# Cyclically adjusted provisions and financial stability

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# Cyclically Adjusted Provisions
# and Financial Stability

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## Abstract

This paper studies the extent to which alternative loan loss provisioning regimes affect the procyclicality of the financial system and financial volatility. It uses a DSGE model with financial frictions (namely, collateral effects and economies of scope in banking) and a generic formulation of provisioning regimes. Numerical experiments with a parameterized version of the model show that cyclically adjusted (or, more commonly called, dynamic) provisioning can be highly effective in terms of mitigating procyclicality and financial risks, measured in terms of the volatility of the credit-output ratio and real house prices, in response to financial shocks. The optimal combination of simple cyclically adjusted provisioning and countercyclical reserve requirement rules is also studied. The simultaneous use of these instruments does not improve the ability of either one of them to mitigate financial volatility, making them (partial) substitutes rather than complements.

**JEL Classification Numbers**: E32, E44, E52.

**Keywords**: Provisioning regimes; reserve requirements; DSGE models.

# 1 Introduction

Since the global financial crisis, the possibility that accounting standards may contribute to banking procyclicality and financial volatility has been the subject of renewed scrutiny. Under the current International Accounting Standard (IAS) 39, the rules for impairment of loans follow the so-called *incurred loss* model, which assumes that loans will be repaid in their entirety and that objective evidence to the contrary—events that would have an impact on the estimated future cash flows of the loan—must be identified before any impairment losses are recognized. Critics of IAS 39 have argued that recognition after identification of evidence, such as a counterparty failing to meet its contractual obligations, is too late in the credit cycle because the expenses in the income statement for impairments then accumulate in downturns, when losses materialize. This provisioning regime therefore tends to exacerbate procyclicality: in good times, when lending is already at a high level, banks are not required to set aside buffers for expected losses that will be revealed only when the boom ends—thereby overstating the economic value of their loan portfolios while understating losses in their income statements. As a result, lending can be expanded beyond the amount that would be advisable. By contrast, in downturns high credit losses occur, but the lack of available provisions increases the losses reported in banks' income statements, which reduce capital and may force banks to recapitalize, reduce lending (thereby exacerbating a credit crunch), or dispose of assets.[1] Thus, from the perspective of procyclicality, the main potential drawbacks of current accounting rules are $a)$ increased volatility caused to banks' financial statements and balance sheets; $b)$ the rules concerning incurred and expected losses in loan portfolios; and $c)$ the impact of accounting standards on banks' lending practices.

Starting on January 1, 2018 a new accounting framework, IFSR 9, will become mandatory for banks. In contrast to the incurred loss model, IFSR 9 implements a forward-looking methodology, the so-called *expected loss* model. Under this model, credit losses that are expected to occur must be recognized early in the credit cycle, without first identifying a credit loss event; impairments are therefore made in a more

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[1]See Cavallo and Majnoni (2002), Bikker and Metzemakers (2005), Beatty and Liao (2011), and Pool et al. (2015) for empirical evidence on the relationship between bank lending, loan loss provisioning, and business cycles.

timely manner, potentially dampening procyclicality in loan provisioning and providing a more accurate profit and loss account. Provisions set aside in good times serve as a buffer against risk and reduce the likelihood of banks becoming insolvent.

Before the development of IFSR 9, Spain was one of the first countries to implement an accounting regime that involves elements of the expected loss model—the so-called "dynamic" provisioning rules.[2] In more recent years a number of countries in Latin America have implemented similar schemes. These countries include Bolivia, Colombia, Peru, and Uruguay.[3] Although the details of these schemes differ in several ways from the Spanish system (see Wezel (2010), Chan-Lau (2012), and Wezel et al. (2012)), they all share a common goal—to ensure that banks are not required to increase the reserves that they must hold against loan losses at exactly the same time that their capacity to lend is needed to help promote an economic recovery.

In recent years a growing body of research has focused on the countercyclical performance of these provisioning systems, and their impact on financial stability. Studies based on Spain's experience by Saurina (2009), Jiménez et al. (2012), and Fernández de Lis and García Herrero (2013) found that the Spanish provisioning model reduced procyclicality but did not eliminate it. López et al. (2014), in a study of Colombia over the period 2003-2011, found that countercyclical loan loss provisions were negatively related with the amplitude of credit cycles. Gómez et al. (2016), using a detailed dataset on Colombian banks for the period 2006-09, found a similar result in terms of credit growth. In a study of Peru's experience since 2008, Cabello et al. (2016) also documented a negative relationship between dynamic provisions and commercial loans.

Several multi-country studies have corroborated these findings. Lim et al. (2011), and a more comprehensive econometric study by Cerutti et al. (2015) over the period 2000-13, found that dynamic provisions were highly effective in mitigating credit procyclicality. In the same vein, Akinci and Olmstead-Rumsey (2015), based on a sample of 57 countries, provide supporting evidence that loan loss provisions contributed

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[2]Dynamic (also referred to as "statistical") provisioning is an extension of through-the-cycle provisioning; the latter refers to provisions made on the basis of the expected loss-given default of a loan throughout its duration, whereas the former is calculated using time series on default probabilities. See Burroni et al. (2009) for a more detailed discussion.

[3]Mexico also introduced gradually—in 2009, 2011, and 2013, for different types of loans—a new provisioning methodology based on expected loss considerations. See Levin et al. (2016) for a discussion.

to mitigating bank credit growth. Using a sample of mostly middle-income countries, Murcia Pabón and Kohlscheen (2016) found that bank provisioning decisions are highly correlated and influenced by past output growth (negatively) and past aggregate credit growth (positively). In addition, they found that provisions mainly respond to current and past changes in reported credit losses, rather than anticipated changes. This predominantly backward-looking behavior could reflect IAS 39 accounting practices for recognizing impaired loans, as noted earlier. Indeed, when the sample is restricted to Colombia and Peru—two countries that adopted dynamic provisioning regimes in 2007 and 2008, respectively—the results show that provisions respond not only to backward-looking loan losses but also to a forward-looking component. Finally, in a study focusing on Latin America, Gambacorta and Murcia (2016) found that loan loss provisions were not only effective in mitigating credit growth but also contributed to limiting risks to the banking sector, as measured (ex post) by the size of nonperforming loans.

However, analytical contributions on the macroeconomic performance of provisioning regimes remain scant. To the best of our knowledge, Goodhart et al. (2013) and Agénor and Zilberman (2015) are the only studies to do so in a general equilibrium setting. In Goodhart et al. (2013) dynamic provisioning is formalized as a requirement for the bank to keep cash on its balance sheet in good states of the world, when the growth of real-estate-related credit exceeds a certain threshold. Provisioning involves banks setting aside a portion of today's profits to cover future (expected) losses. But the form of "provisions" defined in that model is more akin to a reserve ratio, that is, a form of liquidity regulation: when loan growth is high, banks are required to hold a larger proportion of their assets in cash. The effects of requiring banks to build up provisions ahead of a downturn cannot be analyzed in that setting. Agénor and Zilberman (2015), drawing in part on the partial equilibrium framework of Bouvatier and Lepetit (2012), do capture this feature in a dynamic stochastic general equilibrium (DSGE) model with credit market imperfections. They define two alternative loan loss provisioning regimes: a specific provisioning system, in which provisions are triggered by past due payments, and a dynamic provisioning system, in which both past due payments and expected losses over the whole business cycle are accounted for, and provisions are smoothed over the cycle. Their numerical experiments showed that a

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dynamic provisioning regime can be highly effective in mitigating procyclicality of the financial system. However, in studying optimal simple rules they focus mainly on the case of an integrated mandate for the central bank and a dynamic provisioning regime with full smoothing—in the sense that any deviation in the fraction of nonperforming loans from its steady-state value is fully reflected in the calculation of total provisions. The possibility of "over provisioning" (a more than proportional response to deviations in the fraction of nonperforming loans, or any other measure of cyclical fluctuations), as well as independent mandates for monetary policy and macroprudential regulation, are not discussed. Moreover, they do not consider the extent to which dynamic provisioning could be (optimally) combined with other macroprudential instruments to promote financial stability—an issue that policymakers are constantly confronted with.

The purpose of this paper is to fill this gap, using a more general DSGE model with financial frictions and a housing market, as well as a generic formulation that captures some key features of the provisioning regimes currently in use in various countries around the world, especially Latin America. The analysis focuses on the extent to which these regimes affect the procyclicality of the financial system as well as real and financial volatility. In addition, we examine the optimal combination of simple dynamic (or, more appropriately in our view, cyclically adjusted) provisioning and countercyclical reserve requirement rules. This is important because in recent years reserve requirements have been actively used in Latin America and elsewhere, and significantly more so than several other macroprudential instruments, to promote macroeconomic stability and mitigate financial risks (see Claessens et al. (2013) and Gambacorta and Murcia (2016)). At the analytical level, much recent discussion has focused on the use of these requirements as a countercyclical macroprudential tool, rather than as an instrument of liquidity management or a substitute to monetary policy.[4] We also consider two types of financial shocks, one associated with borrowers' default risk and the other with asset prices and collateral values.

Our numerical experiments, based on a parameterized version of the model for a "typical" middle-income economy, allow us to establish three key results. First, we

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[4]See Montoro and Moreno (2011), Cordella et al. (2014), Agénor et al. (2015) and Agénor and Pereira da Silva (2016) for a detailed discussion. Note also that reserve requirements can also be more broadly interpreted as a tax on financial intermediation, aimed in this case at preventing excessive credit growth.

show that cyclically adjusted provisioning can be highly effective in mitigating procyclicality and financial volatility; this is consistent with the results obtained by Agénor and Zilberman (2015) in a simpler framework. However, the relationship between the parameter that characterizes the response of provisions to cyclical shifts in default risk follows a U-shaped pattern. At first, a more aggressive policy mitigates financial volatility—measured in terms of a weighted average of the volatility of the credit-to-GDP ratio and the volatility of real house prices—because the policy stabilizes credit, investment and economic activity. But beyond a certain point, market interest rates become more volatile, and so do lending and aggregate demand; financial volatility therefore begins to increase again. The optimal policy is obtained at the point where the volatility index is minimized. Second, we also show that the optimal policy involves "excess smoothing," in the sense that it entails a more than proportional reaction to cyclical movements in the share of nonperforming loans (or, equivalently here, the probability of default). Third, our analysis shows that cyclically adjusted provisioning and countercyclical reserve requirements are not complements; the use of either one of these instruments does not improve (at the margin) the ability of the other to mitigate financial volatility. At the same time, the optimal countercyclical provisioning rule performs significantly better than the optimal reserve requirement rule. In that sense, the two instruments are only partial substitutes. Fourth, we show that although an optimal cyclically adjusted provisioning regime can be defined alternatively in terms of a reaction function to cyclical output, responding to that variable does not perform as well as responding to changes in nonperforming loans.

The remainder of the paper is divided into six parts. Section 2 presents the model, which is based in part on Agénor et al. (2013) and Agénor and Zilberman (2015). As in the first paper, it considers collateral effects (operating through changes in housing values) as a key source of financial frictions. In addition, and in contrast to these previous contributions, it also accounts for monopolistic competition in banking and costly production of loans and deposits, which creates economies of scope in banking and the possibility for reserve requirements to act in a countercyclical manner through their impact on deposit and loan rates. The equilibrium solution of the model and some key features of its steady state and log linearization are discussed in Section 3, whereas a parameterization for a "typical" middle-income economy is presented in

Section 4. The results of two transitory financial shocks (an increase in the risk of default and a negative shock to asset prices) are discussed in Section 5. The optimal cyclically adjusted provisioning rule, and the optimal combination of that rule with a reserve requirement rule, are analyzed in Section 6. Sensitivity analysis is performed in Section 7. The last section offers some concluding remarks and discusses some possible extensions of the analysis.

## 2 The Model

Consider a closed economy consisting of seven types of agents: a representative household, a representative final good (FG) firm, a continuum of intermediate good (IG) firms, a capital good (CG) producer, a continuum of commercial banks, a government, and a central bank, which also acts as the financial regulator. Each IG firm rents capital from the CG producer and combines it with labor to produce a unique intermediate good. Intermediate goods are then combined by the FG firm, who produces a homogeneous final good, which, in turn, can be used for either consumption, investment or government spending.

Commercial banks receive deposits from households and supply credit to the CG producer for investment purposes. There is monopolistic competition on the markets for deposits and loans; banks therefore set both the deposit and the loan rates. Deposits and loans are differentiated due to the existence of switching costs—fees charged to close or to open a bank account, fees incurred when applying for a loan or renegotiating the terms of an outstanding debt, and so on—which generate a temporary *lock in* effect and give banks some degree of market power (see Freixas and Rochet (2008)).[5] Banks also borrow from the central bank to cover any shortfall in funding. The supply of loans is perfectly elastic at the prevailing lending rate. Banks receive gross interest payments on investment loans and pay back principal plus interest on households' deposits and loans from the central bank. In addition, banks holds loan loss reserves, which are invested in riskless, one-period government bonds. Loan loss provisioning rules are set

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[5]The assumption that loans are differentiated across banks could also be justified by the assumption that, due to proximity for instance, each bank has an advantage over the others in terms of inspecting a borrower's cash flows and balance sheet, observing his activities, and ensuring that he conforms to the terms agreed upon in the loan contract. However, this advantage is again only temporary, given that in a symmetric equilibrium all banks behave identically.

by the central bank.

## 2.1  Household

The representative household consumes, holds deposits and cash, invests in one-period government bonds, and supplies labor to IG firms. Its objective is to maximize the utility function

$$U_t = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left\{ \frac{C_{t+s}^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} + \eta_N \ln(1 - N_{t+s}) + \ln x_{t+s}^{\eta_x} + \ln H_{t+s}^{\eta_H \epsilon_t^H} \right\}, \tag{1}$$

where $C_t$ denotes consumption of the final good, $N_t$ the share of total time endowment (normalized to unity) spent working, $x_t$ a composite index of real monetary assets, and $H_t$ the stock of housing. $\mathbb{E}_t$ is the expectations operator conditional on information available up to period $t$ and $\beta \in (0,1)$ denotes the discount factor. Parameter $\varsigma$ is the intertemporal elasticity of substitution in consumption, whereas $\eta_N, \eta_x, \eta_H > 0$ are preference parameters. In standard fashion, housing services are proportional to their stock. The random variable $\epsilon_t^H$ is a housing demand shock, which follows an $AR(1)$ process of the form $\epsilon_t^H = (\tilde{\epsilon}^H)^{1-\rho^H} \epsilon_{t-1}^{\rho^H} \exp(\xi_t^H)$, where $\rho^H \in (0,1)$ and $\xi_t^H \sim \mathbf{N}(0, \sigma_{\xi^H})$.

The composite monetary asset is generated by combining real cash balances, $m_t^P$, and real bank deposits, $d_t$:

$$x_t = (m_t^P)^\nu d_t^{1-\nu}, \tag{2}$$

where $\nu \in (0,1)$. Both deposits and cash are accounted for because (as noted later) the bond rate is solved from the equilibrium condition of the currency market.

The representative household's budget constraint is given by

$$C_t + d_t + b_t^P + p_t^H \Delta H_t + m_t^P = \left( \frac{1+i_{t-1}^D}{1+\pi_t} \right) d_{t-1} + \left( \frac{1+i_{t-1}^B}{1+\pi_t} \right) b_{t-1}^P \tag{3}$$

$$+ \frac{m_{t-1}^P}{1+\pi_t} + w_t N_t + \int_0^1 \Pi_{j,t}^G dj + \Pi_t^K - T_t,$$

where $i_t^D$ is the interest rate on deposits, $i_t^B$ the return on holdings, $b_t^P$ holdings of one-period government bonds, $w_t$ the real wage, $\int_0^1 \Pi_{j,t}^G dj$ and $\Pi_t^K$ profits made by the IG producers and the CG producer, respectively, $\pi_t$ the inflation rate, $p_t^H$ the real price of housing, and $T_t$ real lump-sum taxes.

Maximizing (1) subject to (2) and (3) with respect to $C_t$, $N_t$, $d_t$, $m_t^P$, $b_t^P$, and $H_t$, and taking interest rates, the wage rate, and prices as given, yields

$$\mathbb{E}_t[(\frac{C_{t+1}}{C_t})^{1/\varsigma}] = \beta\mathbb{E}_t(\frac{1+i_t^B}{1+\pi_{t+1}}),$$ (4)

$$d_t = \frac{\eta_x(1-\upsilon)C_t^{1/\varsigma}(1+i_t^B)}{i_t^B-i_t^D},$$ (5)

$$m_t^P = \frac{\eta_x\upsilon C_t^{1/\varsigma}(1+i_t^B)}{i_t^B},$$ (6)

$$N_t = 1 - \frac{\eta_N C_t^{1/\varsigma}}{w_t},$$ (7)

$$p_t^H H_t^d = \left\{1 - \mathbb{E}_t(\frac{1+\pi_{t+1}^H}{1+i_t^B})\right\}^{-1}\eta_H\epsilon_t^H C_t^{1/\varsigma},$$ (8)

where $\pi_t^H$ is the rate of increase in nominal house prices. All these equations take a familiar form, except for (8), which shows that an increase in the expected future rate of increase in housing prices, or a fall in the bond rate, lead (all else equal) to a rise in today's demand for housing.

## 2.2 Final Good Producer

The final good, $Y_t$, is produced by assembling a continuum of imperfectly substitutable intermediate goods $Y_{jt}$, with $j \in (0,1)$:

$$Y_t = \left\{\int_0^1 [Y_{jt}]^{(\theta-1)/\theta}dj\right\}^{\theta/(\theta-1)},$$

where $\theta > 1$ denotes the constant elasticity of substitution between the differentiated intermediate goods.

The FG producer chooses the optimal quantities of each intermediate good that maximize its profits, taking as given the price of each of these goods, $P_{jt}$, as well as the final good price, $P_t$. This yields

$$Y_{jt} = (\frac{P_{jt}}{P_t})^{-\theta}Y_t.$$ (9)

The zero-profit condition yields the final good price as

$$P_t = \left\{\int_0^1 (P_{jt})^{1-\theta}dj\right\}^{1/(1-\theta)}.$$ (10)

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## 2.3 Intermediate Good Firms

There is a continuum of IG producers, indexed by $j \in (0,1)$. Using capital and labor each firm produces a perishable good, which is sold on a monopolistically competitive market. The IG firm rents capital from the CG producer at the rate $r_t^K$, as well as labor, at the rate $w_t$. Each IG firm $j$ faces the production function

$$Y_{jt} = N_{jt}^{1-\alpha} K_{jt}^{\alpha}, \tag{11}$$

where $N_{jt}$ is labor supplied by the representative household to firm $j$, $K_{jt}$ capital rented by firm $j$, and $\alpha \in (0,1)$.

Each IG producer solves a two-stage pricing decision problem. In the first stage, it minimizes the cost of renting capital and employing labor, taking wages and the rental price of capital as given, that is, $\min_{N_{jt}, K_{jt}} w_t N_{j,t} + r_t^K K_{jt}$, subject to (11). The optimal capital-labor ratio takes the familiar form $K_{j,t}/N_{j,t} = \alpha(1-\alpha)^{-1}\left(w_t/r_t^K\right)$, with the unit real marginal cost equal to

$$mc_{j,t} = \frac{w_t^{1-\alpha}\left(r_t^K\right)^{\alpha}}{\alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha}}. \tag{12}$$

In the second stage, each IG producer chooses a sequence of prices $\{P_{jt+s}\}_{s=0}^{\infty}$ so as to maximize discounted real profits. In Rotemberg fashion, they all incur a cost in adjusting prices, of the form

$$PAC_t^j = \frac{\phi_F}{2}(\frac{P_{jt}}{\tilde{\pi}^G P_{jt-1}} - 1)^2 Y_t, \tag{13}$$

where $\phi_F \geq 0$ is the adjustment cost parameter and $\tilde{\pi}^G = 1 + \tilde{\pi}$ is the gross steady-state inflation rate. The second-stage optimization problem is thus[6]

$$\{P_{jt+s}\}_{s=0}^{\infty} = \arg\max \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \lambda_{t+s} J_{jt+s}^I,$$

where real profits at $t$, $J_{jt}^I$, are defined as $J_{jt}^I = [(P_{jt}/P_t) - mc_t]Y_{jt} - PAC_t^j$. Taking $\{mc_{t+s}, P_{t+s}, Y_{t+s}\}_{s=0}^{\infty}$ as given, the first-order condition for this maximization problem takes the standard form

$$(1-\theta)(\frac{P_{jt}}{P_t})^{-\theta}\frac{1}{P_t} + \theta(\frac{P_{jt}}{P_t})^{-\theta-1}\frac{mc_{jt}}{P_t} - \phi_F\left\{(\frac{P_{jt}}{\tilde{\pi}^G P_{jt-1}} - 1)\frac{1}{\tilde{\pi}^G P_{jt-1}}\right\} \tag{14}$$

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[6]Because IG firms are owned by households (to whom they transfer their profits), each producer's discount factor for period-$t+s$ profits is $\beta^s \lambda_{t+s}$, where $\lambda_{t+s}$ is the marginal utility value (in terms of consumption) of an additional currency unit of profits at $t+s$. The same discount factor is used by the CG producer and banks.

$$+\beta\phi_F\mathbb{E}_t\left\{\frac{\lambda_{t+1}}{\lambda_t}(\frac{P_{jt+1}}{\tilde{\pi}^G P_{jt}}-1)(\frac{P_{jt+1}}{\tilde{\pi}^G P_{jt}^2})\frac{Y_{t+1}}{Y_t}\right\}=0.$$

## 2.4 Capital Good Producer

The CG producer owns all physical capital in the economy and uses a linear technology to produce capital goods. In order to produce these goods, the CG firm spends $I_t$ on the final good. It must pay for these goods in advance and borrows from commercial banks at the beginning of the period. Thus, the real amount borrowed from banks, $l_t$, is

$$l_t = I_t. \tag{15}$$

The household makes its exogenous housing stock, $\bar{H}$, available without any direct charge to the CG producer, who uses it as collateral against which it borrows from banks.[7] However, repayment is uncertain. If loans are repaid in full, an event that occurs with probability $q_t \in (0,1)$, the total cost faced by the CG producer at the end of period $t$ is $(1+i_t^L)l_t$, where $1+i_t^L$ is the aggregate gross interest rate charged by banks. If there is default, which occurs with probability $1-q_t$, the CG producer loses the collateral that it pledged to secure the loan; collateral is given by $\kappa\mathbb{E}_t p_{t+1}^H \bar{H}$, where $\kappa = \int_0^1 \kappa^i di$ and $\kappa^i \in (0,1)$ is the fraction of the housing stock pledged as collateral to each bank $i$, and $K_t = \int_0^1 K_{jt}dj$. Thus, expected repayment is $q_t(1+i_t^L)l_t+(1-q_t)\kappa\mathbb{E}_t p_{t+1}^H \bar{H}$.[8]

To produce new capital the CG firm combines gross investment with the existing stock of capital, adjusted for depreciation and adjustment costs:

$$K_{t+1} = I_t + (1-\delta_K)K_t - \frac{\Theta_K}{2}(\frac{K_{t+1}}{K_t}-1)^2 K_t, \tag{16}$$

where $\delta_K \in (0,1)$ denotes the constant rate of depreciation, and $\Theta_K > 0$ the adjustment cost parameter. The new capital stock is then rented to the IG producers at the rate $r_t^K$.

The CG producer chooses the level of capital stock so as to maximize the value of discounted stream of dividend payments to households subject to equation (16). Specifically, defining $\mathbb{E}_t\Pi_{t+1}^K = r_t^K K_t - q_t(1+i_t^L)l_t - (1-q_t)\kappa\mathbb{E}_t p_{t+1}^H \bar{H}$ as the CG

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[7] Because we assume that all profits made by the CG producer are returned lump sum to households, the assumption that the housing stock is made available free of charge is immaterial.

[8] To avoid a corner solution with no lending we assume that the condition $\mathbb{E}_t p_{t+1}^H \bar{H} \leq (1+i_t^L)l_t$ always holds.

producer's expected real profits at the end of period $t$, the first-order condition yields (see Agénor et al. (2015, Appendix A)):

$$\mathbb{E}_t r_{t+1}^K = q_t(1+i_t^L)\mathbb{E}_t\left\{\left[1+\Theta_K(\frac{K_{t+1}}{K_t}-1)\right](\frac{1+i_t^B}{1+\pi_{t+1}})\right\} \tag{17}$$

$$-\mathbb{E}_t\left\{q_{t+1}(1+i_{t+1}^L)\left[1-\delta_K+\frac{\Theta_K}{2}\left[(\frac{K_{t+2}}{K_{t+1}})^2-1\right]\right]\right\},$$

which shows that the repayment probability affects the expected rate of return to capital through its effect on expected repayment in both period $t$ and period $t+1$.

The amount borrowed by the CG producer is a Dixit-Stiglitz basket of differentiated loans, each supplied by a bank $i$, with a constant elasticity of substitution $\zeta^L > 1$:

$$l_t = [\int_0^1 (l_t^i)^{(\zeta^L-1)/\zeta} di]^{\zeta^L/(\zeta^L-1)}.$$

The demand for type-$i$ loan, $l_t^i$, is thus given by the downward-sloping curve

$$l_t^i = (\frac{1+i_t^{L,i}}{1+i_t^L})^{-\zeta^L} l_t, \tag{18}$$

where $1+i_t^{L,i}$ is the rate on the loan extended by bank $i$ and $1+i_t^L = [\int_0^1(1+i_t^{L,i})^{1-\zeta^L} di]^{1/(1-\zeta^L)}$ the aggregate loan rate.

## 2.5 Commercial Banks

Banks are risk neutral and of comparable size; they are indexed by $i \in (0,1)$. They collect differentiated deposits from households and extend (as discussed earlier) differentiated loans to the CG producer, in an environment of monopolistic competition. The supply of credit is perfectly elastic at the prevailing loan rate and therefore the total amount of lending provided by banks is given by equation (15). To fund any shortfall in funding, each bank borrows a real amount $l_t^{B,i}$ from the central bank at a cost $i_t^R$, which is also referred to as the refinance rate. Moreover, bank $i$ holds one-period government bonds (a safe asset) in quantity $b_t^{B,i}$, which bears an interest rate of $i_t^B$.

### 2.5.1 Balance Sheet

As the loan portfolio takes into account expected losses, consistent with standard practice loan loss reserves, $LR_t^i$, are subtracted from total loans.[9] Bank $i$'s balance

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[9]Loan loss *provisions* are defined, in standard accounting practice, as an estimation of probable loan losses for a current year and are charged as an expense, deducted from current profits (see (28)

sheet is thus

$$l_t^i - LR_t^i + b_t^{B,i} + RR_t^i = d_t^i + l_t^{B,i}, \tag{19}$$

where $RR_t^i$ denotes required reserves held at the central bank, which do not pay interest and are determined by:

$$RR_t^i = \mu_t^R d_t^i, \tag{20}$$

where $\mu_t^R \in (0,1)$ is the required reserve ratio. Equation (19) shows that loan loss reserves, just like bank capital, are fundamentally an alternative way of funding bank lending operations.

In each period banks invest their loan loss reserves in the safe asset $(LR_t^i = b_t^{B,i})$ and earn a return of $i_t^B$ on them. Given this assumption, the balance sheet constraint (19) can be used to determine residually the level of borrowing from (or deposits at) the central bank:

$$l_t^{B,i} = l_t^i - (1 - \mu_t^R)d_t^i. \tag{21}$$

The aggregate supply of deposits by households is a basket of differentiated deposits, each supplied to a bank $i$, with a constant elasticity of substitution $\zeta^D > 1$ between different types of deposits:

$$d_t = [\int_0^1 (d_t^i)^{(1+\zeta^D)/\zeta^D} di]^{\zeta^D/(1+\zeta^D)}.$$

The supply of type-$i$ deposit, $d_t^i$, is thus given by the upward-sloping curve

$$d_t^i = (\frac{1 + i_t^{D,i}}{1 + i_t^D})^{\zeta^D} d_t, \tag{22}$$

where $1 + i_t^{D,i}$ is the deposit rate offered by bank $i$ and $1 + i_t^D = [\int_0^1 (i_t^{D,i})^{1+\zeta^D} di]^{1/(1+\zeta^D)}$ the aggregate deposit rate.

### 2.5.2 Provisioning Regimes

Banks must satisfy regulation in the form of setting loan loss provisions, $LP_t$, which are deducted from current earnings. As in Agénor and Zilberman (2015), they build provisions up gradually during the period; this leads to a partial adjustment formulation,

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below). Loan loss *reserves*, by contrast, are a balance sheet item that depends on (the flow of) loan loss provisions, and the net difference between accumulated recognized loan losses—that is, loans that are in actual default—and loan recoveries. Accounting for the latter two components would not add much additional insight to the analysis as long as they are fixed fractions of loans. They are thus ignored for simplicity.

which takes the form

$$LR_t^i = (LR_{t-1}^i)^{\rho_{LR}}(LP_t^i)^{1-\rho_{LR}}, \tag{23}$$

where $\rho_{LR} \in (0, 1)$ is a persistence parameter.[10]

Provisioning rules can take two forms. With *specific* (or *point in time*) provisioning, provisions are triggered by the fraction of nonperforming loans (or, equivalently here, the probability of default); with *cyclically adjusted* (or *through the cycle*) provisioning, provisions take into account both past due payments, as before, but also expected or latent losses over the business cycle. Thus, provisions are smoothed over the cycle and are less affected by the current state of the economy.

To capture these different regimes, the general specification proposed in this paper is as follows:

$$LP_t^i = \Lambda_0(1 - q_t^i)l_t^i + \max\left\{0, \Lambda_1(\frac{q_t^i}{\tilde{q}^i} - 1)l_t^i + \Lambda_2(\frac{Y_t}{\tilde{Y}} - 1)^{\theta_L}l_t^i\right\}, \tag{24}$$

where $\Lambda_0 > 0$, $\Lambda_1, \Lambda_2 \geq 0$, and $\theta_L \geq 0$. This specification is broadly consistent with the view that if provisions can take into account more credit information and anticipate and quantify better the expected losses associated with a loan portfolio (using either only bank-specific or macroeconomic information), they would provide additional buffers to mitigate procyclicality and promote financial stability. This would occur both by discouraging (although not necessarily eliminating) excessive lending in booms and by strengthening banks prior to downturns.

The case of specific provisions is obtained by setting $\Lambda_1 = \Lambda_2 = 0$, so that

$$LP_t^i = \Lambda_0(1 - q_t^i)l_t^i, \tag{25}$$

where $\Lambda_0$ can be interpreted as the steady-state fraction (or coverage ratio) of expected losses, whose level is defined as $(1-q_t^i)l_t^i$, with $1-q_t^i$ representing the default probability. Thus, given the max operator in (24), specific provisions are the minimum level that banks must comply with.

If $\Lambda_1 > 0$ and $\Lambda_2 = 0$, and the max operator is not binding, expression (24) gives

$$LP_t^i = \Lambda_0(1 - q_t^i)l_t^i + \Lambda_1(\frac{q_t^i}{\tilde{q}^i} - 1)l_t^i, \tag{26}$$

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[10]Recognized loan losses do not affect the dynamics of loan loss reserves, as captured in equation (23), as long as they are (as noted earlier) a fixed fraction of loans.

which generalizes the case considered in Agénor and Zilberman (2015).[11] The difference between (25) and (26) is that with cyclically adjusted provisioning, during an expansion, when the default probability $1 - q_t$ is lower than the estimation of default risk over the whole cycle $1 - \tilde{q}$ (or, equivalently, when $q_t > \tilde{q}$), banks will build up more provisions—and vice versa during a recession.

Specification (24) is more general than the cases considered in the literature in the sense that, in addition to the special cases outlined earlier, it brings in an additional element when $\Lambda_2 > 0$: the possibility that cyclical movements in a macroeconomic variable, aggregate output $Y_t$, may also affect the calculation of cyclically adjusted provisions when $\Lambda_1 \geq 0$. As discussed further later on, the case $\Lambda_1 = 0$, $\Lambda_2 > 0$ is indeed consistent with the Peruvian formula, which uses the growth rate of output (see Wezel et al. (2012) and Cabello et al. (2016)).

### 2.5.3 Interest Rate Determination

As noted earlier, banks are monopolistically competitive in the markets for deposits and loans. They therefore set interest rates to maximize the present value of expected profits. In addition, banks also optimize their monitoring effort. Specifically, each bank can affect the repayment probability on its loan to the CG producer, $q_t^i$, by expending effort; the higher the monitoring effort, the safer the loan. Thus, greater monitoring intensity is also desirable from the borrower's perspective.[12] For simplicity, the probability of repayment itself, rather than monitoring effort *per se*, is taken to be the choice variable, as in Allen et al. (2011) and Dell'Ariccia et al. (2014) for instance.

Formally, each bank sets its (gross) deposit and loan rates, and the repayment probability, in order to maximize the present value of its end-of-period expected real profits:

$$\max_{1+i_t^{D,i}, 1+i_t^{L,i}, q_t^i} \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \lambda_{t+s} \Pi_{t+s+1}^{B,i}, \tag{27}$$

---

[11] Agénor and Zilberman write the right-hand side of (26) in the form $\Lambda_0(1-q_t^i)l_t^i + \Lambda_1\Lambda_0(q_t^i - \tilde{q}^i)l_t^i$, which can also be written as the weighted average $\Lambda_1\Lambda_0(1-\tilde{q}^i)l_t^i + (1-\Lambda_1)\Lambda_0(1-q_t^i)l_t^i$; their focus is on the case where $\Lambda_1 \in (0,1)$.

[12] As noted by Allen et al. (2011, pp. 988-89), one way of interpreting this assumption is that banks observe information about borrowers and then use it to help improve their performance. Another is that banks and borrowers have complementary skills: producers have expertise in running the firm, whereas banks provide financial expertise that helps to improve the borrower's expected value. Note also that, because there is only a single CG producer in this setting, banks do not expend effort to select (*ex ante*) potential borrowers.

where $\mathbb{E}_t\Pi^{B,i}_{t+s+1}$ is defined as, $\forall s$,[13]

$$\mathbb{E}_t\Pi^{B,i}_{t+s+1} = \mathbb{E}_t \left\{ q^i_{t+s}(1 + i^{L,i}_{t+s})l^i_{t+s} \right. \tag{28}$$

$$+(1 - q^i_{t+s})\left(\kappa^i p^H_{t+s+1}\bar{H}\right) + (1 + i^B_{t+s})LR^i_{t+s} - (1 + i^D_{t+s})d^i_{t+s}$$

$$\left. -(1 + i^R_{t+s})[l^i_{t+s} - (1 - \mu^R_t)d^i_{t+s}] - LP^i_{t+s} - x^{M,i}_{t+s} - \Gamma(l^i_t, d^i_t) \right\},$$

where $\Gamma(l^i_t, d^i_t)$ measures the nonseparable cost of producing loans and deposits, and $x^{M,i}_t$ is the real pecuniary cost of monitoring faced by bank $i$, defined as

$$x^{M,i}_t = \Phi\left(\frac{\kappa\mathbb{E}_t p^H_{t+1}\bar{H}}{l_t}, \frac{Y_t}{\tilde{Y}}\right)\frac{(q^i_t)^2}{2}l^i_t, \tag{29}$$

where the unit cost $\Phi$ is the average across banks and is thus predetermined from the perspective of bank $i$. It is assumed to depend on the collateral-loan ratio and cyclical output, $Y_t/\tilde{Y}$, with a '~' denoting a steady-state value.[14] Both variables are assumed to have a negative effect on unit monitoring costs. First, a higher collateral-loan ratio mitigates moral hazard problems and induces borrowers to take less risk and exert more effort in ensuring that their investments are successful; in addition, it may enhance compliance with bank monitoring requirements. Second, in boom times, when profits and cash flows are high, (unit) monitoring costs tend to fall, because borrowers are more diligent and the risk of default abates.

The function $\Gamma(l^i_t, d^i_t)$ is assumed to be strictly increasing and convex in its two arguments, so that $\Gamma_l, \Gamma_d > 0, \Gamma_{ll}, \Gamma_{dd} > 0$; in addition, it is also assumed to be linearly homogeneous. By implication of linear homogeneity, $\Gamma_{ld} < 0$, that is, a higher volume of deposits lowers the cost of lending by providing more information on (potential) borrowers. There is therefore cost complementarity or economies of scope—that is, lower costs of producing a combined set of products than the sum of costs incurred when producing them individually—a well-documented feature of banking.[15]

In what follows, we will focus on the case where $\Gamma(l^i_t, d^i_t)$ can be represented by the Diewert cost function

$$\Gamma(l^i_t, d^i_t) = \gamma_D d^i_t + \gamma_L l^i_t - 2\gamma\sqrt{d^i_t l^i_t}, \tag{30}$$

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[13]Note that provisions, $LP^i_t$, are deducted from the bank's profits but also enter indirectly as gross income because loan loss reserves are invested in government bonds ($LR^i_t = b^{B,i}_t$), as noted earlier.

[14]Allen et al. (2011) and Dell'Ariccia et al. (2014) also assume that monitoring costs are quadratic in the repayment probability.

[15]See Carvallo and Kasman (2005) for evidence on economies of scope in banking in Latin America. Dijkstra (2013) provides a review of the evidence for European countries.

where $\gamma_D, \gamma_L, \gamma > 0$.[16]

Bank $i$ maximizes profits subject to the downward-sloping loan demand equation by the CG producer (18), the balance sheet constraint (21), the upward-sloping supply curve of deposits (22), endogenous monitoring costs (29), the cost function (30), and given the provisioning regime, the value of collateral, the (unit) cost of monitoring, and the refinance rate. As shown in Appendix A, in a symmetric equilibrium, the solution to this optimization problem leads to the following first-order conditions:

$$q_t = \min \left\{ \Phi^{-1}\left(\frac{\mathbb{E}_t p_{t+1}^H \bar{H}}{l_t}, \frac{Y_t}{\tilde{Y}}\right)[1 + i_t^L - \left(\frac{\kappa \mathbb{E}_t p_{t+1}^H \bar{H}}{l_t}\right)], 1 \right\}, \tag{31}$$

$$1 + i_t^D = \frac{\zeta^D}{1 + \zeta^D} \left\{ (1 - \mu_t^R)(1 + i_t^R) + \gamma_D - \gamma\left(\frac{l_t}{d_t}\right)^{0.5} \right\}, \tag{32}$$

$$1 + i_t^L = \frac{\zeta^L}{q_t(\zeta^L - 1)} \left\{ 1 + i_t^R + \gamma_L - \gamma\left(\frac{d_t}{l_t}\right)^{0.5} + \frac{\partial LP_t}{\partial l_t} - \left(1 + i_t^B\right)\frac{\partial LR_t}{\partial l_t} \right\}. \tag{33}$$

Condition (31) shows that, all else equal, a higher loan rate, or a cyclically higher level of output, tends to increase incentives to monitor borrowers. Thus, the optimal level of monitoring is increasing in the loan rate, as in Allen et al. (2011) for instance. Intuitively, a higher loan rate increases incentives to monitor because it raises the bank's pay-off if there is no default and the loan is repaid.

Condition (31) also shows that the collateral-loan ratio exerts conflicting effects on the level of effort and the repayment probability. On the one hand, there is a moral hazard effect (reduced incentives for borrowers to take risks), which raises $q_t$. On the other, there is a loss-limiting effect, due to the fact that collateral limits the loss that the bank incurs in case of default; all else equal, it thus reduces incentives to monitor borrowers and tends to lower $q_t$. In what follows we assume, consistent with the preponderance of the evidence for middle-income countries (see Agénor and Pereira da Silva (2014)), that the former effect dominates, so that the net effect of an increase in the collateral-loan ratio is to raise the probability of repayment. For tractability, and assuming an interior solution, we therefore write (31) in the form

$$q_t = \left(\frac{Y_t}{\tilde{Y}}\right)^{\varphi_1} \left(\frac{\kappa \mathbb{E}_t p_{t+1}^H \bar{H}}{l_t}\right)^{\varphi_2} \left(\frac{1 + i_t^L}{1 + \tilde{i}^L}\right)^{\varphi_3} \epsilon_t^Q, \tag{34}$$

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[16]An alternative specification, which has the same properties as (30) and generalizes the functional form suggested by Edwards and Végh (1997, footnote 14), is $\Gamma(l_t^i, d_t^i) = \sqrt{\gamma_L(l_t^i)^2 + \gamma_D(d_t^i)^2}$, where $\gamma_L, \gamma_D > 0$.

where $\varphi_1, \varphi_2, \varphi_3 > 0$. The random variable $\varepsilon_t^Q$, which captures nonsystematic shocks to the repayment probability, follows an $AR(1)$ process, $\epsilon_t^Q = (\tilde{\epsilon}^Q)^{1-\rho^Q}(\epsilon_{t-1}^Q)^{\rho^Q}\exp(\xi_t^Q)$, where $\rho^Q \in (0,1)$, $\xi_t^Q \sim \mathbf{N}(0, \sigma_{\xi^Q})$, and $\tilde{\epsilon}^Q$ normalized to unity in what follows.

Condition (32) indicates that the deposit rate is a markdown over the marginal cost of borrowing from the central bank, adjusted for the marginal cost of managing deposits. Condition (33) shows that the loan rate depends no only on the repayment probability, the marginal cost of borrowing, and the marginal cost of producing loans, but also on the loan loss provisioning regime. As discussed in Agénor and Zilberman (2015), what may be called the *provisioning cost channel* is captured by the composite term $\partial LP_t/\partial l_t - \left(1 + i_t^B\right)\left(\partial LR_t/\partial l_t\right)$ in (33). This term combines the direct cost of raising provisions and the return on loan loss reserves invested in a safe asset. Intuitively, a one unit increase in lending raises the flow of provisions by $\partial LP_t/\partial l_t$; this is costly for banks (provisions reduce profits) and accordingly they adjust the loan rate upward. However, the fact that the induced change in loan loss reserves, $\partial LR_t/\partial l_t$, yield a gross return of $1 + i_t^B$, tends at the same time to lower the loan rate. From (23),

$$\frac{\partial LR_t}{\partial l_t} = (LR_{t-1})^{\rho_{LR}}\left(1 - \rho_{LR}\right)(LP_t)^{-\rho_{LR}}\frac{\partial LP_t}{\partial l_t},$$

which implies that the composite term in (33) can be written as

$$\frac{\partial LP_t}{\partial l_t} - \left(1 + i_t^B\right)\frac{\partial LR_t}{\partial l_t} = [1 - \left(1 + i_t^B\right)\left(1 - \rho_{LR}\right)(\frac{LR_{t-1}}{LP_t})^{\rho_{LR}}]\frac{\partial LP_t}{\partial l_t},$$

where, from (24), and assuming that the max operator is not binding,

$$\frac{\partial LP_t}{\partial l_t} = \Lambda_0(1 - q_t) + \Lambda_1(\frac{q_t}{\tilde{q}} - 1) + \Lambda_2(\frac{Y_t}{\tilde{Y}} - 1)^{\theta_L}.$$

In turn, this equation implies that, in the case of specific provisions,

$$\frac{\partial LP_t}{\partial l_t} = \Lambda_0(1 - q_t), \tag{35}$$

whereas in the case of cyclically adjusted provisions, with $\Lambda_2 = 0$,

$$\frac{\partial LP_t}{\partial l_t} = \Lambda_0(1 - q_t) + \Lambda_1(\frac{q_t}{\tilde{q}} - 1). \tag{36}$$

To smooth out the dynamics of the loan rate, and in line with the evidence on the high degree of loan rate stickiness in middle-income countries, we follow Agénor and Alper (2012) by imposing a simple partial adjustment to the equilibrium solution (33).[17]

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[17] A more rigourous analysis of loan rate stickiness could involve introducing Rotemberg-type

## 2.6 Central Bank

The central bank's assets consist of loans to commercial banks $l_t^B = \int_0^1 l_t^{B,i} di$ and holdings of government bonds, $b_t^C$, whereas its liabilities are given by currency in circulation, $m_t^S$, and reserve requirements:

$$l_t^B + b_t^C = m_t^S + RR_t. \tag{37}$$

Changes in the central bank's holdings of government bonds are specified as

$$b_t^C - \frac{b_{t-1}^C}{1 + \pi_t} = -\kappa^C (l_t^B - \frac{l_{t-1}^B}{1 + \pi_t}), \tag{38}$$

where $\kappa^C \in (0, 1)$. Combining (37) and (38) yields

$$m_t^S = \frac{m_{t-1}^S}{1 + \pi_t} + (1 - \kappa^C)(l_t^B - \frac{l_{t-1}^B}{1 + \pi_t}) - (RR_t - \frac{RR_{t-1}}{1 + \pi_t}). \tag{39}$$

This equation allows us to distinguish between two monetary policy regimes: open-market operations ($\kappa^C = 1$) and a standing facility ($\kappa^C = 0$), where changes in central bank lending have a one-to-one impact on the supply of cash.

The central bank's refinance rate, $i_t^R$, is set on the basis of a Taylor-type rule:

$$\frac{1 + i_t^R}{1 + \tilde{\imath}^R} = (\frac{1 + i_{t-1}^R}{1 + \tilde{\imath}^R})^\chi \left\{ (\frac{1 + \pi_t}{1 + \pi^T})^{\varepsilon_1} (\frac{Y_t}{\tilde{Y}})^{\varepsilon_2} \right\}^{1-\chi}, \tag{40}$$

where $\pi^T$ is the target inflation rate, $\chi \in (0, 1)$ the degree of interest rate smoothing, and $\varepsilon_1, \varepsilon_2 > 0$.

## 2.7 Government

The government spends $G_t$ on the final good and issues one period risk-free bonds, held by households, commercial banks, and the central bank. It collects lump-sum taxes on households, pays interest to them on their holding of government bonds, and receives all interest income generated by the central bank on its loans to commercial banks and its holdings of government bonds. Thus, its budget constraint in real terms is

$$b_t - \frac{b_{t-1}}{1 + \pi_t} = G_t - T_t + (\frac{i_{t-1}^B}{1 + \pi_t})(b_{t-1} - b_{t-1}^C) - (\frac{i_{t-1}^R}{1 + \pi_t})l_{t-1}^B, \tag{41}$$

quadratic adjustment costs in the profit function (28), as for instance in Hulsewig et al. (2009), Gerali et al. (2010), and Güntner (2011), or Calvo-type pricing, as in Henzel et al. (2009). However, given that (as discussed later) a high degree of inertia is assumed, this would complicate the analysis without providing much additional insight.

where $b_t = b_t^P + b_t^B + b_t^C$ and $b_t^B = \int_0^1 b_t^{B,i} di$. Government spending is a constant fraction of final output:

$$G_t = \psi Y_t, \tag{42}$$

where $\psi \in (0, 1)$.

In what follows we assume that the government maintains a balanced budget by adjusting lump-sum taxes, while keeping its overall stock of bonds constant at $b$. Moreover, the stock of bonds held by the central bank is also assumed to be constant at $b^C$.

Figure 1 summarizes the main real and financial flows among agents in the model.

## 2.8 Market-Clearing Conditions

In a symmetric equilibrium, households are identical, whereas IG firms produce the same output and set equal prices. Therefore, $K_{j,t} = K_t$, $N_{j,t} = N_t$, $Y_{j,t} = Y_t$, and $P_{j,t} = P_t$ for all $j \in (0, 1)$.

The supply of loans by the commercial bank and the supply of deposits by households are assumed to be perfectly elastic at the prevailing interest rates and therefore markets for loans and deposits always clear.[18] The final good market-clearing condition is

$$Y_t = C_t + I_t + G_t + \frac{\phi_F}{2}\left(\frac{1 + \pi_t}{1 + \tilde{\pi}} - 1\right)^2 Y_t. \tag{43}$$

Loans are made in the form of cash. Therefore, the equilibrium condition in the currency market is obtained by equating the supply of cash with total holdings of cash by households and firms:

$$m_t^S = m_t^P + l_t. \tag{44}$$

This condition is used to solve for the equilibrium bond rate, the opportunity cost of cash.

# 3 Steady State and Log-Linearization

The steady-state properties of the model are presented in Appendix B. Several of these properties (regarding, for instance, the relationship between prices and marginal costs) are familiar, so we focus here only on those characterizing the key financial variables.

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[18]The market for bonds always clears dur to Walras's law and is therefore ignored.

Under the assumption of zero inflation in the steady state ($\pi^T = 0$), the long-run value of the bond rate is equal to the policy rate, that is, $\tilde{\imath}^B = \tilde{\imath}^R = \beta^{-1} - 1$. This equality ensures that the commercial bank has no incentive to borrow from the central bank in order to invest in government bonds. From (32), the deposit rate is

$$1 + \tilde{\imath}^D = \frac{\zeta^D}{1 + \zeta^D}\left\{(1 - \tilde{\mu}^R)(1 + \tilde{\imath}^R) + \gamma_D - \gamma(\frac{\tilde{l}}{\tilde{d}})^{0.5}\right\}, \tag{45}$$

which requires appropriate restrictions on the cost parameters $\gamma$ and $\gamma_D$ to ensure that $\tilde{\imath}^R > \tilde{\imath}^D$; otherwise banks would have no incentives to take on deposits.

In the steady state, loan loss reserves and loan loss provisions under all regimes are equal to

$$\widetilde{LR} = \widetilde{LP} = \Lambda_0(1 - \tilde{q})\tilde{l}, \tag{46}$$

where, from (34), $\tilde{q} = (\kappa\tilde{p}^H\bar{H}/\tilde{l})^{\varphi_2}$. Thus, from (33), the loan rate is also the same under both provisioning rules:

$$1 + \tilde{\imath}^L = \frac{\zeta^L}{\tilde{q}(\zeta^L - 1)}\left\{1 + \tilde{\imath}^R + \gamma_L - \gamma(\frac{\tilde{d}}{\tilde{l}})^{0.5} - \tilde{\imath}^B\Lambda_0(1 - \tilde{q})\right\},$$

which again requires appropriate restrictions on $\gamma_L$ and $\gamma$ to ensure that $\tilde{\imath}^L > \tilde{\imath}^R$; otherwise banks would be no incentives to lend.

The log-linearized equations of the model around a non-stochastic steady state are presented in Appendix C. Many of these equations are familiar and, given the issue at stake, are not repeated here. The relevant equations for loan loss provisions, loan loss reserves in the case where $\Lambda_2 = 0$, the repayment probability, and bank interest rates are given by

$$\widehat{LR}_t = \rho_{LR}\widehat{LR}_{t-1} + (1 - \rho_{LR})\widehat{LP}_t, \tag{47}$$

$$\widehat{LP}_t = \begin{cases} \hat{l}_t - [\tilde{q}/(1 - \tilde{q})]\hat{q}_t & \Lambda_1 = 0 \\ \hat{l}_t + [\tilde{q}(\Lambda_1 - \Lambda_0)/\Lambda_0(1 - \tilde{q})]\hat{q}_t & \Lambda_1 > 0 \end{cases}, \tag{48}$$

$$\hat{q}_t = \varphi_1\hat{Y}_t + \varphi_2(\mathbb{E}_t\hat{p}^H_{t+1} - \hat{l}_t) + \varphi_3\hat{\imath}^L_t + \epsilon^Q_t, \tag{49}$$

$$\hat{\imath}^D_t = (1 - \tilde{\mu}^R)\hat{\imath}^R_t - 0.5\gamma\sqrt{\tilde{l}/\tilde{d}}(\hat{l}_t - \hat{d}_t), \tag{50}$$

$$\hat{\imath}^L_t = \hat{\imath}^R_t + 0.5\gamma\sqrt{\tilde{d}/\tilde{l}}(\hat{l}_t - \hat{d}_t) - (1 + \tilde{\imath}^L)\hat{q}_t - (1 - \tilde{q})(1 + \tilde{\imath}^B)\hat{\imath}^B_t \tag{51}$$

$$+ \Lambda_0(1 - \Lambda_1)(1 - \tilde{q})\rho_{LR}(1 - \rho_{LR})(\widehat{LP}_t - \widehat{LR}_{t-1}).$$

21

Using these equations, the potential conflicts between the partial and general equilibrium effects associated with financial shocks can be readily illustrated. An unanticipated increase in default risk for instance (that is, a reduction in $\epsilon_t^Q$) lowers the repayment probability and raises the loan rate. In turn, the increase in the loan rate raises incentives to monitor, thereby mitigating the initial drop in the repayment probability. However, movements in the loan rate also affect the demand for credit as well as the deposit and the bond rates, which in turn affect investment, output, and loan loss provisions and reserves—with feedback effects on interest rates and the repayment probability. To understand these general equilibrium effects, and the extent to which they either mitigate or magnify the partial equilibrium effects, requires a numerical analysis of the complete model.

# 4 Parameterization

As noted in the introduction, most of the countries that introduced cyclically adjusted provisioning regimes in recent years are upper-income Latin American countries. Accordingly, the model is parameterized as much as possible for a "typical" middle-income country of the region. To do so we dwell in part on Agénor et al. (2013), while at the same time providing further supporting evidence from the literature for most of our parameter choices. In addition, for some of the parameters that are "new" or specific to this study, sensitivity analysis is considered later on.

Parameter values are summarized in Table 1. The discount factor $\beta$ is set at 0.99, a fairly standard value in the literature. This gives a steady-state annualized real bond rate of 4.0 percent. The intertemporal elasticity of substitution, $\varsigma$, is 0.5, in line with estimates for middle-income countries (see Agénor and Montiel (2015, Chapter 2)). The preference parameter for leisure, $\eta_N$, is set at 1.5, in order to obtain a proportion of time allocated to market work equal to about one third. Boz et al. (2015) target a similar proportion in their model for Mexico. The preference parameter for composite monetary assets, $\eta_x$, is set at a low value of 0.01, to capture the view that money brings relatively little direct utility (a common assumption in the literature, see for instance Christoffel and Schabert (2015)). The share parameter in the index of money holdings, $\nu$, which corresponds to the relative share of cash in the money supply, is set at 0.38, which corresponds to the average ratio of the monetary base to the

broad money stock over the period 2008-15 for Argentina, Bolivia, Peru, Venezuela, and Brazil, as calculated from the IMF's online *International Financial Statistics* (see http://data.imf.org/). Thus, in line with the broader evidence for developing countries, we consider the case where cash is used relatively intensively. The housing preference parameter, $\eta_H$, is set to 0.02, in order to obtain a ratio of housing wealth to final output of approximately unity in the steady state, consistent with the estimates of the stock of housing to GDP in Brazil during the 1990s by Reiff and Barbosa (2005, Table 4).[19] The autocorrelation coefficient $\rho^H$ is set at 0.7, to capture an intermediate degree of persistence of the housing demand shock.

The share of capital in output of intermediate goods, $\alpha$, is set at the conventional value of 0.3 whereas the elasticity of demand for intermediate goods, $\theta$, is set at 6, as in Gertler et al. (2007) for instance. This implies a steady-state markup rate, $\theta/(\theta - 1)$, of 20 percent. The Rotemberg adjustment cost parameter for prices, $\phi_F$, is set at 74.5; this value implies a Calvo-type probability of not adjusting prices of approximately 0.72 percent per period, or equivalently an average period of price fixity of about 3.6 quarters. These values are consistent with the estimates of Carvalho et al. (2014, Table 2) for Brazil. The rate of depreciation of private capital, $\delta_K$, is set equal to 0.03, again a fairly standard value, which corresponds to an annualized depreciation rate of 12.6 percent. The adjustment cost for transforming investment into capital, $\Theta_K$, is set at 30, to capture significant frictions in that process.

For the parameters characterizing bank behavior, we take the effective collateral-loan ratio, $\kappa$, to be 0.2. This choice aims to capture the difficulty of seizing collateral in developing countries, due to weak legal systems and inefficient debt enforcement procedures (see Djankov et al. (2008) and Agénor and Pereira da Silva (2013, 2014)). The elasticity of the repayment probability with respect to cyclical output is set at $\varphi_1 = 0.03$, whereas the elasticities with respect to the collateral-loan ratio and the loan rate are set at $\varphi_2 = 0.05$ and $\varphi_3 = 0.2$, respectively. The low value of $\varphi_1$ aims to capture the assumption that banks may underestimate the risk of default in good times, whereas the low value of $\varphi_2$ captures a relatively weak financial accelerator effect. Based on these values the initial repayment probability is calibrated at 0.92, to reflect a relatively

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[19]By way of comparrison, Davis and Van Nieuwerburgh (2014, Figure 1) estimate the average ratio of housing wealth to GDP for the United States at about 1.4 over the period 1975-2006.

high default rate. As in Agénor and Zilberman (2015), the persistence parameter $\rho_{LR}$ is set at 0.8, to approximate the standard stock-flow relationship between loan loss reserves and past reserves.[20] For the elasticities of substitution $\zeta^D$ and $\zeta^L$, which measure the degree of monopoly power in banking, there are no readily available model-based estimates for Latin American or other middle-income countries; accordingly, we set them to the values used by Dib (2010), 2.0 and 4.5 respectively. The parameter characterizing the partial adjustment imposed on the loan rate in (33) is set to 0.9, to capture a high degree of stickiness, in line with the early evidence reported by Cottarelli and Kourelis (1994) and more recently by Vargas (2008) for Colombia, Cas et al. (2011) for Latin America, and Tai et al. (2012) for Asia. The costs parameters $\gamma$, $\gamma_D$ and $\gamma_L$ are calibrated at 0.01, 0.1, and 0.1, respectively. These values help to generate reasonable values for steady-state (real) interest rates; these values are $\tilde{\imath}^R = \tilde{\imath}^B = 0.0101$, $\tilde{\imath}^D = 0.009$, and $\tilde{\imath}^L = 0.0515$.[21] Thus, these values satisfy the steady-state restrictions $\tilde{\imath}^L > \tilde{\imath}^R > \tilde{\imath}^D$ stated in the previous section. The degree of persistence of the repayment probability shock is set at $\rho^Q = 0.8$.

Regarding central bank behavior, the persistence, inflation and cyclical output parameters in the central bank's interest rate rule are set at $\chi = 0.8$, $\varepsilon_1 = 1.5$, and $\varepsilon_2 = 0.2$, respectively. All three values are consistent with estimates of Taylor-type rules for Latin America (see, for instance, Moura and Carvalho (2010) and Barajas et al. (2014)). The required reserve ratio $\mu^R$ is set at 0.1, as in Medina and Roldós (2014) and consistent with data for some Latin American countries reported in Montoro and Moreno (2011). We focus on the case where monetary policy is operated through a pure standing facility, so that $\kappa^C = 0$.[22] Finally, as in Agénor and Alper (2012), and Carvalho et al. (2014) for Brazil, the share of government spending on goods and services in output, $\psi$, is set at 0.2.

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[20]Recall that our specification captures lags between provisioning requirements and the actual build-up of provisions. Experiments with a higher value of $\rho_{LR} = 0.95$ show little effects on the results.

[21]As can be inferred from (50) and (51), $\gamma_D$ and $\gamma_L$ play no role in the dynamics of the model.

[22]In preliminary experiments we also considered the case of open-market operations ($\kappa^C = 1$), but differences were relatively minor and are not reported to save space.

# 5 Experiments

To illustrate the role of alternative provisioning rules in the transmission of financial shocks, we consider two transitory disturbances: an increase in the risk of default and a negative shock to asset prices, in the form of a negative disturbance in housing demand.[23] In what follows we focus on the case where $\Lambda_2 = 0$ and will discuss the alternative case where $\Lambda_2 > 0$ in the sensitivity analysis that we report later on. To highlight the role of provisioning regimes in the transmission of financial shocks, we initially compare the performance of specific and cyclically adjusted provisioning rules, respectively, by setting $\Lambda_1 = 0$ and $\Lambda_1 = 1.0$ (the case referred to as "full smoothing" in Agénor and Zilberman (2015)).

## 5.1 Increased Risk of Default

Consider first a transitory increase in default risk, as captured by a one percentage point drop in the repayment probability—or, equivalently here, reduced monitoring effort by banks. The results are reported in Figure 2, under a specific provisioning regime (continuous blue line) and a cyclically adjusted provisioning regime with $\Lambda_1 = 1$ (dashed red line).

The direct effect of an exogenous reduction in the repayment probability is an immediate increase in the (current and future) loan rate. This, in turn, lowers investment and the rate at which physical capital is accumulated, as well as output and employment. By itself a lower capital stock tends to increase the rental rate of capital and thus marginal cost. However, the drop in employment lowers real wages—sufficiently so to ensure that the net effect on marginal cost is negative. Consequently, inflation also falls on the impact.

Because both output and inflation fall, the policy rate falls as well, thereby mitigating the initial increase in the loan rate. The deposit rate, set as a mark down on the policy rate, also drops, resulting in lower demand for deposits and hence (all else equal) an increase in borrowing from the central bank and an expansion in the monetary base. To raise the demand for cash and restore equilibrium in the money market,

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[23]We also experimented with a negative shock to productivity by adding a relevant term in (11), but the results are as expected—alternative provisioning regimes do not make much difference in that case. We therefore omit these results to save space.

the bond rate must therefore fall. The drop in the nominal bond rate exceeds the drop in inflation, implying that the real bond rate also falls. Through intertemporal substitution this results in a higher level of current consumption, which mitigates the initial contraction in output associated with the drop in investment.[24] At the same time, the cyclical drop in output tends to amplify the response of the repayment probability and the increase in the loan rate.

The key channels through which changes in provisions affect the real economy operate through the combination of changes in loan loss reserves invested in a risk-free asset and the direct cost effect of holding provisions—which we earlier referred to as the provisioning cost channel. Following a fall in the repayment probability, the loan loss provisions-loan ratio increases. This leads to a higher loan rate through the direct cost effect of raising provisions—regardless of the provisioning regime. However, as also shown in Figure 2, provisions under the cyclically adjusted regime increase by less, thereby mitigating the increase in the loan rate and dampening fluctuations on the real side of the economy.

Intuitively, with a cyclically adjusted provisioning regime, loan loss provisions are smoothed over the cycle in such a way that provisions (and, to a lower extent, loan loss reserves) are less affected by the current fraction of nonperforming loans. Thus, although the direct effect of the fall in the repayment probability is to *increase* the loan rate, its indirect effect (through the provisioning cost channel) is to *reduce* it when provisions are adjusted to reflect cyclical movements. Because a lower loan rate mitigates the drop in investment and output, a cyclically adjusted provisioning system is more countercyclical than a specific provisioning system.

## 5.2   Negative Asset Price Shock

Consider next a transitory drop in asset prices induced by a negative housing demand shock, as captured by a 10 percentage point drop in the shock $\epsilon_t^H$ in the utility function (1). The results are reported in Figure 3.

A negative shock to the demand for housing services leads to an immediate drop in real house prices, which in turn lowers the collateral-loan ratio. As a result, the

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[24]Had we assumed that a large fraction of households are liquidity-constrained, the initial expansion in current consumption associated with this shock, as well as the drop in asset prices discussed next, could be reversed due to the fall in output.

repayment probability drops on impact, which translates into a higher loan rate. This in turn leads to a contraction in investment and aggregate demand, which therefore leads to downward pressure on inflation. The downward movement in output and inflation combine to produce a lower policy rate, which mitigates the initial increase in the loan rate. Because the deposit rate falls, households have incentives to switch to cash; to maintain equilibrium of the currency market, the nominal bond rate must drop as well. The real bond rate also falls, thereby inducing households to spend more today. This tends to mitigate the effect of a higher loan rate on aggregate demand. Qualitatively, these features of the transmission mechanism of a housing demand shock are thus fairly similar to those associated with a default risk shock.

The qualitative features of the shock also do not change across provisioning regimes, but there are again significant quantitative differences. Loan loss provisions are smoothed to a greater extent under cyclically adjusted provisioning, which means a smaller current and expected increase in the loan rate. As a result, the initial fall in investment is mitigated, and so is the drop in output. Thus, inflation is less volatile and so is the policy rate.

To summarize the results of these shocks, Tables 2 and 3 provide the asymptotic standard deviations under specific provisioning ($\Lambda_1 = 0$) and a cyclically adjusted provisioning regime with $\Lambda_1 = 1$. The tables confirm that the latter regime is highly effective in terms of mitigating the volatility of key macroeconomic and financial variables—including those variables in terms of which financial stability is defined subsequently, the loan-output ratio and real house prices—even though loan loss provisions and reserves are, naturally enough, more volatile. Fundamentally, the reason why a cyclically adjusted provisioning regime is relatively more effective in terms of macroeconomic and financial stability is because it helps to mitigate changes in the stock of loan loss reserves (compared to a specific provisioning regime) in the course of the business cycle, as often argued in practice.

# 6    Optimal Simple Policy Rules

We now focus on optimal, implementable policy rules, in a context where the central bank (which also acts as the financial regulator) is concerned with two objectives, macroeconomic stability and financial stability, and the two mandates are *independent*.

The first objective, which consists of mitigating inflation volatility and output fluctuations, is set by a Monetary Policy Committee and is pursued by setting the policy rate on the basis of the Taylor rule defined earlier. Thus, the central bank does not optimize with respect to monetary policy. The second objective is set by a Financial Stability Committee, which defines financial volatility in terms of a weighted geometric average of two indicators: the volatility of the credit-to-GDP ratio and the volatility of real house prices, measured on the basis of the asymptotic standard deviations of these variables. As documented in the literature, both indicators have often been associated with financial crises, in industrial and developing countries alike.[25] However, the evidence is much more robust statistically—particularly for developing countries—for fluctuations in credit. Indeed, empirical studies suggest that once the magnitude of credit expansion (in terms of the growth rate or as a ratio to output) is taken into account, the occurrence or the magnitude of booms in asset prices do not contribute significantly to predicting financial crises. Accordingly, to measure financial volatility we assign weights of 0.8 to the credit-to-GDP ratio and 0.2 to the volatility of real house prices.[26]

We then assume that the central bank sets its macroprudential instruments to minimize financial volatility and consider two alternative settings: first, the case where it sets the cyclically adjusted provisioning parameter $\Lambda_1$ only; second, the case where it sets *jointly* the optimal values of the parameter $\Lambda_1$ and the reaction parameter in an alternative macroprudential rule. The premise here is that, by itself, cyclically adjusted provisioning may not be effective enough to dampen procyclicality and that policymakers may need to rely on a range of countercyclical macroprudential tools to achieve that goal.[27] In what follows we focus on reserve requirements as an additional instrument. As noted in the Introduction, in recent years policymakers in middle-income countries (especially in Latin America) have often used reserve requirements as part of a countercyclical toolkit to mitigate macroeconomic fluctuations. The novelty

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[25] See Schularick and Taylor (2012), Agénor and Pereira da Silva (2013), Agénor and Montiel (2015), Aikman et al. (2015), and references therein.

[26] Setting the weight of real house prices to zero or increasing it to as high as 0.5 does not affect qualitatively the results of the paper, especially those related to the "excess smoothing" feature of the optimal provisioning policy.

[27] See, for instance, Chan-Lau (2012). Some contributions have focused instead on the combination of macroprudential and monetary policies in the context of alternative institutional mandates; see Agénor and Flamini (2016) and the references therein.

here is that we take a normative view of the issue and consider the use of a *systematic* reserve requirement rule from the perspective of financial stability only.

## 6.1 Cyclically Adjusted Provisioning Rule

First, consider the case where the cyclically adjusted provisioning parameter $\Lambda_1$ in (26) is set so as to minimize financial volatility, while the required reserve ratio is kept constant and $\Lambda_2 = 0$. The results are shown in Figure 4 for the two shocks considered earlier, using a grid step of 0.3 and measuring volatility relative to the specific provisions case, that is, $\Lambda_1 = 0$.

In both cases the relationship between the parameter $\Lambda_1$ and financial volatility follows a U-shaped pattern. Intuitively, as the policy becomes more aggressive, volatility falls at first, because (as can be inferred from Figures 2 and 3) the policy stabilizes credit, investment and output. However, the more aggressive the policy stance is, the more volatile market interest rates become; volatility in domestic interest rates induces more volatility in bank lending, which feeds (through the collateral effect) into the repayment probability and therefore tends to increase financial volatility—so much so that it eventually dominates the initial gains in terms of reduced volatility in credit and aggregate demand. Thus, there exists an optimal value for $\Lambda_1$, which in Figure 4 is 4.5 for the default risk shock and 3.0 for the asset price shock.[28] Put differently, the optimal simple policy rule involves "excess smoothing," in the sense that it reacts more than proportionally to steady-state deviations in the repayment probability ($\Lambda_1 > 1$). Tables 2 and 3 also show that under the optimal $\Lambda_1$, under both shocks volatility for most variables (except most notably for loan loss provisions and reserves, as can be expected) is lower than in the "full smoothing" case $\Lambda_1 = 1$.

## 6.2 Optimal Provisions and Required Reserves

Consider now the case where the Financial Stability Committee sets *both* the cyclically adjusted provisioning parameter $\Lambda_1$ and the parameters of a countercyclical reserve requirement rule that relates changes in the required reserve ratio, $\mu_t^R$, to deviations

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[28]Using a finer grid step than 0.3 yields slightly more precise values for the optimal value of $\Lambda_1$ but doing so is not necessary to illustrate the main point of the analysis.

in the ratio of bank loans to total output:

$$\frac{1 + \mu_t^R}{1 + \tilde{\mu}^R} = (\frac{1 + \mu_{t-1}^R}{1 + \tilde{\mu}^R})^{\chi_1^R} \left\{ (\frac{l_t/Y_t}{\tilde{l}/\tilde{Y}})^{\chi_2^R} \right\}^{1-\chi_1^R}, \tag{52}$$

where $\chi_1^R \in (0,1)$ and $\chi_2^R > 0$. This rule is consistent with the evidence (alluded to earlier and discussed in more detail in Agénor et al. (2015)) that in recent years policymakers in middle-income countries have often used reserve requirements as part of a countercyclical toolkit to maintain macroeconomic and financial stability, with a particular focus on dampening changes in credit.

Because the required reserve ratio is now time varying, equation (50) is replaced by

$$\hat{\imath}_t^D = (1 - \tilde{\mu}^R)\hat{\imath}_t^R - \tilde{\imath}^R\tilde{\mu}^R\hat{\mu}_t^R - 0.5\gamma\sqrt{\tilde{l}/\tilde{d}}(\hat{l}_t - \hat{d}_t), \tag{53}$$

Equations (51) and (53) help to illustrate clearly the *partial* equilibrium effects of an increase in the required reserve ratio. A higher $\hat{\mu}_t^R$ for instance lowers initially the deposit rate $\hat{\imath}_t^D$, which reduces the demand for deposits by households $\hat{d}_t$. At the initial level of loans, $\hat{l}_t - \hat{d}_t$ increases, which raises production costs for the bank. The effect of higher costs is thus to further reduce the deposit rate and to increase the loan rate; the bank interest rate spread increases unambiguously. The policy is countercyclical, at least with respect to investment.

However, the *general* equilibrium effects weaken this result. The reason is that the higher loan rate tends to reduce the demand for loans, $\hat{l}_t$. If this effect is small, the partial equilibrium effects described above will continue to hold. But if the drop in $\hat{l}_t$ is large enough to ensure that $\hat{l}_t - \hat{d}_t$ now falls, bank production costs will also fall, which in turn will mitigate the initial drop in $\hat{\imath}_t^D$ (with possibly $\hat{\imath}_t^D$ increasing on net) and the initial increase in the loan rate.[29] Moreover, changes in $\hat{\imath}_t^R$ and $\hat{q}_t$ over time may affect the loan rate in such a way that an increase in reserve requirements could end up being procyclical or acyclical.

Figure 5 is drawn in a way similar to Figure 4 but with a larger grid step of 0.8, and for a given value of the persistence parameter $\chi_1^R = 0.8$.[30] It shows that the relationship between the required reserve ratio and financial volatility also follows a U-shaped pattern. Intuitively, a more active use of the policy reduces volatility at

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[29] The loan rate must still increase initially for $\hat{l}_t$ to fall in the first place.

[30] Higher or lower values for $\chi_1^R$ within a significant range have no qualitative bearing on the results.

first because it dampens fluctuations in credit, investment and domestic absorption. However, as the policy continues to be aggressively used, the more volatile interest rates and deposits become; this, in turn, induces more volatility in lending—so much so that it ends up dominating the initial gains in terms of reduced volatility in credit and aggregate demand. Thus, there exists an optimal value for $\chi_2^R$, which in Figure 5 is 7.2 for the default risk shock and 8.8 for the asset price shock. However, as shown in Tables 2 and 3, the optimal countercyclical reserve requirement rule is not as effective at mitigating volatility of key macroeconomic and financial variables, compared to either a specific provisioning regime ($\Lambda_1 = 0$) or a cyclically adjusted provisioning regime, regardless of whether $\Lambda_1$ is set to unity (full smoothing) or optimally. This is especially so with respect to the asset price shock.

Suppose now that the Financial Stability Committee sets *both* the parameter $\Lambda_1$ in the cyclically adjusted provisioning rule (26) and the parameter $\chi_2^R$ in the reserve requirement rule (52) so as to minimize financial volatility, defined as before. Intuitively, and as can be inferred from (32) and (33), the two instruments operate through different channels. As discussed earlier, the provisioning rule affects the loan rate directly through both the provisioning cost channel and the repayment probability, which is the variable that it responds to. By contrast, the reserve requirement rule operates directly through the deposit rate. While the former affects the demand for investment and loans, the latter affects the supply of deposits and, through portfolio reallocation effects, the bond rate and current consumption. In both cases, because of economies of scope, changes in the deposit-loan ratio also affect the marginal cost of banking—and thus indirectly both the deposit and loan rates as well.

Now, as discussed earlier, the cyclically adjusted provisioning rule operates mainly through dampening movements in the loan rate and investment. If the net effect of implementing a reserve requirement rule is to reduce at the margin volatility in the bond rate and consumption, or to magnify movements in the loan rate (because of its effect on the deposit-loan ratio, as indicated earlier), it may help to mitigate macroeconomic and financial volatility. In that case, the two instruments are *complementary*; using more of either one of them helps to further mitigate volatility. By contrast, if adding a reserve requirement rule has only insignificant effects on the volatility of market interest rates and consumption, or weakens countercyclical movements in the loan rate, the two

instruments may instead be *substitutes*: using more intensively either one of them does not improve the performance of the other. Which outcome prevails may depend not only on the parameters determining the cost function in banking and the repayment probability (which have a direct impact on the behavior of bank interest rates) but possibly also, given the general equilibrium nature of the model, on other structural parameters.

The results of this experiment are shown in Table 4. They indicate that the simultaneous use of a cyclically adjusted provisioning regime and a countercyclical reserve requirement rule does *not* improve the ability of either policy (when set optimally) to mitigate financial volatility. Indeed, as shown in the table, the lowest value of our financial stability measure in either case is achieved when the reaction parameter of the other instrument is zero. Thus, the two instruments are not complementary (in the sense that financial volatility is not lower when a *combination* of them is used, compared to the case where either one is used separately) but rather substitutes, given that an optimal policy exists in both cases. At the same time, and consistent with the results reported in Tables 2 and 3, the optimal countercyclical provisioning regime appears to perform significantly better than the reserve requirement rule in terms of mitigating financial volatility. The key reason for this result is that countercyclical provisions have very potent direct effects on the loan rate—in contrast to reserve requirements, whose impact on that variable is only indirect. In that sense, the two instruments are thus only *partial* substitutes.

# 7  Sensitivity Analysis

To assess the robustness of the previous results, we focus on four experiments: the sensitivity of the cost of producing loans and deposits, an alternative formula for calculating loan loss provisions that nets out from loan values the collateral pledged by borrowers, the possibility that the repayment probability may depend on the ratio of loan loss reserves to total loans, and the case where changes in the cyclically adjusted provisioning rule accounts for a response to cyclical output.

## 7.1 Stronger Cost Complementarity

Consider first the case where the parameter $\gamma$, which determines the degree of cost complementarity in banking, is increased from its benchmark value of 0.01 to 0.05.[31] As can be inferred from (30, the higher $\gamma$ is, the larger the marginal reduction in costs associated with an increase in either deposits or loans and, as implied by (32) and (33), the larger the magnitude of the reduction in the deposit (loan) rate in response to an increase (reduction) in the loan-deposit ratio. Thus, greater economies of scope tend to lower market interest rates. However, in response to either one of the two shocks considered earlier, the impact on the transitional dynamics are fairly muted; the most noticeable effect is a smaller fall in the bond rate (mirroring the movement in the deposit rate), which mitigates incentives to spend more today.[32] In addition, the results reported earlier on the relative ranking of the provisioning regimes, and the performance of the cyclically adjusted provisioning rule compared to a countercyclical reserve requirement rule, remain the same in terms of their implications for financial volatility.

## 7.2 Provisions and Collateral

Loan loss reserves should in principle reflect not only the probability of default, but also the amount the lender can recover in case of default, namely, the amount of collateral that can be possessed and liquidated. Because collateral has a direct impact on the loss that a bank suffers in the event of default, it should also affect the amount for which it must provision.

However, under current IASB accounting rules, there is no detailed guidance on how collateral should affect provisions. With no international standards, national authorities and bank supervisors have often designed their own regulations on provisions.[33] In some countries, the value of collateral can be subtracted from required provisions to determine actual provisions. In Colombia for instance, provisions depend on the collateral values associated with different types of loans. Regulations on how banks should

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[31]The change in $\gamma$ has no steady-state effect on the policy and bond rates, whereas the deposit and loan rates drop from 0.0090 to 0.0078 and from 0.0515 to 0.0503, respectively. The magnitude of these changes is sufficient for sensitivity analysis.

[32]Given that the results are similar to those illustrated in Figures 2 and 3, graphs specific to the case $\gamma = 0.05$ are not reported to save space.

[33]See Song (2002) for an early discussion, albeit with a focus on high-income countries.

value collateral to assess their provisioning requirements also vary across countries, but in many of them fair market value (adjusted for liquidation costs) is the norm. A more uniform approach will be adopted under the new IFSR 9 standard, to be implemented in January 2018; in particular, the probability of foreclosure on collateral pledged by borrowers, and the resulting cash flows, will explicitly matter for the measurement of expected credit losses and the calculation of provisions.

In the context of the model, the link between provisions and collateral can be captured as follows. Recall that $\kappa\mathbb{E}_t p_{t+1}^H \bar{H}$ denotes the real value of effective collateral pledged by the representative capital producer; thus, if the *net* value of loans is used to determine provisions, and assuming that disposing of collateral entails no costs, the generic provisioning rule (24) can be written as, with $\Lambda_2 = 0$,

$$LP_t = \left\{ \Lambda_0(1 - q_t) + \Lambda_1(\frac{q_t}{\tilde{q}} - 1) \right\} (l_t - \kappa\mathbb{E}_t p_{t+1}^H \bar{H}). \tag{54}$$

This specification is also consistent with the evidence suggesting that property prices (which affect collateral values) and provisions are inversely correlated, as documented by Davis and Zhu (2009) for instance. Thus, shocks to collateral values may potentially amplify credit cycles also through provisioning, in addition to standard financial accelerator effects.

However, this is not the case in the present setting. Given that equations (35) and (36) remain the same, it is immediately clear that this change in the definition of loan loss provisions has no impact on the loan rate, as given in (33). Moreover, given that in each period banks invest all their loan loss reserves in government bonds, this alternative specification does not affect central bank borrowing or the equilibrium condition of the market for cash (39) either, as can be inferred from (21) and (39). Thus, the behavior of the bond rate does not change; given the (linear) structure of the model, defining loan loss provisions net of collateral as in (54) has no tangible macroeconomic effects. However, this issue deserves further investigation, possibly in a nonlinear framework.

## 7.3 Loan Loss Reserves and Default Risk

We now consider the case where the repayment probability is also related to the loan loss reserves-loan ratio, so that $q_t$, is now defined as, instead of (34),

$$q_t = (\frac{Y_t}{\widetilde{Y}})^{\varphi_1}(\frac{\kappa \mathbb{E}_t p_{t+1}^H \bar{H}}{l_t})^{\varphi_2}(\frac{1+i_t^L}{1+\widetilde{i}^L})^{\varphi_3}(\frac{LR_t/l_t}{\widetilde{LR}/\widetilde{l}})^{\varphi_4}\varepsilon_t^Q, \qquad (55)$$

where, as discussed in Agénor and Zilberman (2015), $\varphi_4$ is in general ambiguous. If the ratio of loan loss reserves to loans raises incentives for banks to monitor borrowers (akin to the "skin in the game" argument often made in the context of bank capital), thereby increasing the repayment probability, then $\varphi_4 > 0$; by contrast, if a higher ratio exacerbates moral hazard and induces more risk taking by lenders, then $\varphi_4 < 0$.

To illustrate outcomes in this case, simulation results with $\varphi_4 = 0.4$ and $\varphi_4 = -0.4$ are reported in Figures 6 and 7 for the default risk shock and for both the specific and cyclically adjusted provisioning regimes, in the latter case again for the benchmark value of $\Lambda_1 = 1$.[34] These values are somewhat on the high side (given the evidence reported by Agénor and Zilberman (2015)) but help to illustrate fairly well the issues at stake. When the monitoring incentive effect prevails ($\varphi_4 > 0$), the increase in the loan loss reserves-credit ratio mitigates the drop in the repayment probability documented earlier and therefore dampens the initial increase in the lending rate; as a result, investment falls by less than in the specific provisioning regime, thereby mitigating the impact on output, inflation, and the policy rate. At the same time, because the real bond rate drops by less than before, households have weaker incentives to shift consumption to the present and to increase spending today.

When $\varphi_4 < 0$ a higher ratio of loan loss provisions to investment loans tends, on the contrary, to magnify the initial fall in the repayment probability, in both regimes. Nevertheless, the direct cost effect of provisions on the loan rate dominates the indirect effect associated with the relative stock of provisions, which operates through the repayment probability. As a a result, the net effect is, as in the case where $\varphi_4 > 0$, a smaller drop in the loan rate compared to the specific provisioning regime. Investment and output fall by less as well; and inflation increases by less.

Thus, consistent with the results reported in Agénor and Zilberman (2015), regardless of the sign of $\varphi_4$, and even with deliberately high values of that parameter, the

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[34]Similar results are obtained for the asset price shock; we do not report them to save space.

cyclically adjusted provisioning regime continues to perform better than the specific provisioning regime in terms of mitigating the procyclicality of the financial system and promoting macroeconomic and financial stability.[35]

## 7.4 Response to Cyclical Output

Based on specification (24), suppose that under cyclically adjusted provisioning the cyclical factor is the deviation in output from steady state (in line with the Peruvian formula, as noted earlier), so that, ignoring again the max operator and setting $\Lambda_1 = 0$,

$$LP_t = \Lambda_0(1 - q_t)l_t + \Lambda_2(\frac{Y_t}{\tilde{Y}} - 1)^{\theta_L}l_t, \tag{56}$$

with the log-linearized equation (48) replaced by

$$\widehat{LP}_t = \hat{l}_t - (\frac{\tilde{q}}{1 - \tilde{q}})\hat{q}_t + \frac{\theta_L\Lambda_2}{\Lambda_0(1 - \tilde{q})}\hat{Y}_t. \tag{57}$$

A key issue in this context is whether optimal values of the reaction parameters $\Lambda_2$ and $\theta_L$ exist. We first consider the case where $\theta_L$ is normalized to unity and we solve for the optimal $\Lambda_2$. This case is thus symmetric to the one considered earlier, where the cyclical adjustment is in terms of deviations in the repayment probability.

The results are shown in Figure 8, which is constructed as in Figures 4 and 5 and with the same grid step of 0.8 as in Figure 5. The figure shows indeed that an optimal value for $\Lambda_2$ (equal to 8.0 for the default risk shock and 10.4 for the asset price shock) also exists in that case.

We next solve jointly for the optimal combination of $\Lambda_2$ and $\theta_L$.[36] The results are shown in the three-dimension diagrams of Figure 9, for a uniform grid step of 0.4 in both cases. The optimal values are $\Lambda_2 = 2.8$ and $\theta_L = 2.4$ for the default risk shock and $\Lambda_2 = 3.2$ and $\theta_L = 2.8$ for the asset price shock.

Thus, rather than reacting to a financial variable, in principle cyclically adjusted provisions could equally be made to respond to fluctuations in aggregate output. However, a comparison of the results reported in Tables 3 and 4 shows that, for all the key

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[35] A more formal analysis based on asymptotic variances (as in Table 2) confirms this conjecture. We do not report these results to save space.

[36] Because $\Lambda_2$ and $\theta_L$ enter symmetrically in the log-linearized equation (57), the optimal value for $\theta_L$, given $\Lambda_2 = 1$, is of course the same as in the reverse case. It is nevertheless useful to solve jointly for $\Lambda_2$ and $\theta_L$, given that in practice the rule would be applied in its linear form given in (56). We also tried to solve jointly for $\Lambda_1$ and $\Lambda_2$, but were unable to obtain an optimal combination of these parameters.

macroeconomic and financial variables, a response to cyclical output does *not* perform as well as a response to deviations in the repayment probability, in terms of mitigating volatility.[37]

# 8    Concluding Remarks

In recent years a growing body of literature has emphasized that existing accounting standards exacerbate procyclicality because incurred losses do not relate to expected losses, to the extent that provisions for future losses are not included. During recessions, nonperforming loans tend to rise and banks exhibit losses that reduce their capital and their ability to lend. These problems are exacerbated during periods of sharp declines in liquidity. The negative contemporaneous correlation between provisions and loan or output growth documented in a number of empirical studies suggests that banks build up provisions during, and not before, recessions, thereby magnifying the effects of downturns.

Using a DSGE model with financial frictions—namely, collateral effects associated with changes in housing prices, and costly production of loans and deposits—in this paper we focused on the extent to which alternative provisioning regimes affect the procyclicality of the financial system and financial volatility. Numerical experiments with a parameterized version of the model showed that cyclically adjusted (or, more commonly referred to, dynamic) provisioning can be highly effective in mitigating procyclicality and financial volatility—defined in terms of a weighted average of the credit-output ratio and the volatility of real house prices—in response to financial shocks. In fact, the optimal policy involves "excess smoothing," in the sense that it entails a more than proportional reaction to cyclical movements in the share of nonperforming loans (or, equivalently here, the probability of default).

In addition, we studied the optimal combination of simple, implementable cyclically adjusted provisioning and countercyclical reserve requirement rules. Our analysis showed that the simultaneous use of these instruments does not improve (at the margin) the ability of either one of them to mitigate procyclicality and financial stability.

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[37]In practice, the existence of lags in observing GDP, and the fact that preliminary estimates are often substantially revised over time, also militates in favor of *not* using output as a conditioning variable.

Thus, they are not complementary—in the sense that a combination of them does not help to achieve lower financial volatility than using either one individually—but substitutes, given that an optimal policy exists in both cases. Moreover, our results showed that the optimal provisioning rule may perform significantly better—in terms of mitigating both macroeconomic volatility and financial volatility—than the optimal reserve requirement rule. Indeed, with respect to an asset price shock, the optimal countercyclical reserve rule does not improve outcomes significantly, compared to either a specific provisioning regime or a cyclically adjusted provisioning regime. While we cannot rule out the possibility that these particular results are a feature of our calibration, and may therefore lack robustness, they suggest that the two instruments are only partial substitutes. We also found that even though an optimal cyclically adjusted provisioning regime may be defined in terms of reaction to cyclical output, responding to that variable does not perform as well as responding to changes in nonperforming loans in terms of mitigating macroeconomic and financial volatility.

Our analysis could be extended in several directions. One possibility would be to better account for the potential costs of provisioning regimes. Pérez et al. (2008), in a study focusing on Spanish banks, and Bushman and Williams (2012), in a study of bank behavior across 27 countries, found that banks use provisioning in a discretionary fashion to smooth changes in earnings. Similar results were obtained by Packer et al. (2014) for a group of Asian countries and Murcia Pabón and Kohlscheen (2016) for a sample consisting mostly of middle-income countries. A bank's management may indeed wish to avoid major changes in profitability levels and may choose to increase provisions in times of higher profitability, so that the bank's net income does not vary significantly from year to year. Conversely, banks may choose to smooth their earnings and mitigate the volatility of their reported profits by drawing from loan loss reserves if actual losses exceed expected losses. This could weaken market discipline, as transparency and comparability of financial statements may then be reduced. As a result, the cost of banking activity may increase and this would affect market interest rates—and, by implication, the behavior of output, prices, and other financial variables. Accounting for the potential costs of provisioning regimes (and thus decreasing marginal returns associated with a more aggressive use of them) may also restore a complementarity result between countercyclical reserve requirement rules and dynamic

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provisioning regimes.

Another extension would be to study the performance of, and interactions between, countercyclical capital rules (of the type advocated under Basel III, see Basel Committee on Banking Supervision (2011)) and cyclically adjusted provisioning rules, as discussed in this paper. The focus of our analysis in this paper has been mainly to contrast the performance of specific and countercyclical provisioning regimes—an issue that can be viewed as largely independent of the presence of equity capital. However, decisions to build equity capital could affect the dynamics of loan loss reserves. One element to account for in this analysis is the fact that both capital and provisions may affect monitoring effort and the repayment probability through market signaling effects, but these effects (particularly on the cost of equity capital) may be of a different type. In addition, Basel III allows loan loss reserves to be included in regulatory capital, up to certain limits. It is therefore possible that higher provisioning charges on new loans may cause a decline in banks' capital, which for a given (or desired) leverage will restrain credit growth and mitigate systemic risk. Understanding this type of substitution effects is important for the optimal design of countercyclical financial regulation.

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<div align="center">

Table 1

Benchmark Parameterization: Parameter Values

</div>

| Parameter | Value | Description |
|:---:|:---:|:---|
| *Households* | | |
| $\beta$ | 0.99 | Discount factor |
| $\varsigma$ | 0.5 | Elasticity of intertemporal substitution |
| $\eta_N$ | 1.5 | Relative preference for leisure |
| $\eta_x$ | 0.01 | Relative preference for money holdings |
| $\eta_H$ | 0.02 | Relative preference for housing |
| $\nu$ | 0.38 | Share parameter in index of money holdings |
| *Production* | | |
| $\theta$ | 6.0 | Elasticity of demand, intermediate goods |
| $\alpha$ | 0.7 | Share of labor in output, intermediate good |
| $\phi_F$ | 74.5 | Adjustment cost parameter, prices |
| $\delta_K$ | 0.03 | Depreciation rate of capital |
| $\Theta_K$ | 30 | Adjustment cost parameter, investment |
| *Banks* | | |
| $\kappa$ | 0.2 | Effective collateral-loan ratio |
| $\varphi_1$ | 0.03 | Elasticity of repayment prob wrt cyclical output |
| $\varphi_2$ | 0.05 | Elasticity of repayment prob wrt collateral-loan ratio |
| $\varphi_3$ | 0.2 | Elasticity of repayment prob wrt loan rate |
| $\zeta^D$ | 2.0 | Elasticity of substitution, deposits |
| $\zeta^L$ | 4.5 | Elasticity of substitution, loans to CG producer |
| $\gamma$ | 0.01 | Cost parameter, composite term |
| $\gamma_D$ | 0.1 | Cost parameter, deposits |
| $\gamma_L$ | 0.1 | Cost parameter, loans |
| *Central bank* | | |
| $\mu^R$ | 0.1 | Required reserve ratio |
| $\chi$ | 0.8 | Degree of interest rate smoothing |
| $\varepsilon_1$ | 1.5 | Response of refinance rate to inflation deviations |
| $\varepsilon_2$ | 0.2 | Response of refinance rate to output gap |
| $\rho_{LR}$ | 0.8 | Persistence parameter, stock of loan loss provisions |
| *Government* | | |
| $\psi$ | 0.2 | Share of government spending in output |
| *Shocks* | | |
| $\rho^Q$ | 0.8 | Degree of persistence, repayment probability shock |
| $\rho^H$ | 0.7 | Degree of persistence, housing demand shock |

Table 2

Default Risk Shock: Asymptotic Standard Deviations of Key Variables
under Alternative Provisioning and Reserve Requirement Rules

| | $\Lambda_1 = 0$ | $\Lambda_1 = 1$ | Opt. $\Lambda_1$ | Opt. $\chi_2^R$ | Opt. $\Lambda_2$ | Opt. $\Lambda_2, \theta_L$ |
|---|---|---|---|---|---|---|
| *Real sector* | | | | | | |
| Output | 0.0179 | 0.0128 | 0.0052 | 0.0177 | 0.0105 | 0.0101 |
| Employment | 0.0247 | 0.0178 | 0.0072 | 0.0245 | 0.0147 | 0.0143 |
| Investment | 0.0990 | 0.0712 | 0.0285 | 0.0988 | 0.0593 | 0.0575 |
| Consumption | 0.0073 | 0.0053 | 0.0021 | 0.0071 | 0.0049 | 0.0050 |
| *Price inflation* | 0.0027 | 0.0020 | 0.0007 | 0.0027 | 0.0019 | 0.0024 |
| *Financial sector* | | | | | | |
| Refinance rate | 0.0027 | 0.0020 | 0.0008 | 0.0027 | 0.0017 | 0.0024 |
| Loan rate | 0.7714 | 0.7573 | 0.7068 | 0.7714 | 0.7516 | 0.7506 |
| Bond rate | 0.0017 | 0.0012 | 0.0005 | 0.0017 | 0.0015 | 0.0020 |
| Real house prices | 0.0515 | 0.0397 | 0.0285 | 0.0511 | 0.0296 | 0.0272 |
| Repayment prob. | 0.0140 | 0.0140 | 0.0142 | 0.0140 | 0.0140 | 0.0140 |
| Loan-output ratio | 0.0812 | 0.0584 | 0.0234 | 0.0810 | 0.0488 | 0.0475 |
| Loan loss provisions | 1.2968 | 1.3294 | 1.4466 | 1.2972 | 1.3829 | 1.3856 |
| Loan loss reserves | 0.1222 | 0.1252 | 0.1360 | 0.1223 | 0.1351 | 0.1362 |

Table 3

Asset Price Shock: Asymptotic Standard Deviations of Key Variables

under Alternative Provisioning and Reserve Requirement Rules

| | $\Lambda_1 = 0$ | $\Lambda_1 = 1$ | Opt. $\Lambda_1$ | Opt. $\chi_2^R$ | Opt. $\Lambda_2$ | Opt. $\Lambda_2, \theta_L$ |
|---|---|---|---|---|---|---|
| *Real sector* | | | | | | |
| Output | 0.0007 | 0.0005 | 0.0002 | 0.0007 | 0.0004 | 0.0004 |
| Employment | 0.0010 | 0.0007 | 0.0003 | 0.0010 | 0.0006 | 0.0006 |
| Investment | 0.0038 | 0.0027 | 0.0011 | 0.0038 | 0.0023 | 0.0022 |
| Consumption | 0.0003 | 0.0002 | 0.0001 | 0.0003 | 0.0002 | 0.0002 |
| *Price inflation* | 0.0001 | 0.0001 | 0.0000 | 0.0001 | 0.0001 | 0.0001 |
| *Financial sector* | | | | | | |
| Refinance rate | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Loan rate | 0.0297 | 0.0291 | 0.0286 | 0.0297 | 0.0289 | 0.0289 |
| Bond rate | 0.0001 | 0.0000 | 0.0000 | 0.0001 | 0.0001 | 0.0001 |
| Real house prices | 4.0069 | 4.0068 | 4.0066 | 4.0069 | 4.0068 | 4.0068 |
| Repayment prob. | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| Loan-output ratio | 0.0031 | 0.0022 | 0.0009 | 0.0031 | 0.0019 | 0.0018 |
| Loan loss provisions | 0.0499 | 0.0511 | 0.0530 | 0.0499 | 0.0520 | 0.0524 |
| Loan loss reserves | 0.0047 | 0.0048 | 0.0050 | 0.0047 | 0.0049 | 0.0049 |

Table 4
Optimal Reaction Parameters, Dynamic Provisioning Regime and Reserve Requirements Rule
Financial Volatility Measured in Terms of the Credit-Output Ratio and Real House Prices

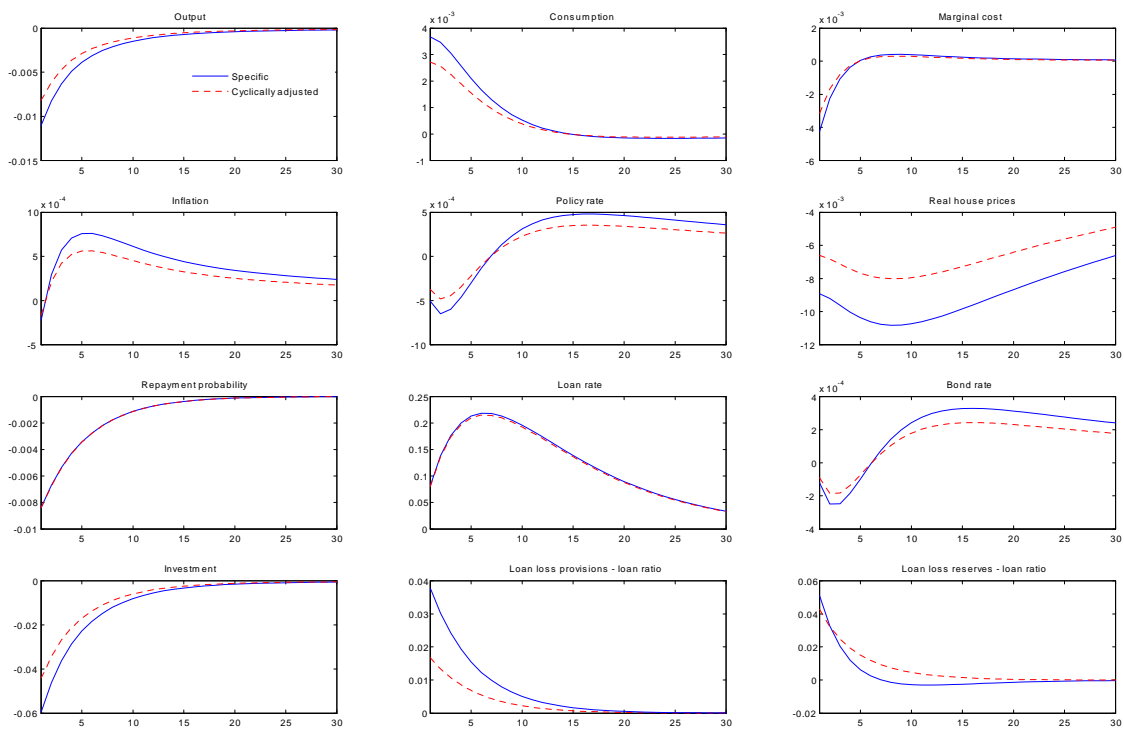| $\chi^R_2$ | $\Lambda_1$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1.2 | 2.4 | 3.6 | 4.8 | 6.0 | 7.2 | 8.4 | 9.6 | 10.8 | 12.0 |
| | | | | | Default risk shock | | | | | | |
| 0 | 1.0000 | 0.9704 | 0.9408 | 0.9136 | **0.9079** | 0.9093 | 0.9113 | 0.9134 | 0.9157 | 0.9180 | 0.9204 |
| 1 | 0.9999 | 0.9703 | 0.9408 | 0.9136 | 0.9079 | 0.9094 | 0.9113 | 0.9135 | 0.9157 | 0.9181 | 0.9205 |
| 2 | 0.9998 | 0.9702 | 0.9407 | 0.9136 | 0.9080 | 0.9094 | 0.9114 | 0.9136 | 0.9158 | 0.9182 | 0.9206 |
| 3 | 0.9997 | 0.9701 | 0.9407 | 0.9136 | 0.9080 | 0.9095 | 0.9115 | 0.9137 | 0.9160 | 0.9184 | 0.9208 |
| 4 | 0.9996 | 0.9701 | 0.9406 | 0.9136 | 0.9081 | 0.9096 | 0.9116 | 0.9138 | 0.9162 | 0.9186 | 0.9211 |
| 5 | 0.9996 | 0.9700 | 0.9406 | 0.9136 | 0.9081 | 0.9097 | 0.9118 | 0.9140 | 0.9164 | 0.9188 | 0.9213 |
| 6 | 0.9996 | 0.9700 | 0.9405 | 0.9136 | 0.9082 | 0.9098 | 0.9119 | 0.9142 | 0.9166 | 0.9191 | 0.9217 |
| 7 | **0.9995** | 0.9700 | 0.9405 | 0.9136 | 0.9083 | 0.9100 | 0.9121 | 0.9145 | 0.9169 | 0.9195 | 0.9221 |
| 8 | 0.9996 | 0.9700 | 0.9405 | 0.9136 | 0.9084 | 0.9101 | 0.9123 | 0.9147 | 0.9172 | 0.9198 | 0.9225 |
| 9 | 0.9996 | 0.9700 | 0.9405 | 0.9136 | 0.9085 | 0.9103 | 0.9126 | 0.9150 | 0.9176 | 0.9203 | 0.9230 |
| 10 | 0.9996 | 0.9700 | 0.9405 | 0.9136 | 0.9086 | 0.9105 | 0.9128 | 0.9154 | 0.9180 | 0.9207 | 0.9235 |
| | | | | | Asset price shock | | | | | | |
| 0 | 1.0000 | 0.9634 | **0.9288** | 0.9295 | 0.9400 | 0.9509 | 0.9620 | 0.9732 | 0.9847 | 0.9963 | 1.0080 |
| 1 | 0.9999 | 0.9633 | 0.9288 | 0.9295 | 0.9400 | 0.9508 | 0.9619 | 0.9732 | 0.9846 | 0.9961 | 1.0079 |
| 2 | 0.9997 | 0.9632 | 0.9288 | 0.9296 | 0.9400 | 0.9508 | 0.9619 | 0.9732 | 0.9845 | 0.9961 | 1.0078 |
| 3 | 0.9996 | 0.9631 | 0.9288 | 0.9296 | 0.9400 | 0.9509 | 0.9619 | 0.9732 | 0.9846 | 0.9961 | 1.0078 |
| 4 | 0.9995 | 0.9631 | 0.9288 | 0.9296 | 0.9401 | 0.9509 | 0.9620 | 0.9733 | 0.9847 | 0.9962 | 1.0079 |
| 5 | 0.9994 | 0.9630 | 0.9288 | 0.9297 | 0.9401 | 0.9510 | 0.9621 | 0.9734 | 0.9848 | 0.9964 | 1.0081 |
| 6 | 0.9994 | 0.9629 | 0.9288 | 0.9298 | 0.9402 | 0.9512 | 0.9623 | 0.9736 | 0.9850 | 0.9966 | 1.0084 |
| 7 | 0.9994 | 0.9629 | 0.9288 | 0.9299 | 0.9404 | 0.9513 | 0.9625 | 0.9738 | 0.9853 | 0.9969 | 1.0087 |
| 8 | 0.9993 | 0.9629 | 0.9288 | 0.9300 | 0.9405 | 0.9515 | 0.9627 | 0.9741 | 0.9856 | 0.9973 | 1.0092 |
| 9 | **0.9993** | 0.9629 | 0.9288 | 0.9301 | 0.9407 | 0.9517 | 0.9630 | 0.9744 | 0.9860 | 0.9978 | 1.0097 |
| 10 | 0.9993 | 0.9629 | 0.9288 | 0.9302 | 0.9408 | 0.9520 | 0.9633 | 0.9748 | 0.9865 | 0.9983 | 1.0102 |

Note: Entries in this table represent financial volatility, measured in terms of the credit-output ratio and real house prices, with weights of 0.8 and 0.2 respectively, relative to the benchmark case where there are no rules under operation, that is, $\chi^R_2 = \Lambda_1 = 0$.

Source: Authors' calculations.

**Figure 1**
**Model Structure: Real and Financial Flows**
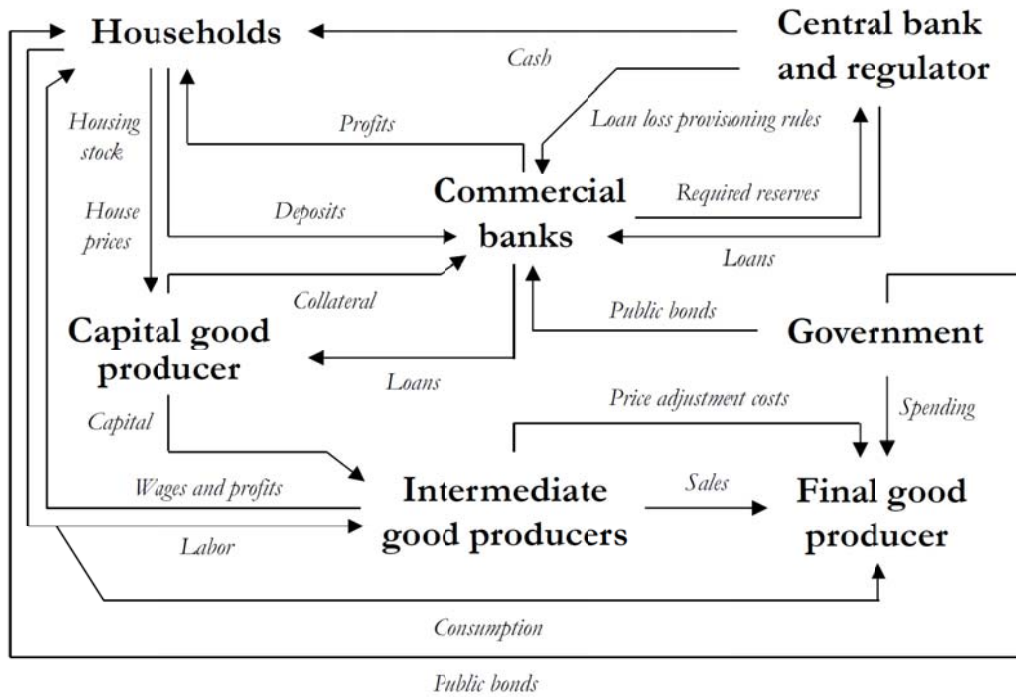
Note: Interest rates, inflation rate and the repayment probability are measured in absolute deviations, that is, in the relevant graphs a value of 0.05 for these variables corresponds to a 5 percentage point deviation in absolute terms.
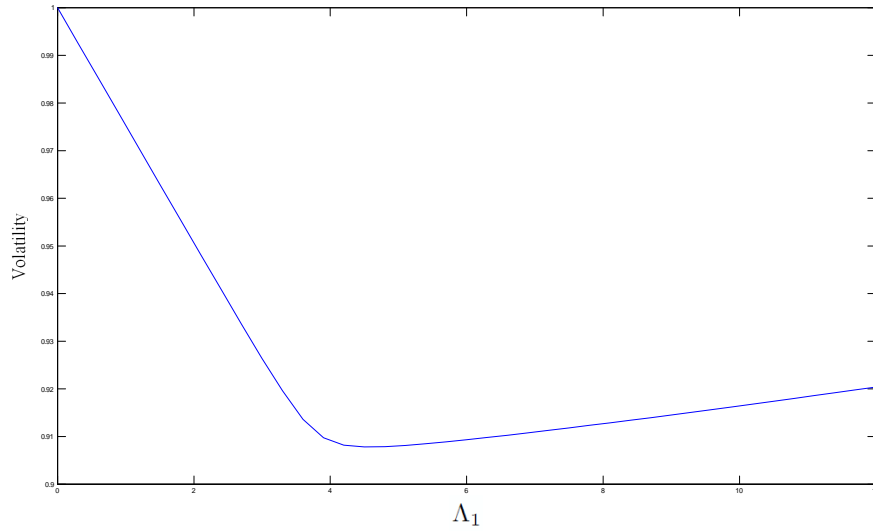
# Figure 3
## Experiment: Transitory Negative Asset Price Shock
## Specific and Cyclically Adjusted Provisioning Rules ($\Lambda_1 = 1.0$)
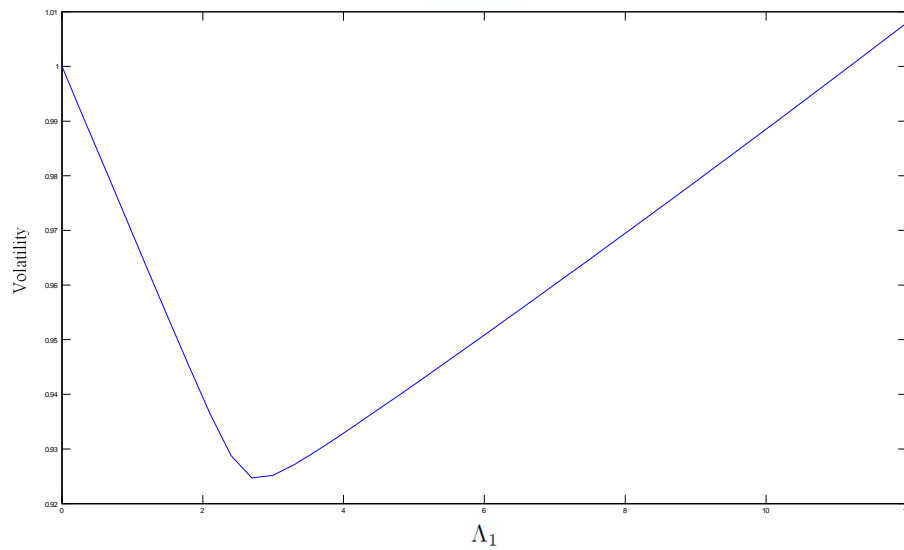(Deviations from steady state)
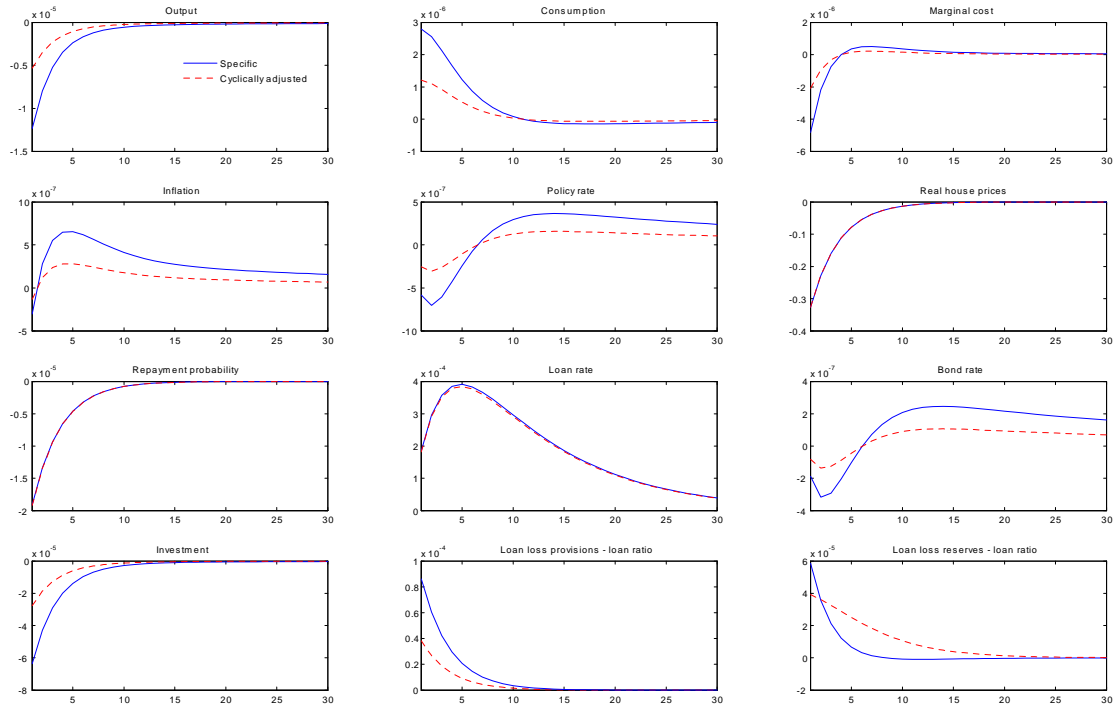


Note: See Note for Figure 2.

## Figure 4
## Financial Volatility and Optimal Reaction Parameter $\Lambda_1$,
## Cyclical Adjusted Provisioning Rule

Transitory Increase in Default Risk



Transitory Negative Asset Price Shock



Note: $\Lambda_1$ measures the response to deviations in the repayment probability in the cyclically adjusted provisioning rule. The vertical axis measures financial volatility, defined in terms of an average of the volatilities of the credit-output ratio and real house prices.

## Figure 5
## Financial Volatility and Optimal Reaction Parameter $\chi_2^R$,
## Reserve Requirement Rule

Transitory Increase in Default Risk
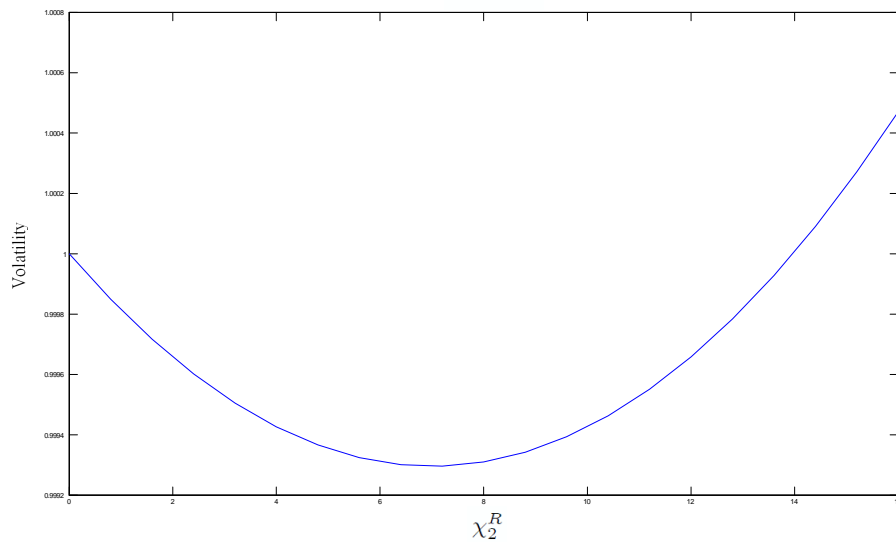


Transitory Negative Asset Price Shock
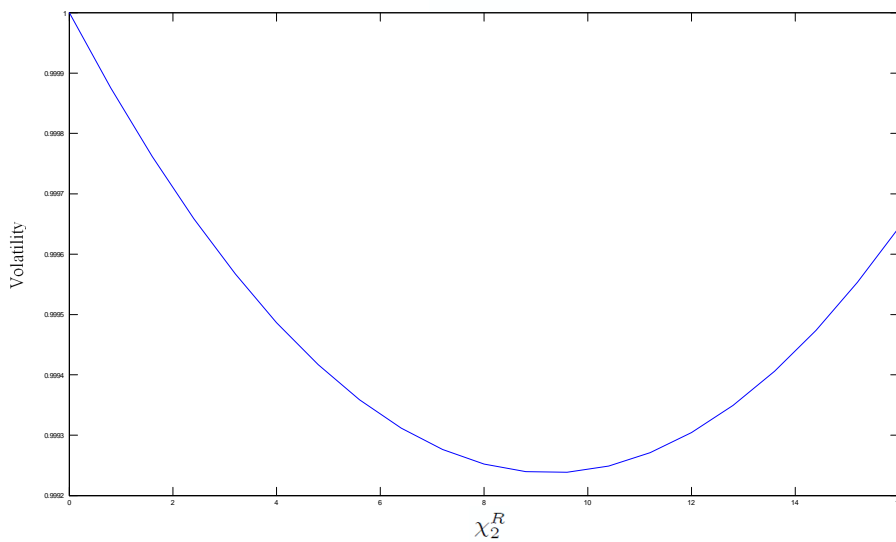


Note: $\chi_2^R$ measures the response to the credit-output ratio in the countercyclical reserve requirement rule. The vertical axis measures financial volatility, defined in terms of an average of the volatilities of the credit-output ratio and real house prices.

Figure 6

**Experiment: Transitory Reduction in Repayment Probability**
**Specific and Cyclically Adjusted Provisioning Rules** ($\Lambda_1 = 1.0$) and $\varphi_4 = 0.4$
(Deviations from steady state)
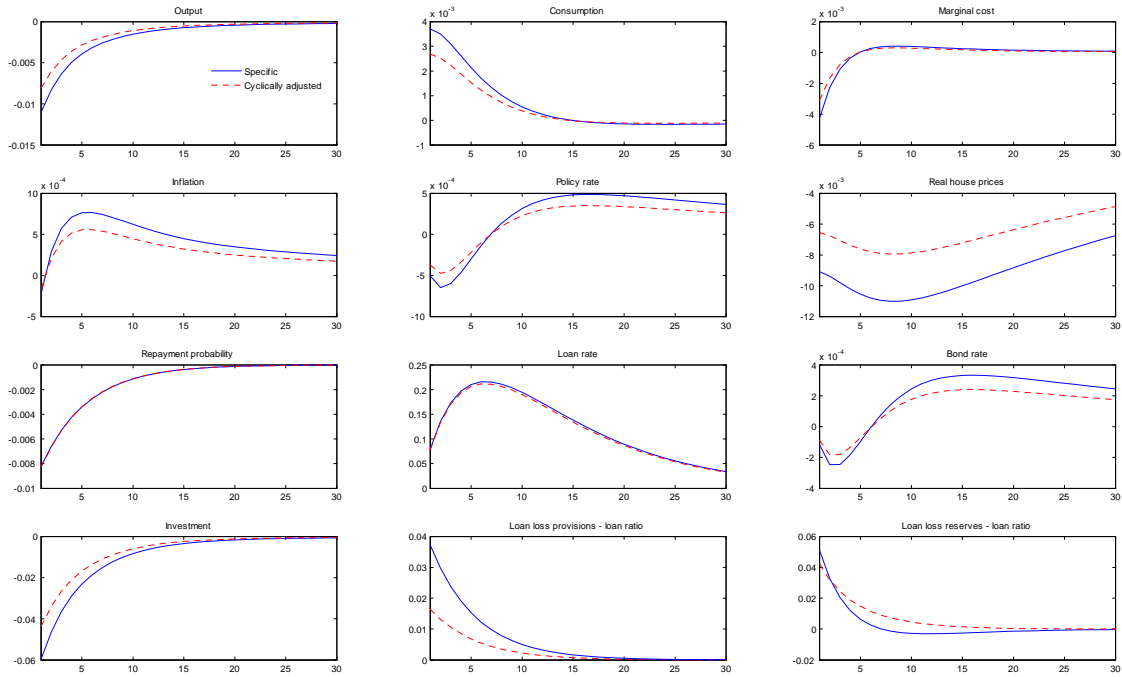


Note: See Note for Figure 2.

**Figure 7**
**Experiment: Transitory Reduction in Repayment Probability**
**Specific and Cyclically Adjusted Provisioning Rules** $(\Lambda_1 = 1.0)$ and $\varphi_4 = -0.4$
(Deviations from steady state)
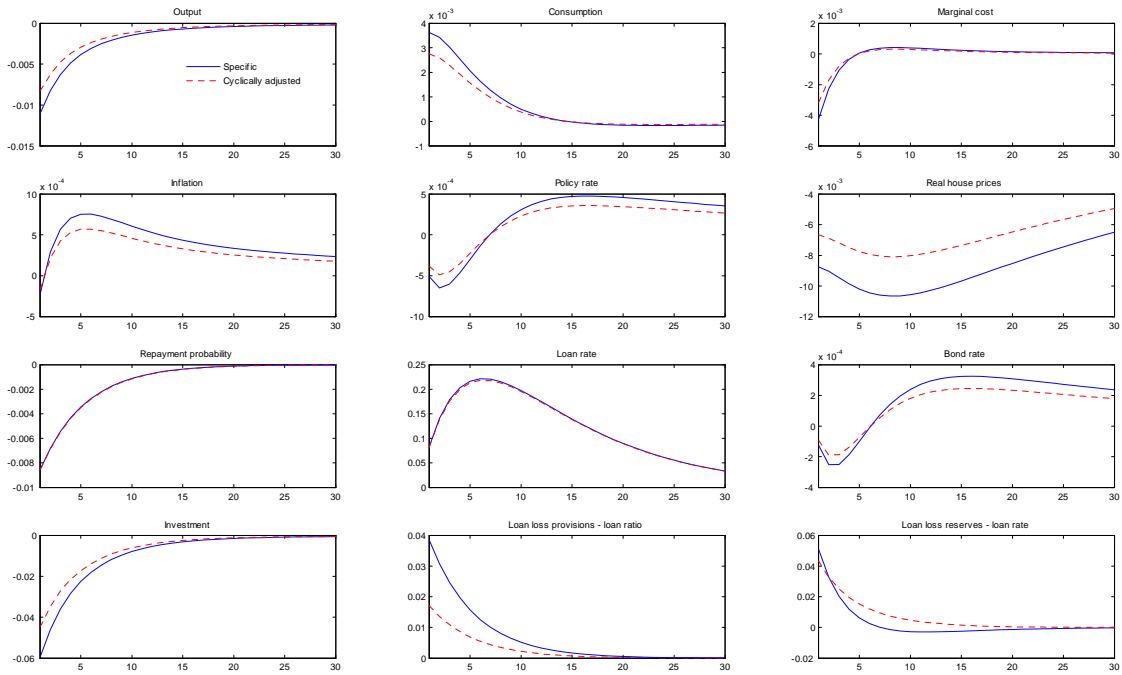


Note: See Note for Figure 2.

**Figure 8**
**Financial Volatility and Optimal Reaction Parameter $\Lambda_2$,**
**Cyclical Adjusted Provisioning Rule: Response to Cyclical Output**
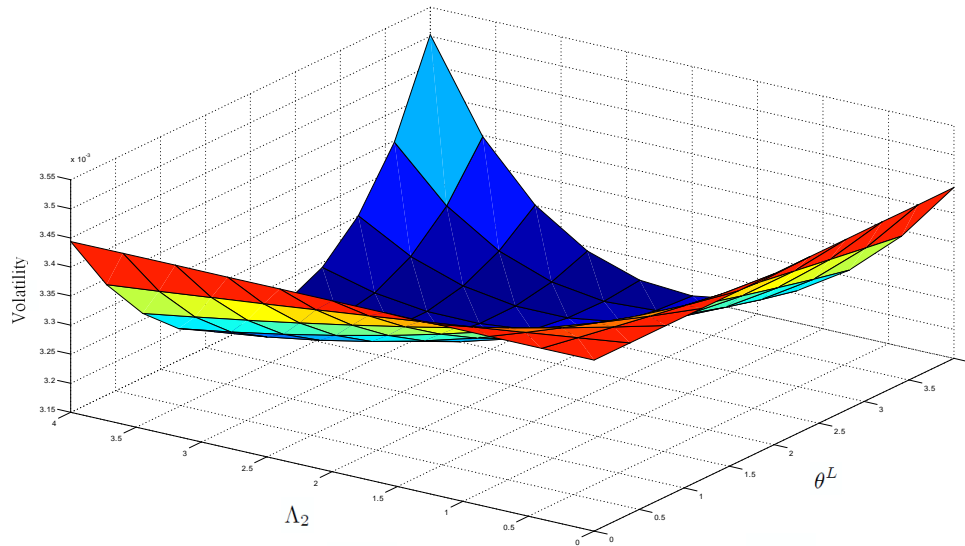
Transitory Increase in Default Risk
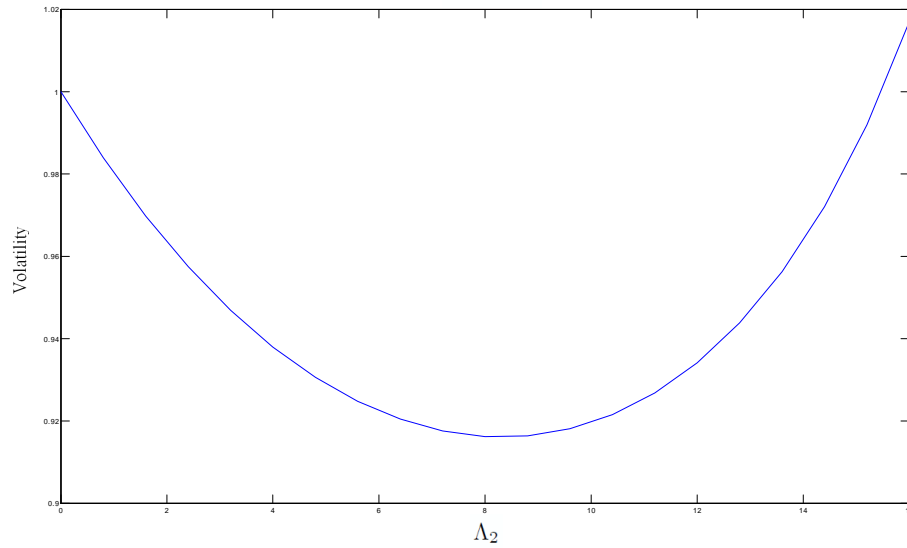


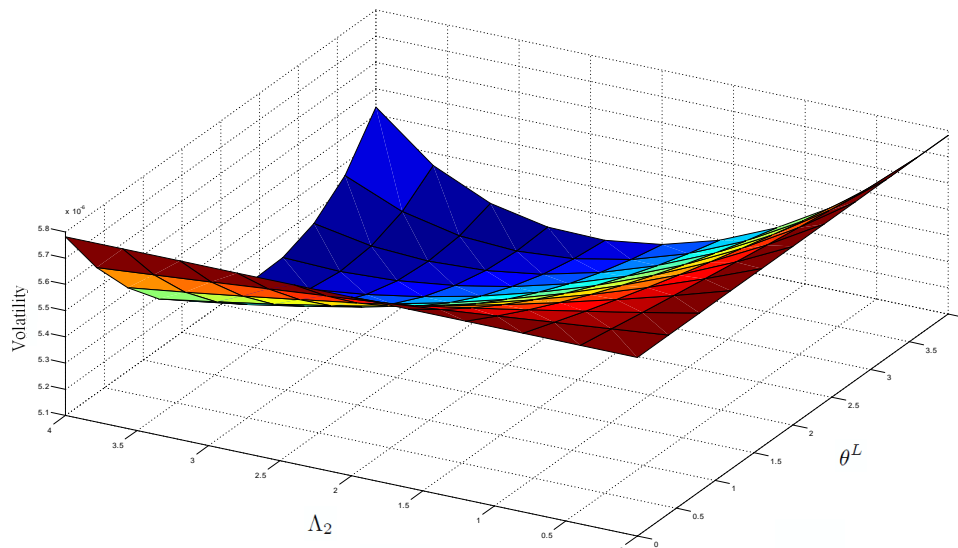Transitory Negative Asset Price Shock
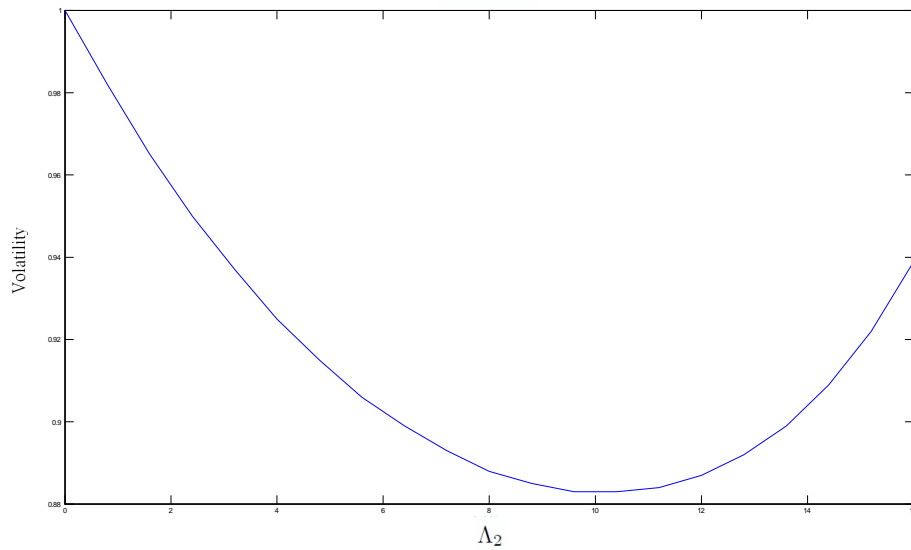


Note: $\Lambda_2$ measures the response to deviations in the cyclical output in the cyclically adjusted provisioning rule. The vertical axis measures financial volatility, defined in terms of an average of the volatilities of the credit-output ratio and real house prices.

## Figure 9
## Financial Volatility and Optimal Reaction Parameter $\Lambda_2$ and $\theta^L$,
## Cyclically Adjusted Provisioning Rule: Response to Cyclical Output

Transitory Increase in Default Risk



Transitory Negative Asset Price Shock



Note: $\Lambda_2$ and $\theta^L$ measure the response to deviations in cyclical output in the cyclically adjusted provisioning rule. The vertical axis measures financial volatility, defined in terms of an average of the volatilities of the credit-output ratio and real house prices.