}K_t)$, and set

$$\psi(\widetilde{R}_{t+1}) = \frac{f(\widetilde{R}_{K,t+1})\,\ell_t}{\left[H(\widetilde{\omega}_{t+1}) - H'(\widetilde{\omega}_{t+1})\,\widetilde{\omega}_{t+1}\right]}.$$

We illustrate the relationship between the distribution of the return on capital and the distribution of the return on loans (or the recovery rate) in Figure 2. Plotted in the graphs are the p.d.f. of $R_K$ and the implied p.d.f. of $R$ based on the model's calibration and taken around the steady state. Note that $R$ is restricted to an interval $(0, R_L]$ by construction.

We can now discuss how to jointly determine the distribution $F(\cdot)$ and the bank's optimal choice of capital. We can find a fixed point of the problem by iterating the following way:

1. Start with an initial guess of the distribution $F(\cdot)$.
2. Derive the bank's first-order conditions taking $F(\cdot)$ as given.
3. Calculate the model's approximate dynamic solution.
4. Use a log-normal distribution to approximate the distribution of the one-step-ahead forecast $R_{K,t+1|t}$.
5. Step 4 gives you another guess of $F(\cdot)$. Go back to step 2, and continue until convergence.

The procedure is clearly based on an assumption that we believe the model is reasonably good at producing density forecasts for $R_{K,t+1}$. This may be a too strong claim since models are often crude simplifications, and cannot explain all dimensions of observed data (not to speak of the fact that they are *not meant* to explain all dimensions), especially variables like asset prices. In more practical applications, we may therefore resort to describing the uncertainty around $R_{K,t+1|t}$ using other (perhaps more empirical) sources of evidence, and allow for a discrepancy between the distribution used to derive the bank's behavior, and the one implied by the model as whole. This is also consistent with the fact that the credit risk is, in the real world, affected by many more factors beyond a single asset price, and our model's return on capital is just an imperfect, yet useful, proxy.

## 2.4 Heterogenous Banks

[Explain why we need heterogenous banks – smooth penalty at an aggregate level ... ] We therefore introduce a continuum of banks indexed by $b \in (0,\, 1)$. Each bank will specialize in a particular sector of the economy (regional or industrial), indexed by the same $b$, and each of these sectors will have its own stochastic component affecting the sector-wide return on capital, $\varepsilon^b_{t+1}$,

$$R^b_{K,t+1} = R_{K,t+1}\varepsilon^b_{t+1}.$$

Each $\varepsilon_{t+1}^{b}$ is is distributed log-normally with $\mathbb{E}_t\left[\varepsilon_{t+1}^{b}\right] = 1$ and $\text{var}_t\left[\varepsilon_{t+1}^{b}\right] = \sigma_\varepsilon^2$, and is independent of the economy-wide return, $R_{K,t+1}$.

The results derived so far for a representative bank will change only in that we need to factor in the new source of uncertainty. In other words, we can introduce a sector-specific c.d.f and p.d.f. of $R_{K,t+1}^{b}$ denoted by $F_b(\cdot)$ and $f_b(\cdot)$, respectively. These new distribution functions replace $F_b(\cdot)$ and $f_b(\cdot)$ in all equations in the previous subsection. The heterogenous banks will have, though, less trivial effects on the aggregation of the model. We describe the aggregate dynamics of the financial sector in a separate subsection.

# 3 Overview of the Complete Model

In this section, we briefly describe the rest of the model and its calibration. The full detail of the optimizing behavior of all model agents, along with a list of parameter values, is provided in the appendices.

The model's financial sector intermediates the flow of funds between the economy and the rest of the world. The banks' only source of non-capital finance is cross-border borrowing. In other words, we assume away the existence of local deposits. Oversimplified though at first sight, the assumption is still a useful shortcut that describes the essence of financial intermediation in many of the emerging-market economies: their transition has been marked with current account imbalances and rapid credit inflow from abroad, with the banking sector playing a prominent role.

We keep the real sector of the model economy relatively uncomplicated in the sense that it is based on a single production function. At the same time, we add a number of features that help to produce realistic dynamics, and make the model's structure flexible to encompass a variety of different types of emerging-market economies. In particular, we design the model so that it provides a high level of flexibility in calibrating the real exchange rate elasticities of final demand components (consumption, investment, exports), and the responses in trade balance, current account, and the economy's net position to cycles in these components. These are, in turn, characteristics most critical to our analysis of the linkages between the real and financial sectors.

The structure of the real sector is as follows. In addition to the financial sector described above, the economy consists of a representative household (with a continuum of members), a producer, a retailer, and an exporter.

The household as a whole (as opposed to individual household members) makes purchases of consumption goods and investment goods. While the consumption goods are produced by the local producer and sold by the local retailer, the investment goods consist of a local component, identical to the consumption goods, and a directly imported component. The two components are perfect complements, and must be combined in fixed proportions. Furthermore, the household supplies labour with some degree of monopoly power (necessary for sticky wages, see below), rents out physical capital, and invests in bank capital.

The representative local producer, who behaves competitively in all input and output markets, combines two local input factors, labour and physical capital, and intermediate imports to produce local goods. These are then demanded by the local retailer and the exporter. The local retailer resells the goods to the household (as consumption and investment) exerting some degree of monopoly power in her output market (necessary for sticky prices). The exporter is a world price taker, in other words, the economy's terms of trade are exogenous. Moreover, like investment goods, exports consist of a local component and a directly imported component (re-exports) and the two must be combined in fixed proportions.

The four agents are constrained by a number of real and nominal rigidities, of which all except the last three are now considered standard in monetary small open economy models:

- External habit in the household's consumption.
- Wage adjustment costs with full backward indexation.
- Investment adjustment costs.
- Price adjustment costs with full backward indexation.
- Adjustment costs of changing the proportion of the two variable input factors (local labour and intermediate imports).
- Export adjustment costs.
- Bank capital market rigidities.

In our experiments, we expose the household to financial dollarization and currency mismatches. In other words, a fixed proportion of bank loans is denominated in foreign currency (while all final and input factor prices are set in local currency). The currency structure is imposed and not optimized by any of the agents. Dollarization of liabilities of households and non-financial firms is one of the major limitations monetary policymakers face when operating under floating exchange rate regimes, and a major source of systemic financial risk.

Finally, the local household owns only a certain proportion of the banks operating in the country, the remainder is in the hands of foreigners. This latter assumption not only reflects the reality of most of the emerging-market economies (whose banking sectors are often dominated by subsidiaries of foreign parent banks) but is also necessary to produce sensible dynamics of the economy's net position and its current account.

# 4 Macroprudential Policy

Unlike monetary policy tools, capital requirements do have permanent effects on the allocation of real resources in equilibrium. Put simply, this is because higher requirements raise the marginal cost of lending and increase the wedge between the bank refinancing rate and the retail lending rates. The consequences thereof are similar to imposing a tax on the households' borrowing. In this sense, macroprudential policy can be viewed more like fiscal policy, a point made also by other authors, such as Bianchi and Mendoza (2010).

We document the above facts by running a simple non-stochastic steady-state comparative static exercise, and plotting the implied long-run levels of various macroeconomic and financial indicators under different levels of the capital requirements, $\gamma$, between 5 and 12 percent, see Figure 3.

We can – very loosely – infer from the graphs that there are both costs and benefits associated with tighter macroprudential policies. In other words, as explained in more detail by Estrella (2004), macroprudential regulators face a trade-off: on the one hand, higher capital requirements reduce output and consumption (in our model, this is mainly because of a higher cost of physical capital – see the increasing lending spread), on the other hand, they also help limit the leverage of both the financial institutions and non-financial agents. This, in turn, gives rise to a more stable financial environment, removing the potential for major crises.

Furthermore, there has been an ongoing debate among national regulators and international prudential regulation bodies about adopting time-varying capital requirements, or other macroprudential tools. The idea is that the macroprudential policy stance should proactively react to the cyclical position of the economy and the financial sector. A reduced-form way of thinking about this idea would be to translate it into macroprudential rules by linking the capital requirements to real economic activity, or to macroprudential policies aimed at stabilizing indicators based on real economic activity, such as credit-to-GDP ratios. But this relies on a very reduced-form way of thinking of macroprudential policy. Consistent with its scope and objectives would be a pro-active macroprudential policy rule prescribing tight capital requirements in times when risk builds up on the balance sheets of financial institutions (forcing the banks create capital cushions), and letting the banks draw the capital cushions down in times when the risk materializes. The fact that times of large risk build-ups are often observed in times of output expansion is a reduced-form empirical observation that cannot be taken for granted. Instead, methodologies need to be developed to measure the amount of systemic risk across the financial sector, and to relate macroprudential policy to such measures. As noted by many, (Tucker (2009), Milne (2009)), the risk measures cannot realistically be based on a single framework or single model, and will involve a large amount of judgment, considerably more than in the business of monetary policy making.

We use a simple pro-active macroprudential rule in our asset price bubble simulation below. In that rule, we measure the credit risk by the observed lending spread,

$$\gamma_t = \bar{\gamma} + \phi_\gamma \left( R_{L,t} - R_{F,t} - \Delta \right) \quad , \tag{15}$$

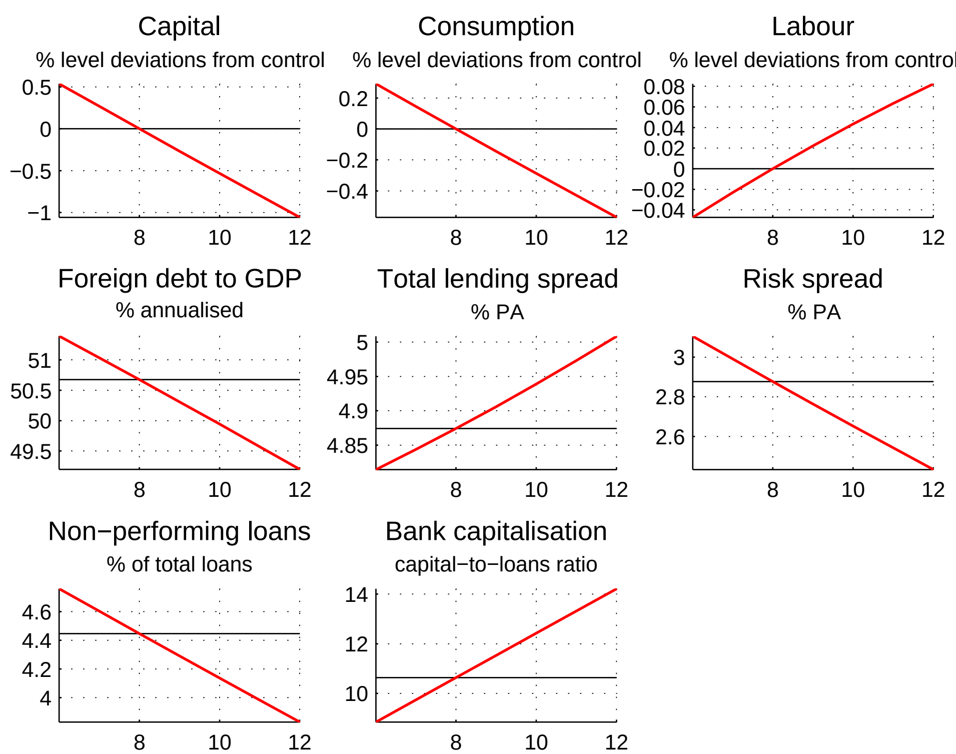
where $\Delta_t := \bar{R}_L - \bar{R}_F$ is the steady-state spread. The rule is, obviously, model specific and is not meant to be adapted mechanically in practical macroprudential policy making.

# 5 Simulation Experiments

In this section, we show a number of shock simulations that trigger an episode of financial distress. We use these simulations to explain the basic interactions between the real and financial cycle, the role of bank capital in the transmission of the shocks, and the tools macroprudential policy can use to contain some of the financial risk arising as a consequence of the shocks.

We first simulate an exogenous shock to the level of bank capital. We do not specify the exact underlying cause of such a capital drop, the experiment is only meant to explain the mechanics of the banks' reaction to such a shock, the way the banks recapitalize themselves again, and the impact on the real economy. Second, we expose the economy to a sudden

Figure 3: Comparative Statics with Changing Capital Requirements.



increase in the country risk premium, the rate at which the banks are able to internationally refinance their loans to households. In this experiment, we compare the outcomes (i) generated with and without the banking sector, and (ii) under two different levels of the premium, “small” and “large” (defined by whether they trigger a systemic risk event) to show the nonlinearities of macrofinancial models. Last, we simulate an asset price bubble (a persistent deviation of the observed market price of physical capital from its fundamentals) and its burst to illustrate the very notion of financial cycles, as times when a considerable amount of risk builds up on the balance sheets of banks, followed by times when the risk can actually materialize. In this experiment, we compare the outcomes under a fixed level of capital requirements and those under a pro-active macroprudential rule.

## 5.1 Bank Capital Shock

In this experiment, we exogenously reduce the level of initial bank capital $E_{t-1}$ by 10 %. As we see in Figure 4, the shock brings the capital adequacy ratios down by about 1 percentage point on impact and eliminates about a half of the regulatory capital cushion. The banks react by cutting back their lending. In the model, the only way to do so is by increasing the lending spreads. We see a 200 basis points hike initially that dissipates gradually over two to three years. In the real world, though, the banks would probably combine price increases with tighter non-price credit conditions, so that the observed interest rates would not be driven so high. The elevated lending spread leads to gradual recapitalization of the banks, as the return on bank capital remains higher than normal for a prolonged period of time.

The effect of the shock on the real economy is offset to some extent by monetary policy. The refinance rate is cut by about 90 basis points during the first year, which is accompanied by a small depreciation followed by steady appreciation. Domestic demand reduction amounts to a drop in GDP by less than 0.3 % in the first year.

## 5.2 Increases in Country Spread

In the following two simulations, we increase the foreign-currency refinance rate, $R_{F,t}$, by 100 and 800 basis points annualized, respectively, see Figures 5–6. The shock is persistent with autocorrelation of 0.90. We report results for two versions of the model: one with the banking sector as described earlier in the paper, and the other without the banking sector. In the latter version, we simply keep the wholesale lending spread as well as the

Figure 4: 10% Negative Shock to Bank Capital

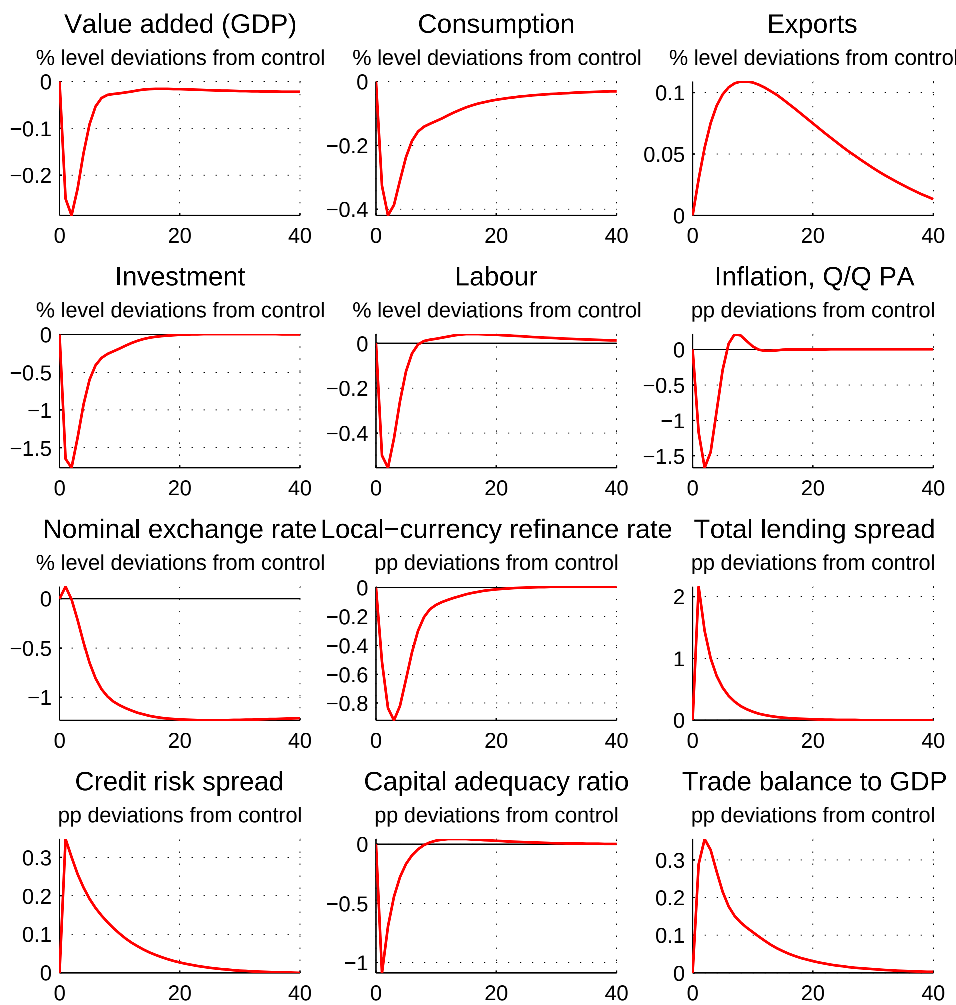


Figure 5: 100 bp Increase in Country Spread — Baseline model – · – No banking sector

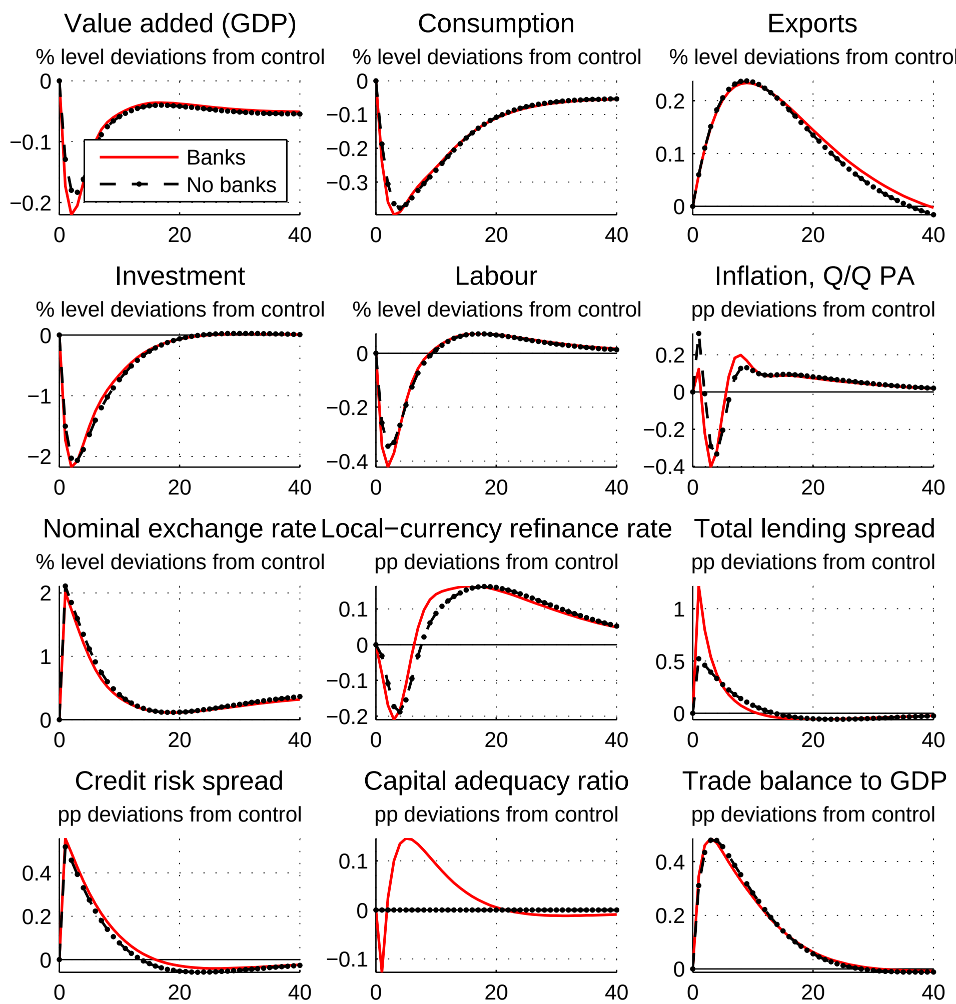
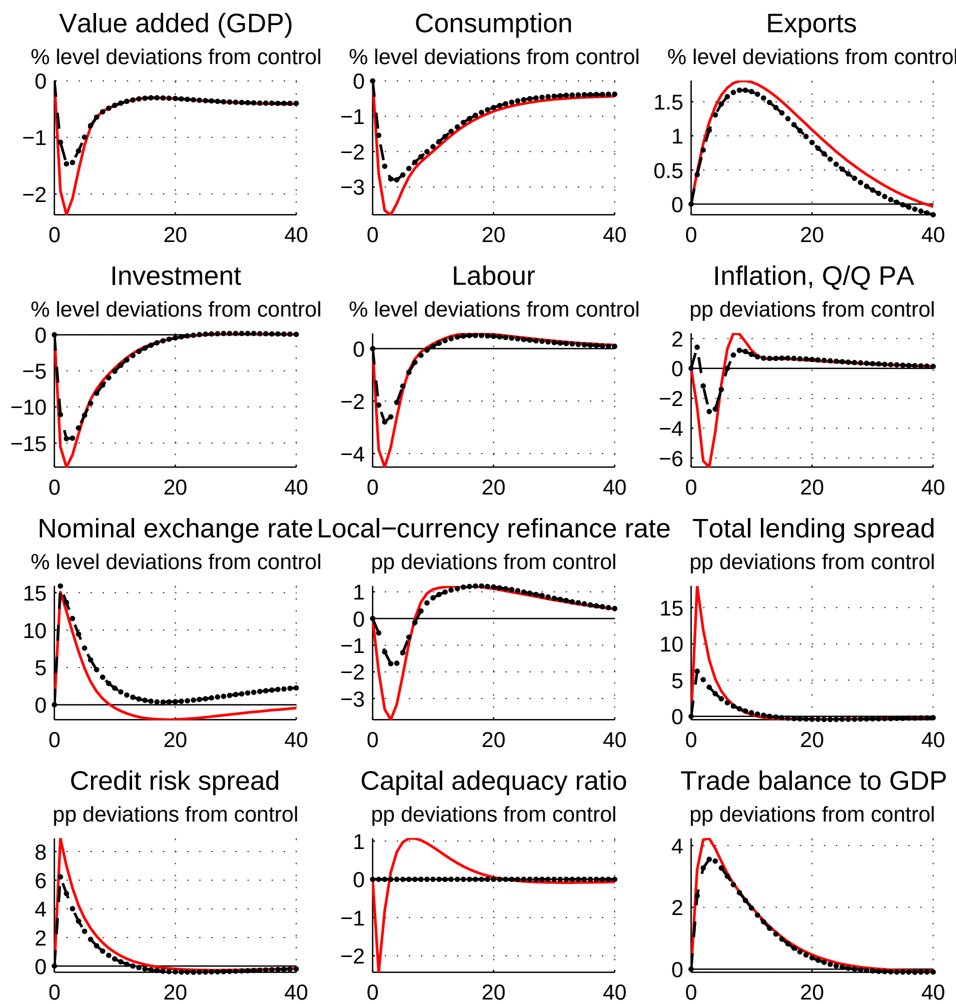


Figure 6: 800 bp Increase in Country Spread — Baseline model – · – No banking sector



bank-capital-to-loans ratio constant (fixed at their respective steady states).

The shock, which bears resemblance with sudden-stop scenarios, triggers a potentially very harmful combination of an exchange rate depreciation and an asset price fall. In economies with substantial financial dollarization, such a combination may push the leverage of the non-financial sector unusually high above the levels prevailing in normal times, and result in increases in non-performing loans. If the losses on the bank assets exceed the bank capital cushions, the shock can create serious systemic risk.

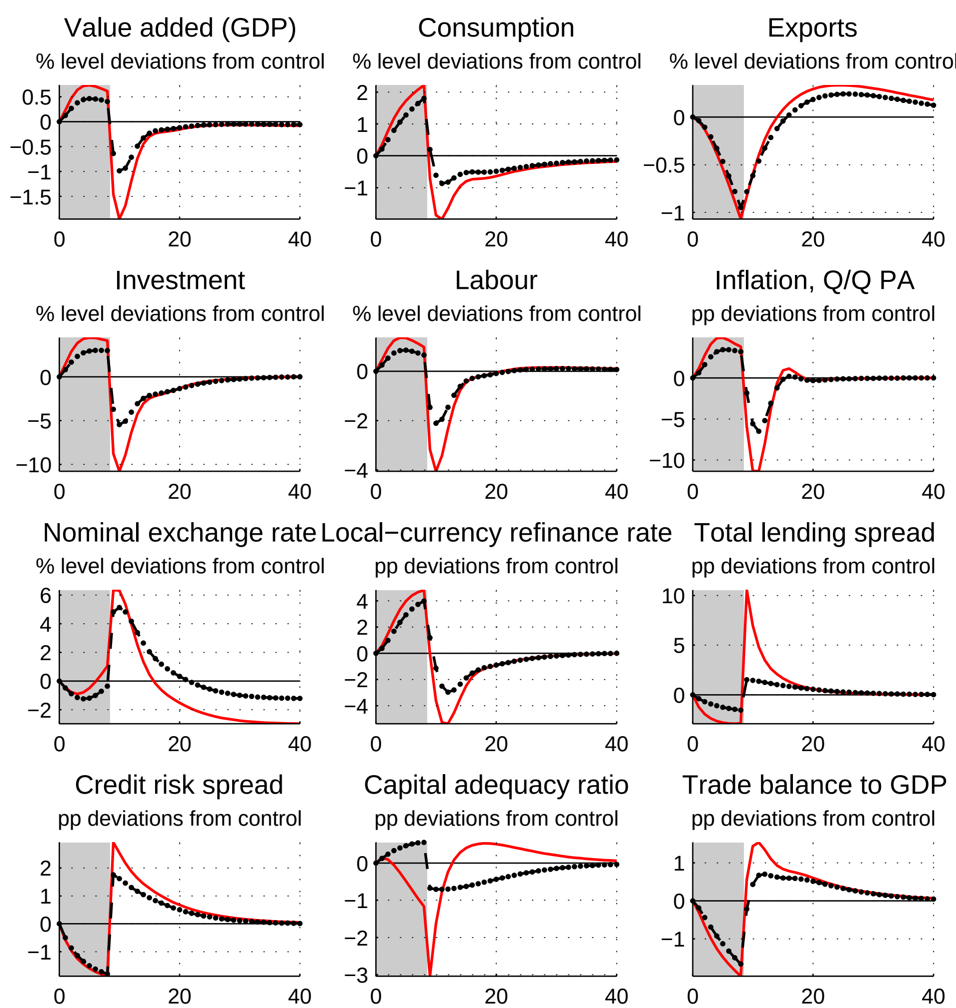
The uncertainty about the eventual effects of such a shock in the real world is large. This is because the mechanisms that determine whether a systemic crisis occurs or not are intrinsically non-linear and exhibit a kind of threshold behavior. Such mechanisms are therefore very difficult to parameterize. We document the nonlinearities by simulating two different sizes of the shock, a small one of about 100 basis points annualized, and a large one of about 800 basis points annualized, with the latter sufficient to significantly hit bank capital. Note that the 800 basis points shock corresponds well to observed increases in spreads that faced some emerging-market economies when the global financial crisis spread across the world.

### 5.3 Asset Price Bubble

We simulate an *irrational* bubble in the price of physical capital and its subsequent burst. The term irrational, introduced by Bernanke and Gertler (1999), refers to the fact that there exists a persistent exogenous wedge between the observed (or market) asset price and its fundamental path which breaks the model's rational-expectations asset price equation.

We calibrate the bubble as follows. Once arisen, the bubble is expected to persist into the next period growing at a quarterly rate of 2.5 % with a probability about 96 %, or burst (with asset prices abruptly falling straight back to their fundamental value) with a probability of about 4 %. Whether the bubble continues or bursts is determined exogenously (by the design of the experiment), and is out of control of any of the model's agents, including the monetary authority or macroprudential regulator. We let the bubble grow over eight consecutive quarters (the probability of which is about 76 %) with the capital prices exceeding the fundamentals by about 20 %. At the beginning of the third year, we prick the bubble. The simulation results are shown in Figure 7. The highlighted area depicts the initial eight quarters during a time when the bubble exists.

Figure 7: Asset Price Bubble — Fixed capital requirements – · – Capital requirements rule



From a macroprudential point of view, the initial period is a time when considerable risk builds up on the bank balance sheets. The burst of the bubble is then a moment when the risk materializes. Putting aside the problem of how to accurately measure the risk in the real world (or, equivalently, how to measure the extent of an asset price bubble in this particular case), we show that a rule featuring pro-active capital requirements could reduce the effects that the bursting bubble has on the position of the financial institutions, and help prevent a systemic crisis in a larger region of shocks.

# 6 Conclusions

We have developed a simple model that integrates monetary and macroprudential policy transmission. Special emphasis is placed on two aspects, the emerging-markets angle and a realistic modeling of financial intermediation. The latter conceptualizes banks not as direct investors in risky physical assets, but, as in the real world, as agents that make loans which bear unconditional interest rates, and which can default if both the economy and the individual institution are hit by adverse shocks, thereby exposing the bank's equity base to risk. Furthermore, a combination of self-interest and regulation is assumed to make it costly for banks to experience very low equity to loans ratios. The combination of these characteristics gives banks an incentive to endogenously accumulate capital in good times as a buffer against adverse shocks. The model has been designed as a tool for practical policy making and advice, by allowing the policymaker to think through realistic scenarios, designed in this case particularly for a typical emerging market. This is illustrated by exposing the model economy to shocks to the country spread, terms of trade shocks, and asset price bubbles, and then thinking through the implications for policy when the banking sector is a critical part of the transmission mechanism.

In future work we aim to expand this research agenda to systematically explore the differences between economies with and without a banking sector. Furthermore, it will be interesting to explore the consequences, both for macroeconomic volatility and for welfare, of employing rules such as (15) in a systematic counter-cyclical fashion, by encouraging the accumulation of bank capital in good times and using it as a buffer in bad times.

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# A Details of Financial Structure

To be completed.

# B The Real Sector

## B.1 Households

The representative household chooses consumption, $C_t$, investment in physical capital, $I_t$, labour, $N_t$, the wage rate, $W_t$, and bank capital (equity), $E_t$, supplied to the market, to maximise its expected lifetime utility,

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \log \left( C_t - \chi \bar{C}_{t-1} \right) - \tfrac{\kappa}{\eta} N_t{}^{\eta} \right]$$

where $\bar{C}_{t-1}$ is the last period's aggregate consumption (external habit), and $N_t$ is labour (hours worked) supplied to the manufacturer. The budget constraint is given by

$$\begin{aligned} P_{K,t} K_t - L_t + \kappa E_t (1 - \tau_{E,t}) = & \\ & R_{K,t} P_{K,t-1} K_{t-1} - R_{L,t-1} L_{t-1}\, g_t + \kappa R_{E,t} E_{t-1} + W_t N_t (1 - \tau_W) \\ & \qquad - P_t C_t - \left[ \psi P_t + (1 - \psi) P_{M,t} \right] I_t (1 + \tau_{I,t}) + v_t \quad , \end{aligned}$$

where $\kappa$ is the proportion of bank capital owned by the local households (the remainder is owned by foreign agents), and $v_t$ is the sum of profits received by all agents owned by the household, and private costs incurred by the various agents in the model economy are transferred back to the household's budget. The profits and costs entering the budget through $v_t$ are enumerated in subsection B.4 where we aggregate the model's stocks and flows. The law of motion for physical capital is

$$K_t = (1 - \delta_K) K_{t-1} + I_t \quad ,$$

and the demand curve for labor is

$$N_t = (W_t / \bar{W}_t)^{-\frac{\mu}{\mu - 1}} \bar{N}_t \quad ,$$

where $\bar{W}_t$ and $\bar{N}_t$ are taken as given, and $\mu$ describes the monopoly power of the household in the labour market. The return on capital, $R_{K,t}$ is given by

$$R_{K,t} := \frac{Q_t + (1 - \delta_K) P_{K,t}}{P_{K,t-1}}.$$

The term $\tau_{E,t}$ in the budget constraint above captures a cost associated with bank capital market imperfections (rigidities):

$$\tau_{E,t} := \tfrac{\xi_E}{2} \left[\log E_t - \log(\delta_E R_{E,t} E_{t-1})\right]^2 \quad .$$

The role of this cost is to limit banks' ability to raise fresh capital in response to adverse shocks or changes in capital regulation. The mechanics can be seen from the first-order condition for $E_t$. Here, we reproduce only an approximate condition (with some of the second-order terms dropped from it) for the reader's convenience:

$$\begin{aligned} &\mathbb{E}_t \left[ \frac{\beta \Lambda_{t+1}}{\Lambda_t} R_{E,t+1} \right] \overset{\text{f.o.}}{\approx} \\ &1 + \xi_E \left[\log E_t - \log(\delta_E R_{E,t} E_{t-1})\right] - \beta \xi_E \left[\log E_{t+1} - \log(\delta_E R_{E,t+1} E_t)\right] \quad . \end{aligned} \tag{16}$$

In the extreme case with $\xi_E \to \infty$, bank capital would be supplied only at the level of past retained earnings (corrected by a constant $\delta_E$ whose only purpose is to make sure that $E_t$ behaves well along a balanced-growth path; the constant is set to the inverse of the long-run return on equity, $R_{E,t}{}^{-1}$). When $\xi_E > 0$ but finite, the household's willingness to increase bank capital supply above retained earnings will be a function that is increasing in expected returns. In times of financial distress or banks' undercapitalisation, which are associated with higher-than-normal expected returns on bank capital in our model, the household will provide capital injections helping thus to re-capitalise the banks. Note that we allow for negative flows of bank capital, meaning dividends paid to the household.

Finally, the quantities $L_t$, $K_t$, $R_{L,t-1} L_{t-1}\, g_t$, and $R_{K,t} P_{K,t-1} K_{t-1}$ refer to the respective integrals over all individual members of the household, and are deteremined by the individual decisions detailed in the previous section. The household as a whole takes these as given.

## B.2 Production, Retail, and Export

**Manufacturing** The representative manufacturer, who behaves competitively in both input and output markets, uses capital, $K_t$, labour, $N_t$, and imports, $M_t$, to produce local goods,

$$Y_t = k_t^{1-\alpha_N-\alpha_M} (A_t N_t)^{\alpha_N} M_t{}^{\alpha_M},$$

where $A_t$ is an exogenous productivity process. The manufacturer faces adjustment costs of changing the quantity of labour, $N_t$ and imports, $M_t$, employed. By choosing the input factors, $k_t$, $N_t$, and $M_t$, and the level of output, $Y_t$, she maximises the firm's value,

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Lambda_{t+1} \left[ P_{Y,t} Y_t - R_{K,t} k_t - P_t N_t (1 + \tau_{N,t}) - P_{M,t} M_t (1 + \tau_{M,t}) \right],$$

with the two adjustment costs given, respectively, by $\tau_{N,t} := \frac{\xi_N}{2} (\log N_t - \log N_{t-1})^2$ and $\tau_{M,t} := \frac{xi_M}{2} (\log M_t - \log M_{t-1})^2$. The adjustment costs are adopted from Shapiro (1986) and Hall (2004). The imports, $M_t$, are purchased from abroad, at a world price converted by the nominal exchange rate, $P_{M,t} = S_t P_t^*$, where $P_t^*$ is an exogenous process.

**Local Retail** The representative local retailer resells goods purchased from the manufacturer. She operates with monopoly power $\mu$ subject to price adjustment costs, and chooses the final price, $P_t$, and output, $D_t$ to maximise the firm's value,

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Lambda_{t+1} \left[ P_t D_t (1 - \tau_{P,t}) - P_{Y,t} D_t \right],$$

subject to a CES demand curve

$$D_t = (P_t / \bar{P}_t)^{-\frac{\mu}{\mu-1}} \bar{D}_t$$

where $\bar{P}_t$ and $\bar{D}_t$ are taken as given. The price adjustment cost is similar to Rotemberg (1982), but augmented by full backward indexation:

$$\tau_{D,t} := \frac{\xi_Y}{2} \left[ \log \left( P_t / \bar{P}_{t-1} \right) - \log \left( P_{t-1} / \bar{P}_{t-2} \right) \right]^2.$$

**Exports** The representative exporter resells goods purchased form the manufacturer in an international market, taking the output price, $P_{X,t}$ as given, subject to adjustment costs of changing the level of exports. She chooses $X_t$ to maximise the firm's value,

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Lambda_{t+1} \left\{ P_{X,t} X_t (1 - \tau_X) - \left[ \psi P_{Y,t} + (1 - \psi) P_{M,t} \right] X_t \right\},$$

where

$$\tau_{X,t} := \frac{\xi_Y}{2} \left[ \log X_t - \log X_{t-1} \right]^2.$$

The country's terms of trade, $T_t = P_{X,t} / P_{M,t}$ follow an exogenous process.

All the adjustment costs above, including the bank capital adjustment cost incurred by the household, are private costs, not social costs, and are paid back to the household's budget, see also the definition of the term $v_t$ in (17).

## B.3 Monetary and Macroprudential Policy

**Monetary Policy** In our simulation exercises, we experiment with two different basic types of monetary policy conduct: an exchange rate peg, and inflation targeting. The peg is introduced simply by exogenising the path for the nominal exchange rate,

$$\log S_t = \log S_{t-1} + \epsilon_{S,t},$$

where $\epsilon_{S,t}$ can be thought of as changes in the central parity. Because our model does not have a portfolio balance channel built in we implicitly assume that the exchange rate is managed through unsterilised foreign exchange operations, and the central bank loses control of the local money market. We refer the readers to Sarno and Taylor (2001) for a detailed discussion of this matter.

Under inflation targeting, on the other hand, the central bank's systematic behaviour is summarised in an interest rate rule,

$$R_{F,t} = \varrho R_{F,t-1} + (1-\varrho)\left[\bar{R}_F + \phi_p\left(\mathbb{E}_t \log[\Pi^4_{t+h}] - \log \bar{\pi}^4\right)\right] + \epsilon_{R,t},$$

where $\epsilon_{M,t}$ is a monetary policy surprise, $\Pi^4_t := P_t/P_{t-4}$ is a year-on-year gross rate of final price changes, $\bar{\pi}^4$ is the central bank's inflation target, and the policy control horizon, $h$, is treated parameterically.

**Macroprudential Policy** Macroprudential policy consists of setting two parameters, the minimum capital requirements, $\gamma$, and the penalty, $\upsilon$. In our simulations, we fix the value of $\upsilon$ and experiment with time-varying reaction functions for $\gamma$.

## B.4 Symmetric Equilibrium and Aggregation

In symmetric equilibrium, we set $\bar{C}_t = C_t$, $\bar{P}_t = P_t$, $\bar{D}_t = D_t$. Furthermore, the following three market clearing conditions hold: $Y_t = D_t + \psi X_t$, $D_t = C_t + \psi I_t$, and $k_t = K_{t-1}$.

The term $v_t$ in the household's budget consists of the following:

$$\begin{aligned} v_t := {} & P_{Y,t} Y_t - R_{K,t} k_t - P_t N_t (1 + \tau_{N,t}) - P_{M,t} M_t (1 + \tau_{M,t}) \\ & + P_t D_t (1 - \tau_{P,t}) - P_{Y,t} D_t \\ & + P_{X,t} X_t (1 - \tau_X) - P_{Y,t} X_t \\ & + \kappa \, E_t \, \tau_{E,t} + W_t N_t \, \tau_{N,t} + P_{M,t} M_t \, \tau_{M,t} + P_t D_t \, \tau_{P,t} + P_{X,t} X_t \, \tau_X . \end{aligned} \tag{17}$$

We can now use the household's budget constraints to express a balance of payments equation, which effectively describes the law of motion for the net financial position of the country as whole. Denoting net foreign liabilities by $NFL_t$,

$$NFL_t := L_t - \kappa E_t,$$

we can write

$$\begin{aligned} NFL_t = R_{W,t-1} NFL_{t-1} \\ + (R_{L,t-1} g_t - R_{W,t-1}) L_{t-1} - \kappa (R_{E,t} - R_{W,t-1}) E_{t-1} \\ - \left[\psi P_{X,t} X_t - P_{M,t} M_t - (1-\psi) P_{M,t} I_t\right]. \end{aligned}$$

## B.5 Parameter Calibration

Table 1: Steady-state parameters

| | | |
|---|---|---|
| $\alpha_M$ | Import share of gross production | 0.20 |
| $\alpha_N$ | Labour share of gross production | 0.40 |
| $\beta$ | Household discount factor | 0.976 |
| $\gamma$ | Capital requirements | 0.08 |
| $\delta$ | Physical capital depreciation | 0.01 |
| $\epsilon$ | Proportion of bank equity held by local households | 0 |
| $\eta$ | Inverse of labour supply elasticity | 0 |
| $\kappa$ | Proportion of capital collateralising bank loans | 0.25 |
| $\mu$ | Monopoly power in goods and labour markets | 1.10 |
| $\nu$ | Liquidation costs | 0.04 |
| $\sigma$ | Std. dev. of idiosyncratic shocks to return on capital | 0.35 |
| $\varsigma$ | Std. dev. of aggregate return on capital | 0.15 |
| $\upsilon$ | Regulatory penalty | 0.02 |
| $\psi$ | Share of directly imported investment and exports | 0.60 |

Table 2: Transitory dynamics and policy parameters

| | | |
|---|---|---|
| $\theta$ | Degree of financial dollarisation | 1.00 |
| $\xi_E$ | Bank capital market rigidities | $\infty$ |
| $\xi_I$ | Investment adjustment cost | 0.50 |
| $\xi_K$ | Capital adjustment cost | 0.50 |
| $\xi_P$ | Price adjustment cost | 18.00 |
| $\xi_W$ | Wage adjustment cost | 18.00 |
| $\xi_X$ | Export adjustment cost | 100.00 |
| $\xi_Y$ | Adjustment cost of changing labour-import ratio | 3.00 |
| $\chi$ | Consumer habit | 0.80 |
| | | |
| $\phi_R$ | Monetary policy response to inflation | 2.00 |
| $h$ | Monetary policy horizon | 3 |
| $\phi_\gamma$ | Macroprudential response to lending spread | $\{0, 5\}$ |