Discussion Paper Series

Macroprudential Regulation and the Monetary Transmission Mechanism

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July 2013
Number 185

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Forthcoming, *Journal of Financial Stability*

Abstract

The paper presents a simple dynamic macroeconomic model of a bank-dominated financial system that captures some of the key credit market imperfections commonly found in middle-income countries. The model is used to analyze the interactions between monetary and macroprudential policies, involving, in the latter case, changes in reserve requirements. In addition to a qualitative analysis, a calibrated version is used to study numerically the transitional dynamics and steady-state effects of an increase in the reserve requirement ratio, under alternative parameter values. The analysis shows that understanding how these tools operate is essential because they may alter, possibly in substantial ways, the monetary transmission mechanism.

JEL Classification Numbers: E31, E44, E52.

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1 Introduction

The global financial crisis highlighted the need to make financial frictions front and center in macroeconomic analysis and monetary policy formulation. Among the various approaches that have been developed to address these issues, much interest has focused on extending models in the tradition of Bernanke et al. (2000), where agency costs—which arise endogenously—are the main source of credit market frictions and operate essentially through the cost of investment in physical capital. A key result of these models is that variations in borrowers' net worth (or collateral values) tend to magnify the impact of monetary shocks on prices and the supply side through a financial accelerator effect. Some of these extensions have taken the form of introducing banking systems and capital regulation in New Keynesian models, with more recent emphasis on the integration of countercyclical regulatory rules and how they interact with monetary policy.[1]

By and large, almost all the recent literature has focused on industrial countries. However, because there are significant differences between the financial systems in developed and developing countries, it is important to develop models that are appropriate for the latter group, instead of simply "importing" models that may turn out to be misleading for policy analysis.

Accordingly, the purpose of this paper is twofold. First, it presents a simple dynamic macroeconomic model of a bank-dominated financial system that captures some of the key credit market imperfections commonly found in middle-income countries.[2] The model builds on the static framework developed by Agénor and Montiel

[1] An integrated overview of the recent literature—which, admittedly, is evolving at a torrid pace—is sorely lacking. See Agénor and Alper (2012) and Brunnermeier et al. (2012), and the references therein, for the literature on New Keynesian models with banking and Agénor et al. (2012) for the literature on bank capital regulation in these models.

[2] We focus on middle-income countries because in most of them the financial system is sufficiently developed to allow monetary policy to operate through the manipulation of a short-term interest rate whose "pass-through" effect on market rates is fairly rapid, as in more developed countries. In many low-income countries, by contrast, monetary policy continues to be based on indirect

(2008a, 2008b) and extended by Agénor and Pereira da Silva (2012a). Even though its aggregate demand relationships are not derived from first principles, they are fairly intuitive and consistent with the evidence.[3] It provides in our view a better starting point to think about monetary policy in middle-income countries, compared to, say, the simple New Keynesian model (as described in Galí and Gertler (2007) for instance), which by now is largely discredited. The days of studying monetary policy in models without money (and credit) are over, and we believe that some of the insights of our analysis may also prove useful in a developed-country setting.

Second, the paper uses the model to analyze how monetary and macroprudential policies interact to shape macroeconomic outcomes and mitigate the degree of procyclicality of the financial system.[4] This issue has received growing attention in the recent literature, but much of it is based on full-blown numerical models, where the intuition regarding the key mechanisms at play is not always clear. By contrast, we do so in a fairly transparent setting, and this is important to draw some general lessons. Our goal is to highlight, using a fully articulated macroeconomic framework, that understanding how macroprudential tools operate requires improved understanding of the monetary transmission mechanism, and that this in turn requires models in which credit market imperfections take center stage. Equally important, however, is the fact that macroprudential policy regimes may alter the monetary transmission

instruments. At the same time, however, we also account for the fact that capital markets in middle-income countries remain underdeveloped or illiquid. Thus, firms in these countries have no real alternative but to borrow from commercial banks.

[3]The lack of explicit microfoundations for the aggregate demand side makes the model vulnerable to the Lucas critique. However, replacing these empirically-based behavioral relationships by optimization-based first-order conditions for which knowledge is incomplete or limited does not eliminate the problem; both approaches may end up making unwarranted assumptions about agents' response to a change in the policy environment (see Caballero (2010)). In addition, supposedly structural parameters may exhibit drift over time (see Hurtado (2014)).

[4]See Athanasoglou et al. (2014) for an overview of the literature on procyclicality in banking and Committee on the Global Financial System (2010), Bank of England (2011), International Monetary Fund (2011), and Galati and Moessner (2013) for a general discussion of macroprudential policy tools. Claessens et al. (2013) offer some evidence on the performance of these tools.

mechanism, and understanding why and how this occurs is critical to the conduct of monetary policy.

The paper continues as follows. Section 2 provides some background to the analysis, in the form of a brief review of the type of financial market frictions that are prevalent in middle-income countries. Section 3 presents the model. It combines the cost channel of monetary policy with an explicit analysis of the links between bank monitoring, collateral, and bank pricing behavior. The bank lending rate is shown to incorporate a risk premium, which varies—in a manner similar to Bernanke et al. (2000)—inversely with the value of collateral. Moreover, at the prevailing lending rate, the supply of loans is perfectly elastic. There is therefore no endogenous credit rationing, although the nature and intensity of financial frictions do affect indirectly (through changes in the risk premium that banks impose on borrowers) the supply of credit. The central bank's supply of liquidity is perfectly elastic at a target interest rate. Abstracting from collateral considerations and penalty premia by the central bank, this is conceptually similar to assuming that monetary policy is implemented through a standing facility.[5] Section 4 presents the model's solution and characterizes its steady-state properties under two cases, exogenous and endogenous policy rates. Section 5 examines qualitatively the transmission mechanism of monetary and macroprudential policies, namely, increases in the central bank rate and the reserve requirement ratio. We focus on reserve requirements for two reasons. First, central banks in many developing countries (especially in Latin America) have used them extensively, time and again, as a substitute to monetary policy.[6] Second, their po-

[5]In practice, standing facilities take the form of narrow corridors that constrain deviations of a short-term interest rate (typically a money market rate) from its target value, with open-market operations used for smoothing liquidity and dampening interest rate fluctuations. By providing unlimited access (subject to collateral and eligibility rules) to base money at the posted interest rate, these facilities make the supply of liquidity by the central bank endogenous. The implicit assumption here is that there is a zero-width band around the target rate.

[6]See Montoro and Moreno (2011) and Agénor and Pereira da Silva (2013). In recent years reserve requirements were indeed used in a countercyclical fashion to smooth the expansion phase of the cycle and to tighten monetary conditions without attracting capital inflows. During the

tential value as a tool capable of mitigating systemic risk and enhancing financial stability has regained importance in recent years—despite the fact that they may distort the financial intermediation process. We show, in particular, that a financial accelerator effect does exist, but it operates in different ways than in Bernanke et al. (2000); it occurs not through changes in asset prices but rather through changes in loan rates and factor prices. We also emphasize how the transmission process of each policy is affected by the nature of the other policy. In Section 6 the model is calibrated and used to study the transitional dynamics and steady-state effects of an increase in the reserve requirement ratio, under alternative parameter values. The final section considers some possible extensions of the analysis and offers some concluding remarks.[7]

2 Background

In most middle-income countries, commercial banks continue to dominate the financial system. Equity issues remain limited, despite recent progress in deepening local capital markets and changes in the ownership structure of firms. Although in recent years privatization and cross-border acquisitions have been accompanied by a significant improvement in the degree of banking sophistication in many countries, their financial systems continue to lag behind developments in industrial markets. In particular, and despite some exceptions, the expansion of nonbank financial intermediaries, the shift toward the "originate and distribute" model of banking, and the development of opaque, off-balance sheet instruments, have not reached the same

global financial crisis, reserve requirements were lowered, in order to inject liquidity rapidly in the financial system and to restore market activity affected by sudden reversals in capital flows.

[7] The working paper version of this article considers how the transmission mechanism of monetary policy is altered in the presence of another macroprudential tool, an upper limit on banks' leverage ratio.

importance as they have in advanced economies.[8]

At the same time, financial market imperfections remain pervasive in most of these countries. These imperfections cover a broad spectrum.[9] First, the fact that capital markets remain underdeveloped implies that there are limited alternatives (such as corporate bonds and commercial paper) to bank credit, to finance either short-term working capital needs or longer-term investment projects. Second, there is limited competition among banks, which leads to monopolistic or oligopolistic market structure and pricing practices, segmentation of credit markets, and efficiency losses—without necessarily, however, undermining financial stability (see Ariss (2010)). Third, asymmetric information problems tend to be more severe than in industrial countries; this makes screening out good credit risks from bad ones difficult, and fosters collateralized lending and short-maturity loans. Fourth, governments in many countries continue to play a pervasive role in banking, directly or indirectly, despite recent trends toward privatization. Implicit public guarantees (particularly with respect to the financial safety net) tend to exacerbate moral hazard problems. Fifth, disclosure and transparency requirements on corporate firms are largely inadequate.[10] With poor regulation of corporate governance and weak financial accounting

[8] In some industrial countries, non-banks—hedge funds, commodities funds, private equity groups, and money market funds—have become essential sources of credit (see Pozsar et al. (2010)). Alternatives to conventional bank finance include invoice factoring or discounting (where a business borrows money against its invoices), asset-based financing (where money is borrowed against assets such as plant or machinery), peer-to-peer and consumer-to-business lending (in which individuals agree to lend money to each other or to businesses through an online money exchange). New lending models also involve providing cash advances to businesses (e.g., restaurants and hotels) that derive much of their income through credit card sales. However, some of these new lending models do have high defaults risks, so the cost of finance is not necessarily lower than in conventional banking. Even in industrial countries, they also haven't reached a critical mass of borrowers to be considered serious alternatives to bank finance.

[9] The discussion in this section is based on Agénor and Pereira da Silva (2010, 2013). See also Tornell and Westermann (2004) and Inter-American Development Bank (2005) for a discussion and a review of the evidence for Latin America. The emphasis in Tornell and Westermann is on financing constraints (which affect, in their view, mainly firms in the nontradables sector), currency mismatches, and implicit bailout guarantees.

[10] See for instance Black et al. (2010) for Brazil.

transparency, firms have limited incentives to consider equity issuance as an alternative source of funding—preferring instead either to rely on internal funds or to borrow from banks with which they have established close links. Sixth, property rights are weak and the legal system is highly inefficient, thereby making contract enforcement difficult. In particular, procedures for liquidating the assets of firms in default are weak and inefficient in many developing countries.[11] Bankruptcy law typically provides little creditor protection. This in turn results in weak intermediation, a high cost of capital, high rates of collateralized lending, and low recovery rates for creditors.[12]

Finally, the financial system in middle-income countries (although not all of them) is often subject to weak supervision and a limited ability to enforce prudential regulations.[13] As documented by the Inter-American Development Bank (2005) and Dermirguc-Kunt et al. (2008), the quality of bank supervision—as measured by the overall compliance index with the so-called Basel Core Principles for Effective Bank Supervision, which include a number of recommendations on prudential regulation and requirements—tend to be much lower for developing countries, especially those of Latin America. In turn, a weak regulatory environment may lead to regulatory capture and create perverse incentives for banks to engage in risky activities. It also implies that prudential instruments should not be overly difficult to implement in order for them to be effective. The fact that reserve requirements for instance are

[11]See Araujo and Funchal (2005) for the case of Latin America and Djankov et al. (2008) for a general review of bankruptcy and debt insolvency procedures in developing countries.

[12]These financial distortions tend to be magnified in a volatile economic environment, characterized by a high incidence (compared to industrial countries) of domestic and external shocks (such as abrupt movements in capital flows). In turn, increased exposure to adverse shocks magnifies the possibility of default and the risk of bankruptcy by borrowers and lenders alike. The former tends also to foster collateralized lending.

[13]See Barth et al. (2004, 2008). In some cases inadequate supervision and porous regulations are the legacy of heavy public sector involvement in the banking system, which weakens enforcement incentives, and an inadequate pay structure, which makes it difficult to lure well-qualified individuals away from more lucrative private activities.

so widely used in middle-income countries (see Montoro and Moreno (2011)) surely reflects an adequate understanding of this constraint.

An implication of the type of credit market imperfections described earlier is that a large majority of small and medium-size firms (often operating mostly in the informal sector) are simply squeezed out of the credit market, whereas those who do have access to it—well-established firms, with "traditional" connections with specific banks—face an elastic supply of loans and borrow at terms that depend on their ability to pledge collateral. However, even with "connected" lending, actual collateral ratios may be quite high; average collateral values in percent of loans can be well above 100 percent in many developing countries—reflecting perhaps a weak judiciary environment and high recovery costs, as noted earlier. Equally important, credit rationing (which results fundamentally from the fact that inadequate collateral would have led to prohibitive rates) is largely exogenous in normal times. Another implication is the importance of the cost channel (short-term loans to finance working capital needs), which becomes a key part of the monetary transmission mechanism.[14]

More generally, the foregoing discussion suggests that because banks continue to play a dominant role in the financial system in middle-income countries, accounting for credit market imperfections in macroeconomic models—even at the simplest level—is essential to study the effectiveness of both monetary and macroprudential policies and how these policies interact.[15] We now turn to the description of a model that we believe provides a significant step in this direction.

[14]As documented in Agénor and Alper (2012), there is evidence that the cost channel may be significant in some industrial countries as well. See also Fernandez-Corugedo et al. (2011).

[15]Furthermore, if middle-income countries indeed have limited ability to enforce financial regulation, this should influence the choice of macroprudential tools—and possibly the design of monetary policy rules. This issue is discussed further in Agénor and Pereira da Silva (2012*b*).

3 A Simple Dynamic Model

The model developed in this section captures many of the financial market imperfections described earlier: a predominant role of banks in financing short-term working capital needs and investment in physical capital; monopolistic banking markets; collateralized lending (due to severe asymmetric information problems, inadequate disclosure and transparency requirements on corporate firms, weak property rights, and high contract enforcement costs); and a perfectly elastic supply of loans to firms, at the prevailing lending rate. The fact that households continue to have limited access to consumer credit (as opposed to mortgage loans) in many middle-income countries is also captured, to the extent that it affects their ability to borrow and lend for expenditure smoothing purposes. The weak capacity to enforce financial regulations is captured indirectly as well, to the extent that we consider a country that relies on a prudential instrument that is relatively easy to implement—reserve requirements.

In what follows we describe the behavior of the four types of agents that populate the economy: a continuum of firms, a continuum of households, a single commercial bank, and the central bank.[16]

3.1 Firms

Firms produce a single, homogeneous good. To finance their working capital needs, which consist solely of labor costs, firms must borrow from the bank.[17] Total production costs faced by the representative firm are thus equal to the wage bill plus the interest payments made on bank loans. For simplicity, loans contracted for the

[16] We abstract from the government for simplicity.

[17] This may seem a bit strange in a continuous time model where each instant is infinitely short. The assumption is that each instant is the equivalent of a period in a discrete time model.

purpose of financing working capital are taken to be fully collateralized by the firm's capital stock, and are therefore made at a rate that reflects only the cost of borrowing from the central bank, i_t^R.[18] Firms repay working capital loans, with interest, after goods have been produced and sold. All profits are transferred to the firms' owners, households.

Let Y_t denote output and N_t the quantity of labor employed. The production function of the representative firm takes the form

$$Y_t = N_t^{\alpha}, \tag{1}$$

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

Let W_t denote the nominal wage, and i_t^R the official rate charged by the central bank to the commercial bank (or the refinance rate, for short). The wage bill, inclusive of borrowing costs, is thus $(1 + i_t^R)W_t N_t$. The maximization problem faced by the representative firm can be written as

$$N_t = \arg\max[P_t Y_t - (1 + i_t^R)W_t N_t], \tag{2}$$

where P_t is the price of the good.

Solving problem (2) subject to (1), taking i_t^R, P_t and W_t as given, yields

$$\alpha P_t N_t^{\alpha-1} - (1 + i_t^R)W_t = 0.$$

This condition yields the demand for labor as

$$N_t^d = [\alpha^{-1}\frac{(1 + i_t^R)W_t}{P_t}]^{-1/(1-\alpha)}, \tag{3}$$

which shows that labor demand is inversely related to the real *effective* cost of labor, $(1 + i_t^R)W_t/P_t$, which accounts for the cost of bank borrowing.

[18] As discussed later, the interest rate on working capital loans could also be made a choice variable for the bank, without much effect on the results. Adding a fixed markup over the refinance rate for that type of loans would also have no qualitative effect on the subsequent discussion.

Suppose that labor supply is perfectly elastic and that there is full backward indexation, in the form $W_t = P_{t-1}$ in discrete time; by implication, $W_t/P_t = P_{t-1}/P_t = (1+\pi_t)^{-1}$, where π_t is the inflation rate. The effective cost of labor is thus $(1+i_t^R)/(1+\pi_t)$. Substituting this result in (3) yields

$$N_t^d = [\alpha^{-1}(\frac{1+i_t^R}{1+\pi_t})]^{-1/(1-\alpha)} = N^d(\pi_t; i_t^R), \tag{4}$$

where, with a '$\tilde{}$' used to denote steady-state values,

$$N_\pi^d = \frac{\tilde{N}^d}{(1-\alpha)(1+\tilde{\pi})} > 0, \quad N_{i^R}^d = -\frac{\tilde{N}^d}{(1-\alpha)(1+\tilde{\imath}^R)} < 0.$$

Substituting (4) in (1) gives

$$Y_t^s = [\alpha^{-1}(\frac{1+i_t^R}{1+\pi_t})]^{-\alpha/(1-\alpha)} = Y^s(\pi_t; i_t^R), \tag{5}$$

where

$$Y_\pi^s = \frac{\alpha\tilde{Y}^s}{(1-\alpha)(1+\tilde{\pi})} > 0, \quad Y_{i^R}^s = -\frac{\alpha\tilde{Y}^s}{(1-\alpha)(1+\tilde{\imath}^R)} < 0.$$

Thus, an increase in the inflation rate lowers the real wage and stimulates both employment and output, whereas a rise in the refinance rate has a contractionary effect.

Note that the assumption of perfectly elastic labor supply-full wage indexation could be replaced by a wage curve, which would relate the *level* of the real wage to the unemployment rate, defined as $u_t = (\bar{N}^s - \bar{N}_t^d)/\bar{N}^s$, where $\bar{N}^s$ is now the exogenous supply of labor. This would lead to a negative relationship between labor demand and output supply with the policy rate only, with no effect of inflation.[19] However, as noted later, stability conditions require the net effect of inflation on excess demand to be positive, so assuming that $N_\pi^d = Y_\pi^s = 0$ would not affect qualitatively the results. Thus, full wage indexation is retained for simplicity.

[19] Thus, the positive, partial equilibrium effect of inflation on aggregate supply would disappear. But it should also be noted that, in the case of an endogenous policy rule (as discussed later), the fact that the refinance rate increases with inflation gaps implies that the net effect of an autonomous increase in inflation is not necessarily positive.

Real investment is negatively related to the real lending rate:

$$I_t = I(i_t^L - \pi_t), \tag{6}$$

where i_t^L is the nominal loan rate and $I' < 0$.[20]

The amount of loans demanded (and allocated by the bank) to finance labor costs and capital accumulation, L_t^F, measured in real terms, is thus[21]

$$\frac{L_t^F}{P_t} = \frac{N_t^d}{1+\pi_t} + I_t. \tag{7}$$

3.2 Households

Households consume goods and hold two imperfectly substitutable financial assets: currency (which bears no interest), in nominal quantity Z_t, and bank deposits, in nominal quantity D_t. The real demand for deposits is positively related to the nominal interest rate on that category of assets, i_t^D, adjusted for inflation:

$$\frac{D_t}{P_t} = d(i_t^D - \pi_t), \tag{8}$$

where $d' > 0$. Total holdings of assets are proportional to consumption spending, as a result of a "money-in-advance" constraint:

$$Z_t + D_t = \psi P_t C_t, \tag{9}$$

[20] Throughout the analysis, and given the continuous time setting of the model, we assume that expected and actual inflation rates are equal. It is worth noting that recent research in monetary economics has emphasized departures from pure forward-looking (or perfect foresight) assumptions about expectations, either in the form of partially backward-looking schemes or (as in the present case) myopic expectations. See Orland and Roos (2013), Woodford (2013), and the references therein.

[21] Given the continuous time nature of the model, the stock specification in equation (7) implictly assumes (somewhat unrealistically) that the maturity of loan contracts is instantaneous. In principle, it is the *flow* of credit, $\dot{L}_t^F$, that should appear in that equation. However, this would increase the order of the dynamic systems studied later by one, thereby precluding the use of phase diagrams.

where C_t denotes real private expenditure and $\psi > 0$. Thus, currency and deposits are perfect substitutes as means of transactions, even though they are imperfect substitutes as portfolio assets (or stores of value) earning different rates of return.[22]

From (8) and (9), the real demand for currency is thus positively related to the level of transactions and negatively to its opportunity cost:

$$\frac{Z_t}{P_t} = \psi C_t - d(i_t^D - \pi_t). \tag{10}$$

Real consumption expenditure by households depends positively on income from production, and negatively on the real deposit rate, which captures an intertemporal effect:

$$C_t = \alpha_0 + \alpha_1(\pi_t)Y_t^s - \alpha_2(i_t^D - \pi_t), \tag{11}$$

where $\alpha_1 \in (0, 1)$ is the marginal propensity to consume out of current income, and $\alpha_0, \alpha_2 > 0$.[23] The positive effect of current income on private spending is consistent with the evidence regarding the pervasiveness of liquidity constraints in developing countries (see Agénor and Montiel (2008*a*)) and the fact that households cannot borrow directly from banks to smooth consumption.[24] In addition, inflation generates a capital loss, or a *wealth erosion effect*, which induces households to reduce spending to rebuild their assets through a reduction in current spending and higher savings; thus, $\alpha_1' < 0$. This is consistent with the buffer stock theory of saving, according to which households adjust their savings to reach or maintain a wealth target (see

[22]Imperfect substitution between curency and deposits could be introduced by replacing (9) by a specification of the form $\Gamma(Z_t, D_t) = \psi P_t C_t$, where $\Gamma()$ is assumed to be strictly increasing, convex, and linearly homogeneous, so that $\Gamma_Z, \Gamma_D > 0$, $\Gamma_{ZZ}, \Gamma_{DD} > 0$; and by implication of linear homogeneity, $\Gamma_{ZD} < 0$. This more general specification would complicate the analysis without altering qualitatively our results.

[23]We abstract from interest payments on deposits as a source of current income, and assume instead that they enter directly into financial wealth accumulation. Equivalently, the marginal propensity to consume out of interest income is zero.

[24]There is evidence that the proportion of constrained households is also quite substantial in industrial countries. For instance, Coenen and Straub (2005) found that the proportion of constrained households in the Euro area varies between 0.25 and 0.37.

for instance Wen (2009)). To the extent that high inflation signals greater income uncertainty in the future, it is also consistent with models of precautionary savings. The wealth erosion effect implies that, all else equal, an increase in inflation (which lowers the real deposit rate) has an ambiguous effect on consumption.

Note that, given (9), accounting explicitly for a standard, positive wealth effect on consumption would not affect qualitatively the analysis. Indeed, imagine that we add in (11) a term $\alpha_3(Z_t + D_t)/P_t$, where $\alpha_3 > 0$. Using (9), this term is equivalent to $\alpha_3\psi C_t$, which implies that adding a conventional real balance effect leads simply to replacing α_h in (11) by $\alpha_h/(1 - \alpha_3\psi)$, for $h = 0, 1, 2$. As long as $\alpha_3\psi < 1$, a plausible restriction in practice, and the marginal propensity to consume remains less than unity, the analysis would remain essentially the same.[25]

3.3 Commercial Bank

Assets of the commercial bank consist of total credit extended to firms, L_t^F, and mandatory reserves held at the central bank, RR_t. The bank's liabilities consist of household deposits, and borrowing from the central bank, L_t^B. The balance sheet of the bank can therefore be written as:

$$L_t^F + RR_t = D_t + L_t^B, \tag{12}$$

where all variables are measured in nominal terms. We thus abstract from excess reserves (see Agénor and El Aynaoui (2010)). Reserves held at the central bank pay no interest and are set in proportion to deposits:

$$RR_t = \mu D_t, \tag{13}$$

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

[25] The empirical estimates of Peltonen et al. (2009) for instance, based on panel data for 14 emerging economies—most of them middle-income countries—suggest that a 10 percent increase in money wealth, proxied by broad money, raises consumption by about 0.4-0.5 percent.

The bank is risk-neutral and sets both deposit and lending rates, as well as monitoring effort, so as to maximize its expected profits. Specifically, the bank can affect the repayment probability on its investment loans, $q_t \in (0,1)$, by expending effort to select (*ex ante*) and monitor (*ex post*) its borrowers; the higher the effort, the safer the loan. For simplicity, the probability of repayment itself, rather than monitoring effort *per se*, is taken to be the choice variable.

The bank's optimization problem is thus

$$i_t^D, i_t^L, q_t = \arg\max \left\{ \frac{i_t^R W_t N_t^d}{P_t} + q_t i_t^L I_t + (1-q_t)\frac{V_t}{P_t} - \frac{i_t^D D_t}{P_t} - \frac{i_t^R L_t^B}{P_t} - x_t^M \right\},$$

where $V_t \leq P_t I_t$ is the *effective* value of collateral pledged by borrowers and x_t^M is the total cost of monitoring (in real terms), defined as

$$x_t^M = \phi_t \frac{q_t^2}{2} I_t, \tag{14}$$

where $\phi_t > 0$. The first term in the profit expression is interest income from working capital loans. The second term, $q_t i_t^L I_t$, represents interest payments that the bank obtains if there is no default, which occurs with probability q_t. The third term represents what the bank earns in case of default, which occurs with probability $1 - q_t$. The fourth term is interest payments on deposits, whereas the fifth is interest payments on central bank loans. The last term is monitoring costs, which are increasing in the amount of loans and the level of effort.[26] For simplicity, we abstract from standard operating costs.

The bank internalizes the fact that the demand for loans (supply of deposits) depends negatively (positively) on the lending (deposit) rate, and takes prices, the value of collateral, the refinance rate, and ϕ_t as given. For simplicity, when choosing the lending rate, it takes the total cost of monitoring as given as well.[27]

[26] A similar quadratic cost function is used in Dell'Ariccia et al. (2011) and Allen et al. (2011). However, neither study considers the impact of collateral on monitoring, as we do here.

[27] If the bank internalizes the fact that x_t^M depends indirectly on the loan rate, the term $-\phi_t q_t^2 I'/2$

Using (12) to substitute L_t^B out, as well as (13) and (14), first-order conditions for this problem are given by

$$-d_t - [i_t^D - i_t^R(1-\mu)]d' = 0, \tag{15}$$

$$q_t I_t + (q_t i_t^L - i_t^R)I' = 0, \tag{16}$$

$$i_t^L I_t - \frac{V_t}{P_t} - \phi_t q_t I_t = 0, \tag{17}$$

where $d' > 0$ measures the response of deposits to i_t^D (see equation (10)) and $I' < 0$ the response of the demand for investment loans to the lending rate (see equation (6)).

Let $\eta_D = d' i_t^D / d_t$ denote the constant interest elasticity of the supply of deposits.[28] Condition (15) yields therefore the desired deposit rate as

$$i_t^{D,d} = \varepsilon^D (1-\mu) i_t^R, \tag{18}$$

where $\varepsilon^D = (1 + \eta_D^{-1})^{-1}$. This equation shows that the equilibrium deposit rate is set as a markup over the refinance rate, adjusted (downward) for the implicit cost of holding reserve requirements.

Similarly, let $\eta_L = I' i_t^L / I_t$ denote the interest elasticity of the demand for investment loans. Condition (16) yields the desired loan rate as

$$i_t^{L,d} = (1 + \frac{1}{\eta_L})^{-1} \frac{i_t^R}{q_t}, \tag{19}$$

which implies that the lending rate is also proportional to the cost of borrowing from the central bank. The lower the repayment probability, the higher the lending rate.

would appear on the right-hand side of expression (16). This would not change the key result that the repayment probability has a negative effect on the loan rate (as shown in 19). However, the solution of the complete model would become more involved.

[28] The interest rate on short-term working capital loans (say, i_t^S) could be made a choice variable as well. Suppose that there are costs to processing this type of loans, and that these costs are a fraction $\theta^N \in (0,1)$ of their value, $W_t N_t^d$. The first-order condition for profit maximization would yield therefore $i_t^S = (1+\eta_N^{-1})^{-1}(i_t^R + \theta^N)$, where η_N is (the absolute value of) the elasticity of labor demand with respect to the loan rate. As long as θ^N is constant, however, this would not alter qualitatively our analysis.

Condition (17) can be rearranged to give

$$q_t = \phi_t^{-1}(i_t^L - \frac{V_t}{P_t I_t}). \tag{20}$$

Assuming that this solution is admissible, it implies that the optimal level of monitoring is increasing in the loan rate (as in Allen et al. (2011), for instance), and decreasing in the collateral-investment loan ratio. Intuitively, collateral limits the loss that the bank incurs in case of default; all else equal, it thus reduces incentives to monitor borrowers. As a result, the repayment probability is lower. A higher level of investment loans has opposite effects.

Suppose now that the cost term ϕ_t is also inversely related to the collateral-investment loan ratio, that is

$$\phi_t = \phi(\frac{V_t}{P_t I_t}). \tag{21}$$

A higher value of collateral (for a given level of loans) mitigates moral hazard on the part of borrowers and induces them to exert more effort in ensuring that their investments are successful.[29] This may also induce them to be more compliant with bank monitoring requirements. Thus, $\phi' < 0$ and an increase in $V_t/P_t I_t$ will now tend to *raise* the repayment probability q_t. As a result, there are conflicting effects of the collateral-loan ratio on the level of effort and the repayment probability. In what follows, and consistent with what we believe to be the preponderance of the evidence for middle-income countries, we will assume that the "moral hazard" (borrower) effect dominates the "risk-shifting" (lender) effect, so that the net effect of an increase in that ratio is to raise the probability of repayment. Combining (20) and (21) yields therefore

$$q_t = q(i_t^L, \frac{V_t}{P_t I_t}), \tag{22}$$

where $q_{i^L}, q_{V/PI} > 0$.

[29] Put differently, collateral reduces moral hazard, by increasing borrowers' effort and reducing their incentives to take on excessive risk. See for instance Boot et al. (1991) and Bester (1994) for a more detailed discussion.

Effective collateral is defined as

$$V_t = \kappa P_t Y_t, \tag{23}$$

that is, the *net* value of collateral pledged by borrowers is a fraction $\kappa \in (0,1)$ of aggregate output, $P_t Y_t$. Coefficient κ is net in the sense that it is the difference between the gross fraction of output pledged, minus the fraction of the value of collateral "eaten up" by the legal and administrative costs of enforcing the terms of loan contracts in case of bankruptcy; it provides therefore a summary measure of the degree of credit market imperfections.

Substituting (22) and (23) in (19) yields

$$i_t^{L,d} = \varepsilon^L [1 + \theta^L (i_t^L, \frac{\kappa Y_t^s}{I_t})] i_t^R, \tag{24}$$

where $\varepsilon^L = (1 + \eta_L^{-1})^{-1}$, $1 + \theta^L() \simeq q^{-1}()$, and $\theta^L_{i^L}$, $\theta^L_{Y^s/I} < 0$.

Given that q^{-1} is greater than unity, the approximation used for that term is fairly convenient. Indeed, the term $\theta^L()$ may now be interpreted as a risk premium on lending to firms, which is inversely related to the loan rate and the ratio of firms' collateral over their investment borrowing. Note that, in this specification, an increase in inflation stimulates both output (by lowering the real wage, as shown in (5)) and investment (by reducing the real lending rate, as shown in (6)). Thus, both collateral and borrowing increase; the net effect on the ratio $\kappa Y_t^s / I_t$ is thus ambiguous. This is important to understand the dynamics of the loan rate and inflation, as discussed subsequently. It can be noted also that (24) is based on flows, rather than stocks, as in Agénor and Montiel (2008*a*, 2008*b*). There is therefore no balance sheet effect *per se* on the premium, as in Bernanke et al. (2000), but rather a (flow) collateral effect.

Consistent with the evidence (see Agénor and Alper (2012)), the actual deposit rate adjusts immediately to its optimal value ($i_t^D = i_t^{D,d}$) whereas the actual lending rate adjusts only gradually to that value, given in (24). Using a simple partial adjustment equation yields:

$$di_t^L/dt = \lambda^F \left\{ [\varepsilon^L[1 + \theta^L(i_t^L, \frac{\kappa Y_t^s}{I_t})]i_t^R - i_t^L \right\}, \tag{25}$$

where $\lambda^F \geq 0$. Instantaneous adjustment therefore occurs for $\lambda^F \to \infty$.

Given that L_t^F and D_t are determined by private agents' behavior, the balance sheet constraint (12) together with (13) can be used to determine residually borrowing from the central bank:

$$L_t^B = L_t^F - (1 - \mu)D_t. \tag{26}$$

3.4 Central Bank

The central bank sets the refinance rate i_t^R and provides all the liquidity demanded by the commercial bank through a standing facility. Its balance sheet consists, on the asset side, of loans to the commercial bank, L_t^B, and on the liability side, of the monetary base, M_t:

$$L_t^B = M_t. \tag{27}$$

The monetary base is defined as the sum of total currency in circulation and required reserves:

$$M_t = Z_t + RR_t. \tag{28}$$

Because central bank liquidity is endogenous, the monetary base is also endogenous; equations (27) and (28) can thus be combined to determine the supply of currency.

3.5 Equilibrium and Price Dynamics

There are five market equilibrium conditions to consider: four financial (deposits, loans, central bank credit, and cash), and one for the goods market. Markets for deposits and loans adjust through quantities, with the bank setting prices in both cases. The supply of central bank credit is perfectly elastic at the official refinance rate and the market also equilibrates through quantity adjustment.

Prices adjust gradually to disequilibria between aggregate demand and aggregate supply. Using again a simple partial adjustment mechanism yields

$$d\pi_t/dt = \lambda^G(C_t + I_t - Y_t^s), \tag{29}$$

where $\lambda^G \geq 0$. The goods market is therefore in continuous equilibrium, and inflation adjusts instantaneously, when $\lambda^G \to \infty$. This specification is consistent with Fuhrer and Moore (1995) and has been used in a number of contributions.[30]

The last equilibrium condition relates to the market for cash, and (under the assumption that the counterpart to bank loans is held by firms in the form of currency) involves (10) and (27)-(28). However, there is no need to write this condition explicitly, given that by Walras' Law it can be eliminated.

Table 1 summarizes the list of variables and their definitions.

4 Solution and Steady State

We now consider the solution of the model under alternative specifications regarding the determination of the refinance rate, and study its steady-state properties.

[30] An alternative approach would be to assume a forward-looking specification, as in Calvo (1983). However, Calvo pricing leads to the counter-intuitive result that a negative demand shock leads to an *increase* in the change in inflation. Moreover, the evidence provided in Agénor and Bayraktar (2010) suggests that past inflation is a significant component of the inflation process for a number of middle-income developing countries.

4.1 Exogenous Refinance Rate

With the policy rate constant, first substitute equations (5) and (6) for output and investment in the desired loan rate equation, (24); this yields

$$i_t^{L,d} = \varepsilon^L \left\{ 1 + \theta^L [i_t^L, \frac{\kappa Y^s(\pi_t; i^R)}{I(i_t^L - \pi_t)}] \right\} i^R. \tag{30}$$

Substituting (30) in (25) yields

$$\frac{di_t^L}{dt} = \lambda^F FF(i_t^L, \pi_t; i^R), \tag{31}$$

where

$$FF_{i^L} = \varepsilon^L i^R [\theta_{i^L}^L - \theta_{Y^s/I}^L \kappa \tilde{Y}^s (\frac{I'}{\tilde{I}^2})] - 1 < 0,$$

$$FF_\pi = \varepsilon^L i^R \theta_{Y^s/I}^L \kappa (\frac{Y_\pi^s}{\tilde{I}} + \frac{\tilde{Y}^s I'}{\tilde{I}^2}) \lesseqgtr 0,$$

$$FF_{i^R} = \varepsilon^L [(1 + \theta^L) + \theta_{Y^s/I}^L \kappa (\frac{Y_{i^R}^s}{\tilde{I}}) i^R] > 0.$$

A rise in the lending rate increases monitoring effort and reduces the premium. It also lowers investment, which increases (at the initial inflation rate) the collateral-loan ratio. This, in turn, raises the repayment probability. The risk premium therefore falls unambiguously.

An increase in the inflation rate exerts two independent effects on the repayment probability and the risk premium. On the one hand, it tends to raise output (by reducing real wages) and the value of collateral, which tends to increase the repayment probability and reduce the premium, thereby lowering the *nominal* lending rate and stimulating investment. On the other, it tends to reduce the *real* lending rate, which also stimulates investment. Thus, both output and investment loans increase, implying that the net effect on the collateral-investment loan ratio (and thus the change in the actual loan rate) is ambiguous. If the effect on investment dominates, the result will be a fall in the collateral-loan ratio and an increase in the loan rate.

The condition for $FF_\pi > 0$ is $-I'\tilde{\pi}/\tilde{I} > Y_\pi^s\tilde{\pi}/\tilde{Y}^s$, or equivalently that the elasticity of investment with respect to inflation exceed the elasticity of output with respect to that variable.

An increase in the policy rate raises the desired loan rate both directly and indirectly, in the latter case by reducing output (given the increase in the effective cost of labor) and lowering the collateral-investment loan ratio, thereby raising the risk premium.[31] Its effect on changes in the loan rate is therefore unambiguously positive. Note also that if the risk premium does not depend endogenously on the collateral-investment loan ratio, $|FF_{i^R}|_{\theta^L_{Y^s/I}=0} < FF_{i^R}$. Put differently, the endogeneity of the premium is the source of a financial accelerator effect, as discussed in more detail in the next section.

The second step is to derive the dynamic equation of the inflation rate. Using (5), (6), (11) and (18) to substitute out for Y_t^s, I_t, C_t, and i_t^D in (29) yields, with $\alpha_0 = 0$ for simplicity,

$$\frac{d\pi_t}{dt} = \lambda^G\{I(i_t^L - \pi_t) - \alpha_2[\varepsilon^D(1-\mu)i^R - \pi_t] - [1 - \alpha_1(\pi_t)]Y^s(\pi_t; i^R)\}. \tag{32}$$

Solving this expression yields

$$\frac{d\pi_t}{dt} = \lambda^G GG(i_t^L, \pi_t; i^R, \mu), \tag{33}$$

where

$$GG_{i^L} = I' < 0,$$

$$GG_\pi = -I' + \alpha_2 - [1 - \alpha_1(\tilde{\pi})]Y_\pi^s + \tilde{Y}^s\alpha_1' \lessgtr 0,$$

$$GG_{i^R} = -\alpha_2\varepsilon^D(1-\mu) - [1 - \alpha_1(\tilde{\pi})]Y_{i^R}^s \lessgtr 0,$$

$$GG_\mu = \alpha_2\varepsilon^D i^R > 0.$$

[31] Note that, in calculating the partial effect of the policy rate on changes in the loan rate, the actual loan rate is taken as given; the indirect effect through investment is therefore not accounted for.

A rise in the loan rate lowers investment and creates excess supply, which tends to reduce inflationary pressures. An increase in the inflation rate exerts four types of effects on excess demand. First, it lowers the real lending rate and stimulates investment. Second, it reduces the real deposit rate, which induces households to increase current consumption. Third, it increases capital losses, which creates incentives to reduce the propensity to spend on current income. Fourth, it lowers real wages and raises aggregate supply and income, which in turn stimulates household spending. Thus, consumption may either increase or fall; in what follows we will focus on the case where the capital loss or wealth erosion effect is not too strong (compared to the income and intertemporal effects), implying that the net effect on consumption is positive. Although not necessary, this condition is sufficient to ensure that aggregate demand also increases. But because both aggregate demand and supply increase, the net effect on excess demand (and thus inflationary pressures) is ambiguous. Assuming that the aggregate demand effect dominates implies that $GG_\pi > 0$.[32]

In the same vein, an increase in the policy rate has conflicting effects on inflationary pressures. On the one hand, it lowers aggregate supply, by raising the effective cost of labor; on the other, it lowers aggregate demand, by reducing consumption (through the intertemporal effect). If the cost channel is mild or inexistent ($Y^s_{i^R} = 0$), only the standard aggregate demand effect operates, and a tightening of monetary policy lowers unambiguously the rate at which inflation increases ($GG_{i^R} < 0$). By contrast, if the cost channel is sufficiently strong, this effect is reversed. In what follows we will consider both cases.

Finally, an increase in the reserve requirement rate lowers the deposit rate and

[32]A sufficient (although not necessary) for this to be the case is that $I' + [1 - \alpha_1(\tilde{\pi})]Y^s_\pi < 0$, or equivalently $-I'\tilde{\pi}/\tilde{I} > (Y^s_\pi \tilde{\pi}/\tilde{Y}^s)\{[1-\alpha_1(\tilde{\pi})]\tilde{Y}^s/\tilde{I}\}$. If $[1-\alpha_1(\tilde{\pi})]\tilde{Y}^s/\tilde{I} > 1$, the condition for having $FF_\pi > 0$ does not in general ensure that $GG_\pi > 0$. Note also that if a wage curve (relating the levels of real wages and the unemployment rate) had been assumed, as noted earlier, then $Y^s_\pi = 0$ and the condition $GG_\pi > 0$ would always hold.

induces households to shift consumption toward the present, thereby increasing aggregate demand and, all else equal, inflationary pressures.

The model therefore boils down to a dynamic system in two variables, the loan rate and the inflation rate, i_t^L and π_t. The steady-state equilibrium solutions for these variables can be determined directly from (25) and (29), by setting $di_t^L/dt = d\pi_t/dt = 0$; using (18), these solutions are

$$\tilde{\imath}^L - \varepsilon^L[1 + \theta^L(\frac{\kappa Y^s(\tilde{\pi}, i^R)}{\tilde{I}})]i^R = 0, \tag{34}$$

$$[1 - \alpha_1(\tilde{\pi})]Y^s(\tilde{\pi}, i^R) + \alpha_2[\varepsilon^D(1 - \mu)i^R - \tilde{\pi}] + I(\tilde{\imath}^L - \tilde{\pi}) = 0, \tag{35}$$

which can be used to formally assess the long-run effects of a change in the policy rate. However, as discussed next, it is more convenient to do so graphically.

Before doing so, note also that in the steady state, the real wage must be constant, at, say, $\tilde{\omega}$.[33] From (4) and (5), this implies that labor demand and output in the long run, $\tilde{N}^d$ and $\tilde{Y}^s$, do *not* depend on the inflation rate, only on the refinance rate. As a result, a higher inflation has no effect on the supply side in the long run.[34] From (7), and because of the constancy of the real wage, the real credit stock must be constant in the steady state as well.

Equation (34) defines the combinations of the loan rate and inflation rate for which the actual loan rate is equal to the desired rate; it is shown as curve FF in Figure 1. Similarly, equation (35) defines the combinations of the loan rate and inflation rate for which aggregate supply is equal to aggregate demand, and inflation is constant; it is shown as curve GG in the same figure. In what follows we focus solely on the case where both FF_π and GG_π are positive. Thus, both curves are upward sloping.

[33] This means that the nominal wage must grow at the same rate as the level of prices.

[34] Again, under the assumption of a wage curve, then $Y_\pi^s = 0$ and inflation would have no direct effect on output, neither during the transition nor in the steady state.

The Appendix discusses the stability conditions of the model in the vicinity of the steady state. As discussed there, stability requires that the loan rate adjust relatively faster than goods prices (that is, λ^F to be relatively high compared to λ^G) and that FF be steeper than GG, as shown in Figure 1.[35] The figure also shows two illustrative adjustment paths (both counter-clockwise, one with cycles), starting from an initial point A at $t = 0$.[36]

4.2 Endogenous Refinance Rate

The policy rate is now endogenous and determined by a Taylor-type rule,

$$di_t^R/dt = \chi_1(\pi_t - \pi^T) + \chi_2(C_t + I_t - Y_t^s), \tag{36}$$

where $\chi_1, \chi_2 > 0$ and $\pi^T \geq 0$ is the central bank's inflation target. Thus, in a manner similar to the way monetary policy should be conducted under a flexible inflation targeting regime, changes in the policy rate respond to inflation gaps and excess demand for goods. This specification implies a persistence parameter of unity, which is consistent with some of the evidence for middle-income countries (see Mohanty and Klau (2004)).

To maintain analytical tractability (and the ability to use phase diagrams), the loan rate is now taken to adjust instantaneously, so that $\lambda^F \to \infty$. Equation (30) can then be solved for the loan rate as a function of the inflation rate and the policy rate:

$$i_t^L = J(\pi_t, i_t^R), \tag{37}$$

[35] For given values of the adjustment speed parameters, it can also be shown that instability may result either from a strong accelerator effect, as captured by $\theta^L_{Y^s/I}$, or from strong sensitivity of investment to the real lending rate, as captured by I'. Thus, instability may be caused by either real or financial factors.

[36] The Appendix shows also that if the wealth erosion effect is very strong, so that $GG_\pi < 0$, the system is always stable. In that case curve GG has a negative slope. For the remainder of the paper, however, we will continue to focus on the case where $GG_\pi > 0$.

where[37]

$$\Omega = 1 - \varepsilon^L \tilde{\imath}_R \left\{ \theta^L_{i^L} - \theta^L_{Y^s/I} (\frac{\kappa \tilde{Y}^s}{\tilde{I}^2}) I' \right\} > 0,$$

$$J_\pi = \frac{\varepsilon^L \theta^L_{Y^s/I} \kappa}{\Omega} [(\frac{Y^s_\pi}{\tilde{I}} + \frac{\tilde{Y}^s I'}{\tilde{I}^2})] \tilde{\imath}^R \lesseqgtr 0,$$

$$J_{i_R} = \frac{\varepsilon^L}{\Omega} \left\{ (1 + \theta^L) + \frac{\theta^L_{Y^s/I} \kappa Y^s_{i^R}}{\tilde{I}} \right\} > 0.$$

As before, a rise in inflation has in general an ambiguous effect on the loan rate, because of positive effects on both output and investment, which implies that the net effect on the collateral-loan ratio is indeterminate; if, as discussed earlier, the investment effect dominates (that is, $-I'\tilde{\pi}/\tilde{I} > Y^s_\pi \tilde{\pi}/\tilde{Y}^s$) the loan rate will go up ($J_\pi > 0$). An increase in the refinance rate raises the cost of funds for the bank, and this is "passed on" directly to borrowers. This lowers the demand for working capital loans. In turn, the fall in output tends to reduce the collateral-loan ratio, which tends to increase the premium. Thus, as before, the loan rate increases unambiguously.

Substituting (37) in (32) yields

$$\frac{d\pi_t}{dt} = \lambda^G \left\{ I[J(\pi_t, i^R_t) - \pi_t] - \alpha_2[\varepsilon^D(1-\mu) i^R_t - \pi_t] - [1 - \alpha_1(\pi_t)] Y^s(\pi_t, i^R_t) \right\},$$

which can be solved to give

$$\frac{d\pi_t}{dt} = \lambda^G GG(\pi_t, i^R_t; \mu), \tag{38}$$

where now

$$GG_\pi = I'(J_\pi - 1) + \alpha_2 - [1 - \alpha_1(\tilde{\pi})] Y^s_\pi + \tilde{Y}^s \alpha'_1 \} \lesseqgtr 0,$$

$$GG_{i^R} = I' J_{i^R} - \alpha_2 \varepsilon^D (1-\mu) - [1 - \alpha_1(\tilde{\pi})] Y^s_{i^R} \lesseqgtr 0,$$

$$GG_\mu = \alpha_2 \varepsilon^D \tilde{\imath}^R > 0.$$

[37] Of course, there is a direct link between the coefficients in (31) and those in (37); in particular, $\Omega = -FF_{i^L}$ and $J_x = -FF_x / FF_{i^L}$, for $x = \pi, i^R$.

As before, we will focus on the case where the aggregate demand effect of a rise in inflation dominates the supply effect, so that $GG_\pi > 0$. We will again consider separately the cases where $Y^s_{i^R}$ is relatively small (so that $GG_{i^R} < 0$) and the case where $Y^s_{i^R}$ is sufficiently large to ensure that $GG_{i^R} > 0$.

Substituting (5), (6), (11) (18) and (37) for Y^s_t, I_t, C_t, i^D_t and i^L_t in (36) yields now

$$\frac{di^R_t}{dt} = \chi_1(\pi_t - \pi^T) + \chi_2 \left\{ I[J(\pi_t, i^R_t) - \pi_t] \right.$$
$$\left. -\alpha_2[\varepsilon^D(1-\mu)i^R_t - \pi_t] - [1 - \alpha_1(\pi_t)]Y^s(\pi_t, i^R_t) \right\},$$

or equivalently

$$\frac{di^R_t}{dt} = RR(\pi_t, i^R_t; \mu), \tag{39}$$

where

$$RR_\pi = \chi_1 + \chi_2[I'(J_\pi - 1) + \alpha_2 - [1 - \alpha_1(\tilde{\pi})]Y^s_\pi + \tilde{Y}^s\alpha_1'\}] \gtrless 0,$$

$$RR_{i^R} = \chi_2[I'J_{i^R} - \alpha_2\varepsilon^D(1-\mu) - [1 - \alpha_1(\tilde{\pi})]Y^s_{i^R}] \gtrless 0,$$

$$RR_\mu = \chi_2\alpha_2\varepsilon^D\tilde{\imath}^R > 0.$$

An increase in inflation raises both aggregate supply and aggregate demand, implying an ambiguous effect on the policy rate; if the aggregate demand effect dominates, as discussed before, the policy rate will unambiguously increase ($RR_\pi > 0$).[38] Similarly, an increase in the policy rate raises the loan rate as well as the deposit rate, dampening both investment and consumption; aggregate demand falls, but so does output, as a result of the cost channel. We will consider again the two

[38]Whether the Taylor principle holds here cannot be ascertained because RR_π measures the effect of an increase in inflation on the *change* in the policy rate. At first sight, it might be thought that in the present setting the principle requires that the nominal policy rate increase sufficiently to ensure that the *real* deposit and loan rates (which affect consumption and investment) increase as well following a positive shock to inflation, to ensure a fall in aggregate demand. However, a rise in real market rates is neither necessary nor sufficient. The reason is the endogeneity of the risk premium and the fact that changes in the policy rate exert supply-side effects. Put differently, the real interest rate is no longer the only variable influencing the output gap (or excess demand) and hence inflation.

separate cases, where $Y^s_{i^R}$ is low enough for $RR_{i^R} < 0$ (the standard case) and $Y^s_{i^R}$ is high enough to ensure that $RR_{i^R} > 0$.

Equations (38) and (39) determine the dynamics of inflation and the policy rate. Their steady-state equilibrium solutions are given by

$$[1 - \alpha_1(\tilde{\pi})]Y^s(\tilde{\pi}, \tilde{\imath}^R) + \alpha_2[\varepsilon^D(1-\mu)\tilde{\imath}^R - \tilde{\pi}] - I[J(\tilde{\pi}, \tilde{\imath}^R) - \tilde{\pi}] = 0, \quad (40)$$

$$\tilde{\pi} = \pi^T. \quad (41)$$

Equation (40) defines the combinations of the policy rate and inflation rate for which aggregate supply is equal to aggregate demand, and inflation is constant; it is shown as curve GG in Figure 2. Equation (41) is a vertical line, given that in the steady state the inflation rate is equal to the target rate. It is shown as curve RR in the same figure.[39] The initial equilibrium is at point E and trajectories from any initial point (π_0, i^R_0) may involve a counter-clockwise spiraling approach, just as in Figure 1.

The Appendix discusses also the stability properties (in the vicinity of the steady state) of the model with endogenous policy response. As shown there, stability depends now importantly on the strength of the cost channel, as captured by $Y^s_{i^R}$. With a "mild" or inexistent cost channel, stability requires only that the speed of adjustment of the goods market be relatively small, because the slope of GG is always less than the slope of RR, as shown in Figure 2. By contrast, with a "strong" cost channel the model is unstable—despite the fact that the policy rate adjusts endogenously to mitigate inflation deviations from target and excess demand. Intuitively, with a strong cost channel, increases in the policy rate tend to create large increases in excess demand and stronger inflationary pressures, which in turn lead to further hikes in the policy rate, thereby further reducing output supply and

[39] With (41) determining the steady-state inflation rate, equation (40) determines the steady-state policy rate.

increasing excess demand, and so on.[40]

Finally, note that our analysis has focused on a simple Taylor-type rule, expressed directly in terms of the *rate of change* of the policy rate and with the inflation gap and excess demand as explanatory variables. Alternatively, if the central bank had been assumed to set its interest rate to minimize quadratic costs associated with deviations in the loan rate and inflation from their target values (say, π^T and $i^{L,T}$), optimal stabilization policy would yield a rule in the *level* of i_t^R that is linear in $\pi_t - \pi^T$ and $i_t^L - i^{L,T}$; see Turnovsky (2011) for instance. This rule could then be either substituted in (31) and (33) to yield a dynamic system in π_t and i_t^L, if the policy rate is subject to instantaneous adjustment, or instead, combined with these two equations to yield a dynamic system in π_t, i_t^L, and i_t^R, if the policy rate is subject to a partial adjustment process of the type shown in (25).

5 Monetary and Regulatory Policies

To examine the transmission process of monetary and macroprudential policies, we consider an autonomous and permanent increase in the refinance rate, and a permanent rise in the reserve requirement ratio, μ.

5.1 Increase in Refinance Rate

The macroeconomic effects of an autonomous increase in the refinance rate are illustrated in Figures 3 and 4. The immediate effect of an increase in i_R (at the initial loan and inflation rates) is to raise the loan rate, because it represents an increase in the marginal cost of funds, which is "passed on" directly to borrowers. There is also a direct adverse effect on production costs, which lowers output. The resulting drop in collateral tends to put upward pressure on the risk premium. Thus, the change in

[40] As shown in the Appendix, with $GG_\pi < 0$, the model is always stable if the cost channel is mild or inexistent, and always unstable if the cost channel is strong.

the loan rate is unambiguously positive on impact.

The increase in the lending rate lowers investment, which in turn tends to lower the risk premium by reducing the volume of bank loans. As discussed earlier, the investment effect dominates, and the collateral-investment loan ratio rises. Thus, the net effect of an increase in the policy rate is to raise the premium and the loan rate over time, at least during the first phase of the transition.

To analyze the transitional dynamics of this policy shock, we need to consider two cases: a "mild" or inexistent cost channel (a low value of $Y^s_{i^R}$, so that $GG_{i^R} < 0$), displayed in Figure 3, and a "strong" cost channel (with GG_{i^R} high enough to ensure that $GG_{i^R} > 0$), illustrated in Figure 4. Graphically, curve FF shifts upward in both figures, but curve GG may shift either upward or downward. If $GG_{i^R} < 0$, the shock creates excess supply, and the rate of inflation must fall; GG shifts downward. Conversely, with $GG_{i^R} > 0$, GG shifts upward and inflation must increase—at least during some part of the transition to the new equilibrium.

Indeed, during the transition the impact on inflation results from several effects. As noted earlier, both aggregate supply and investment fall. In addition, the refinance rate raises the deposit rate, thereby lowering current consumption. Aggregate demand therefore falls as well. Because aggregate supply and aggregate demand both fall, prices may either increase or fall to restore equilibrium in the goods market.

Consider first the standard case of a mild or inexistent cost channel, illustrated in Figure 3. Curve GG shifts downward. If the loan rate adjusts gradually, there are several trajectories possible. In both of the cases shown in the figure, the loan rate increases at first. After the initial rise in the loan rate, it begins to drop, because the fall in inflation reduces investment by more than output, implying therefore an increase over time in the collateral-investment loan ratio; thus, the premium falls over time. There is therefore overshooting. The economy converges to the new equilibrium point E', characterized by both lower inflation and a lower loan rate.

The loan rate most likely overshoots its new, lower equilibrium value.[41]

There are two particular cases worth pointing out. If instead the loan rate adjusts instantaneously, it will jump from E to point A on the new FF curve, and the adjustment process will occur monotonically along FF toward point E'. If the aggregate supply and aggregate demand effects of a change in the policy rate exactly offset each other, so that $GG_{i^R} = 0$, curve GG will not shift; the long-run equilibrium will then be at point E''. Although it is possible for the adjustment process from E to E'' to be monotonic (as shown in the figure), it may also involve cycles.

Consider now the case of a strong cost channel. Outcomes are now more ambiguous, depending on how strong that channel is. Figure 4 illustrates some alternative scenarios. If the upward shift in GG is not too large, the economy may converge to point E'; even though inflation increases initially, the rise in the loan rate over time is such that the initial excess demand is worked off fairly rapidly, thereby putting downward pressure on inflation and reversing the initial upward movement in the loan rate. The economy in that case converges to an equilibrium characterized by a higher loan rate than initially but also a lower inflation rate.

Alternatively, if the upward shift in GG is large, the initial increase in inflation lowers the collateral-loan ratio over time and leads to a higher loan rate, as before. However, the higher rate of inflation serves to stimulate investment by more than output, in such a way that excess demand prevails during the whole transition process; the economy converges (possibly monotonically) to the equilibrium point E'', characterized by both higher inflation and a higher loan rate. There is therefore a "price puzzle," in the sense that a monetary contraction leads to higher inflation, despite higher loan rates.

If the loan rate adjusts instantaneously ($\lambda^G \to \infty$), the increase in the policy rate leads again to an immediate upward jump in the loan rate, to point A, and

[41] Overshooting of inflation cannot be ruled out either, because the approach to point E' may also involve a spiralling trajectory.

depending on the magnitude of the shift in GG, the economy may converge to either E' or E''. Thus, the speed of adjustment of the loan rate does not affect whether a price puzzle may emerge or not.

In what sense does a financial accelerator effect operate in the model? Essentially it results from the fact that the magnitude of the shift in the financial equilibrium condition FF curve on whether the risk premium is endogenous or not. As shown earlier, $|FF_{i^R}|_{\theta^L_{Y^s/I}=0} < FF_{i^R}$; so the greater $\theta^L_{Y^s/I}$, the larger the upward shift in FF, and thus (all else equal) the larger the initial increase in the loan rate. In that sense, indeed, the initial upward effect of a rise of the policy on the loan rate is magnified. Note, however, that the financial accelerator effect is most likely only temporary; stability of the adjustment process means that it is very likely to be followed by a counter-clockwise "decelerator" effect, which reflects essentially the dynamics of inflation.[42]

The role of the regulatory regime is captured by μ. A high value of the reserve requirement rate does not affect the pass-through from the refinance rate to the loan rate but it does mitigate the pass-through from the policy rate to the deposit rate. In turn, this dampens the effect of an increase in the refinance rate on consumption—making it more likely that the supply-side effect will dominate. Graphically, if the cost channel is strong it means that the upward shift in GG is magnified with a higher μ—thereby increasing the likelihood of an *increase* in inflation. Put differently, in this setting, a macroprudential policy that relies on higher reserve requirements may make it more difficult for the central bank to achieve low inflation. This is a somewhat counterintuitive result.

However, it is important to note that the analysis so far does not capture the possibility that macroprudential policy may also exert a signaling effect with respect

[42]Note also that if GG does not shift—which is the case if $GG_{i^R} = 0$—the transition from the initial equilibrium to the new equilibrium at E'' can occur monotonically, as shown in Figure 3. There is therefore no accelerator effect *per se*.

to the safety of the banking system. Suppose indeed that what matters to depositors is the expected real deposit rate, given by $p(\mu)(i_t^D - \pi_t)$, where $p(\mu)$ is the probability of payment by the bank, which depends positively on the reserve requirement rate; thus, $p' > 0$. It can be easily established that now the first term in the expression for GG_{i^R}, given below equation (33), is $-\alpha_2\varepsilon^D p(\mu)(1-\mu)$; and if $p'/p > 1/(1-\mu)$, a higher value of μ makes that term larger (in absolute terms), not smaller, which magnifies the demand-side effect of an increase in the refinance rate and mitigates the upward shift in GG—thereby making it less likely to observe the price puzzle. Thus, if macroprudential policy is effective, in the sense that it raises confidence by households in the banking system, it will also contribute to making monetary policy more effective. This analysis illustrates well the importance of understanding the monetary transmission mechanism in designing an integrated monetary-macroprudential framework.

5.2 Increase in Reserve Requirement Rate

In developing countries, changes in reserve requirements have often been used as a substitute to interest rate policy—especially during episodes of large capital inflows—to mitigate their impact on domestic liquidity and credit growth.[43] But in normal times, reserve requirements are fundamentally a prudential tool, which can help to absorb liquidity shocks and thereby enhance *systemic* resiliency. The role of liquidity-absorbing instruments has received renewed attention since the global crisis. Indeed, one of the measures envisaged under Basel III—to be phased in starting in 2015—is to require banks to increase their holdings of liquid assets, by imposing a minimum liquidity coverage ratio (see Basel Committee on Banking Supervision (2011)). It is therefore useful to consider the macroeconomic effects of an increase in the required

[43] See Montoro and Moreno (2011) for a review of the evidence on the use of reserve requirements in Latin America. See also Agénor and El Aynaoui (2010) for a theoretical analysis of the role of reserve requirements in a context of excess liquidity.

reserve ratio in our setting.

The results are illustrated in Figures 5 and 6, depending on whether the policy rate is endogenous or not. In both cases, an increase in the reserve requirement rate lowers the deposit rate and induces on impact households to shift consumption toward the present, thereby increasing initially aggregate demand and inflationary pressures.

Abstracting from the possible nonmonotonic nature of the adjustment paths, what are the core features of the adjustment mechanism? With an exogenous policy rate, over time the higher inflation rate stimulates output and investment. Under the assumption that the collateral-investment loan ratio falls, the net effect is an increase in the loan rate, which tends to mitigate the expansionary effect of higher inflation on investment. On impact, FF does not change whereas GG shifts upward. The equilibrium moves from point E to point E', with a higher loan rate and a higher inflation rate. Thus, in this setting, with a full cost channel and a weak wealth erosion effect, a macroprudential policy based on higher reserve requirements is inflationary in the short run—and possibly in the long run, in the (admittedly, less realistic) case where monetary policy is passive.[44] Under the monetary policy regime that we consider, changes in reserve requirements have no direct effect on banks' cost of funds. Because the central bank stands ready to provide the funds demanded by banks at the given policy rate, increases in reserve requirements leave banks' cost of funds—and therefore their lending rates—unaffected while lowering the interest rate that represents the opportunity cost of current versus future consumption, thereby generating an expansionary effect and fueling excess demand.

With an endogenous policy rate, the central bank does adjust its policy instrument to choke off the inflationary pressures that tend to develop initially, and as

[44]This effect was pointed out by Agénor and Montiel (2008*b*), in a static model where macroeconomic equilibrium is defined in terms of the price level, rather than inflation. Of course, if we were to assume instead that *deposit* rates adjust at a slower rate than lending rates, then aggregate demand would unambiguously fall initially, thereby putting downward pressure on inflation.

a result, in the long run the inflation rate does not deviate from its target value. The higher policy rate raises the loan rate, which tends to reduce investment and aggregate demand, thereby mitigating inflationary pressures over time. However, the initial effect remains the same as in the case of an exogenous policy rate, as illustrated in Figure 6: the inflation rate always rises during the first phase of the transition process.

Can the model generate a drop in inflation on impact? A possible way to do so is to alter the specification of the aggregate demand side. As before, consider the case where macroprudential policy exerts a signaling effect regarding the health of the banking system, and that what matters for portfolio decisions is the expected real deposit rate, given again by $p(\mu)(i_t^D - \pi_t)$, with $p' > 0$. It can be easily established that GG_μ, given below either (33) or (38), is now equal to $\alpha_2 \varepsilon^D i^R [p - (1-\mu)p'] \lesseqgtr 0$. In particular, if $p'/p > 1/(1-\mu)$, then $GG_\mu < 0$, and the increase in μ will lead to a *downward* shift in GG in both Figures 5 and 6. As a result, and abstracting from cycles, the transitional dynamics will be characterized either by continuous reductions in inflation (path from E to E'' in Figure 5) or lower, instead of higher, inflation initially (path from E to E'' in Figure 6). Another possibility is to include interest payments to households, $i_t^D d_t$, in the definition of income upon which consumption of liquidity-constrained agents depend. By lowering directly interest income, an increase in the reserve required ratio would therefore generate conflicting income and intertemporal substitution effects; depending on the values of α_1 and α_2, the net effect could be a fall in consumption. A third possibility is to alter the specification of the supply side, and consider how the combination of parameters affecting the demand and supply sides may interact to generate a drop in inflation on impact. We do so next by calibrating the model and performing numerical experiments.

6 Calibration and Numerical Experiments

To further explore the properties of the model, we now provide an illustrative (but fairly representative) calibration for a middle-income country and study the short- and long-run effects of a change in the reserve requirement ratio.[45] We focus on the case where the refinance rate is endogenous, as this represents the more empirically-relevant case, with the dynamic system consisting of (29) and (36). Thus, although inflation and the refinance rate cannot jump on impact in response to a change in μ—and thus neither can the loan rate, investment, nor aggregate supply—the deposit rate, consumption and aggregate demand can. To facilitate numerical computations, the behavioral equations (6), (8) and (11) are written as

$$d_t = \exp[d_0 + d_1(i_t^D - \pi_t)], \quad I_t = \exp[i_0 - i_1(i_t^L - \pi_t)],$$

$$C_t = \exp[\alpha_0 - \alpha_{11}\pi_t + \alpha_{12}\ln Y_t^s - \alpha_2(i_t^D - \pi_t)],$$

where d_0, i_0, and α_0 are scale parameters, α_{12} is the elasticity of consumption with respect to income, d_1, i_1, and α_2 are semi-elasticities of deposits, investment, and consumption with respect to interest rates, and α_{11} is the semi-elasticity of consumption with respect to inflation.

We also solve equation (24) for i_t^L and normalize the coefficient of the refinance rate to unity (to ensure a complete pass-through) in the resulting equation; thus, the loan rate is now given by $i_t^L = i_t^R + \Theta_t^L$, where

$$\Theta_t^L = \Theta_0^L(\frac{\kappa Y_t^s}{I_t})^{-\Theta_1},$$

where Θ_0^L is a scale parameter and Θ_1 an elasticity. In addition, to consider various assumptions about the strength of the cost channel, equation (4) is rewritten as

$$N_t^d = [\alpha^{-1}(\frac{1 + \psi^L i_t^R}{1 + \pi_t})]^{-1/(1-\alpha)},$$

[45]For lack of space, we do not consider the effect of changes in the policy rate.

where $\psi^L \in (0, 1)$ measures the fraction of the wage bill that must be financed by bank loans prior to production. This implies that equation (7) must also be changed to $L_t^F = \psi^L W_t N_t^d + P_t I_t$. The absence of the cost channel corresponds therefore to $\psi^L = 0$.

Dwelling on Agénor and Alper (2012) and Agénor et al. (2012, 2013), as well as some other sources, we calibrate these parameters as follows. On the household side, the parameter ψ, which represents the ratio of currency plus deposits over consumption, is set at 0.3. The labor share in the production function is set at $\alpha = 0.66$, a fairly standard choice. The cost channel is assumed to be relatively weak initially, so that $\psi^L = 0.1$; a higher value of $\psi^L = 0.6$ is used later for sensitivity analysis. The semi-elasticity of investment with respect to the real loan rate, i_1, is set at 3.0, to capture a high sensitivity of investment with respect to changes in the cost of borrowing. An alternative value of 1.5, which is close to the value estimated by Minella and Souza-Sobrinho (2013) for Brazil for instance, is also used later on. In the consumption function, the wealth depletion effect on consumption, α_{11}, is calibrated at 0.1, meaning that a 1 percentage point increase of inflation causes, everything else equal, a 0.1 percent fall in consumption to replenish savings. The income elasticity of consumption α_{12} is set equal to 0.8, to reflect the evidence, alluded to earlier, that a large proportion of households in middle-income countries are liquidity constrained and tend to have short planning horizons. The semi-elasticity of consumption with respect to the real deposit rate, α_2, is set equal to 0.3 initially, close to the value estimated for instance by Minella and Souza-Sobrinho (2013) for Brazil. An alternative value of 0.1, which reflects better the evidence of a weak intertemporal substitution effect (see Agénor and Montiel (2008*a*)), is also used for sensitivity analysis.

The elasticity of the risk premium with respect to the effective collateral-investment loan ratio, Θ_1, is set at 2, which implies a convex relationship: as the collateral-loan ratio rises, the premium rises at an increasing rate, eventually leading to outright rationing. The parameter measuring the effective share of output used as collateral, κ, is set at 0.2, as in Agénor and Alper (2012). This is somewhat lower than the value of 0.31 used in Cavalcanti (2010) for instance, but consistent with the evidence (discussed earlier) suggesting that, due to weak legal systems, seizing collateral is difficult in many developing countries.

Regarding the central bank, the coefficients in the Taylor rule are set at $\chi_1 = 1.5$ and $\chi_2 = 0.5$, in line with some of the estimates reported by Moura and Carvalho (2010) for a group of Latin American countries. The reserve requirement rate is set at 0.2 initially, consistent with the average value reported in Montoro and Moreno (2011). The speed of adjustment of inflation to excess demand is set at $\lambda^G = 0.4$; sensitivity analysis with higher values (which are not reported here to save space) had limited effects on the results, given that changes in λ^G do not affect the steady state.

In terms of initial values, the inflation target is set at $\pi^T = 0.02$. The scale factors $\alpha_0, i_0, \Theta_0^L$ and d_0 are adjusted so as to replicate some key ratios and values for the interest rates in the initial steady state. First, we set the policy rate at 0.03 and the loan rate at 0.08. Setting $\varepsilon^D = 1$ in (18) for simplicity, the deposit rate is therefore 2.4 percent. Given the approximation defined earlier, this also implies that the risk premium is initially 0.05, close to the value used in Agénor et al. (2012). We also assume that the private investment-consumption ratio is 0.25, and that the currency-deposit ratio of 0.2. Thus, consistent with existing data for middle-income countries, investment is a relatively small fraction of output compared to consumption, and a large share of the narrow money stock is in the form of bank deposits, as opposed to cash. Benchmark parameters and initial values are summarized in Table 2.

Consider now a permanent increase in the reserve requirement rate, from its initial value of 0.2 to 0.3. As noted earlier, this experiment helps to illustrate the use of an instrument that can be viewed both as a monetary policy tool and a macroprudential tool (depending on the objectives of the policy change), and to illustrate how a change in that instrument interacts with changes in the policy rate, which responds endogenously to inflation and excess demand.

The results with the benchmark parameters described above are shown in Figure 7. The direct effect of the shock is to reduce the deposit rate (by about 30 basis points), which induces households to lower savings and increase consumption today. Because investment cannot change on impact, this creates excess demand at the initial policy rate and puts immediately upward pressure on inflation ($\dot{\pi}_0 > 0$). As a result of both higher inflation and the initial increase in aggregate demand, the policy rate begins to rise ($di_0^R > 0$). This exerts two types of effects. First, it raises the (real) loan rate, which tends to lower investment over time. Second, it puts upward pressure on labor costs. Because the increase in inflation tends to lower the real wage, whether the *effective* cost of labor, which is here given by $(1+\psi^L i_t^R)/(1+\pi_t)$, increases also is in general ambiguous. In the simulation reported in Figure 7, and given the calibration adopted (namely, the low value of ψ^L), the effective wage actually falls initially, and begins increasing after a few periods (once inflation begins to fall). The initial drop in the effective wage raises aggregate supply at first. Because investment falls and output supply rises, the collateral-loan ratio increases unambiguously over time; as a result, the risk premium falls, thereby mitigating the impact of the higher policy rate on the loan rate. In the long run, the loan rate therefore rises by less (9.4 basis points) than the policy rate (12 basis points), given that the risk premium is lower.

During the first phase of the transition, because the increase in consumption dominates the drop in investment, aggregate demand increases as well and does so at a faster rate than aggregate supply; thus, excess demand develops, putting continued upward pressure on inflation. The policy rate therefore continues to rise, which tends to reverse the initial downward movement in the deposit rate. As a result, consumption begins to fall. Combined with a continuous decline in investment, aggregate demand also falls, reducing therefore over time inflationary pressures and dampening the rise in the policy rate. The drop in inflation, coupled with continued increases in the refinance rate, reverses the initial fall in the effective real wage and translates eventually into a contraction of aggregate supply. However, during the second phase of the transition the fall in aggregate demand dominates the fall in aggregate supply, implying that after an initial period during which inflation increases, it begins to fall. Inflation returns to its initial equilibrium π^T, but all other variables are permanently affected: the policy rate and the lending rate are higher (by about 12 and 9.4 basis points, respectively, as noted earlier), the deposit rate lower (by about 21.6 basis points), aggregate demand and supply lower (by about 0.02 percent), and the effective cost of labor higher. Thus, although it is initially expansionary, the increase in required reserves has a contractionary effect on output in the long run.

Figues 8, 9 and 10 provide sensitivity analysis for alternative parameter values.[46] Figure 8 considers the case of a stronger cost channel, by assuming that $\psi^L = 0.6$ instead of 0.1. The key difference is that the aggregate supply now falls almost immediate, implying that excess demand is stronger; as a result, inflation rises by more than in the benchmark case, which therefore implies that the policy rate also rises by more. The larger drop in output exceeds the larger contraction in investment, implying that the risk premium rises also by more. In the steady state, interest rates are higher, and aggregate supply and demand are both lower.

Figure 9 considers the case where the intertemporal substitution effect is weaker than assumed in the benchmark experiment ($\alpha_2 = 0.1$ instead of 0.3). The key difference now is that the initial increase in consumption is smaller; as a result, the rise in excess demand is mitigated, and inflation rises by less than in the benchmark.

[46] More extensive sensitivity analysis was conducted (with respect to α_{12}, κ, Θ_1, λ^G, and so on) but the results are not reported here due to lack of space.

The implication again is that the central bank increases the policy rate by less than before, implying a smaller rise in the lending rate and a smaller contraction in investment. The adjustment process associated with a stronger wealth erosion effect (that is, a higher value of α_{11}) is qualitatively similar to what is depicted in Figure 9, given that it also mitigates the increse in household expenditure.

Finally, Figure 10 focuses on the case where the semi-elasticity of investment with respect to the loan rate is smaller than the value assumed in the benchmark experiment ($i_1 = 1.5$ instead of 3.0). Interestingly, because investment is a relatively small fraction of output, this parameter change does not have much effect on the initial phase of the transitional dynamics; eventually, the smaller drop in investment and aggregate demand adds to inflationary pressures, which implies that the refinance and lending rates rise by more. As a result, in the long run, both aggregate supply and demand are lower than in the benchmark case.

Overall, these simulations provide a useful complement to the phase diagram analysis presented earlier, based on the assumptions of a full cost channel and a relatively weak wealth erosion effect. In the short run, whether aggregate supply and aggregate demand respond in the same direction to a change in that ratio depends on the strength of the cost channel, in addition to the parameters that affect the sensitivity of demand components (consumption and investment) to interest rates. These include not only sensitivity to interest rates but also wealth (erosion) effects associated with inflation. Moreover, because inflation changes as a result of any disequilibrium in the goods market, and the policy rate responds endogenously to changes in inflation, the long-run effects of the shock depend crucially on the nature of monetary policy.

In the long run, a change in reserve requirement tends to reduce aggregate supply and demand, with no effect on inflation, in the short run, however, unless aggregate demand falls initially, an increase in the reserve requirement ratio is likely to be higher inflation. This is because in the model, neither the inflation rate nor aggregate supply can jump on impact. As noted earlier, a fall in aggregate demand may occur if one takes into account the fact that higher required reserves may signal a stronger banking system. The numerical experiments suggest that even without a signaling effect, this may still happen, depending on the configuration of parameters: if the degree of intertemporal substitution is low, the magnitude of the wealth erosion effect is high, and the cost channel is weak, consumption and excess demand may actually fall, implying therefore downward pressure on inflation on impact. However, at the same time, lower excess demand and the drop in inflation will induce the central bank to lower the refinance rate, which will stimulate investment; if investment is highly sensitive to the cost of borrowing, the initial drop in aggregate demand can be significantly mitigated—and so is its downward effect on inflation. Thus, this analysis illustrates well how the impact of macroprudential policy (in addition to its effect on risk perceptions) depends on the monetary policy regime.

7 Concluding Remarks

The purpose of this paper has been to present a simple dynamic macroeconomic model of a bank-dominated financial system that captures some of the key credit market imperfections commonly found in middle-income countries. The model assumes that the bank engages in costly monitoring to reduce the credit risk in its loan portfolio. This led to an endogenous determination of the risk premium in loan rates, which was shown to vary inversely with the ratio of collateral (measured in terms of a fraction of output supply) to bank borrowing for investment purposes. Thus, even though net worth or balance sheet effects are not explicitly introduced, the model retains a key feature of the literature on credit market imperfections in the tradition of Bernanke et al. (2000), namely, the possibility of a financial accelerator effect due to changes in collateral-loan ratios, induced not by changes in asset prices but rather by endogenous adjustment in factor prices and borrowing costs.

The model was used to analyze the interactions between monetary and macroprudential policies, involving, in the latter case, changes in reserve requirements. A qualitative analysis of these policies was followed by quantitative experiments, based on a calibrated version of the model.

One of the key lessons of these experiments is that, in response to a change in reserve requirements, there are a number of factors that affect how excess demand (and thus inflationary pressures) change in the short run—the strength of the cost channel, the magnitude of interest rate and wealth effects on aggregate demand components, but also the response of monetary policy to inflation gaps. In particular, if the cost channel is weak, and the sensitivty of aggregate demand to interest rates and inflation is such that the increase in aggregate demand is also weak, excess demand may actually fall, implying therefore downward pressure on inflation. In the long run, the impact of a change in the reserve requirement ratio is contractionary. The response of monetary policy matters for both the short- and the long-run effects of the policy.

The model could be extended in various directions. First, the theory underlying the determinants of private investment was kept deliberately simple, with a focus on the cost of loans, and the dynamics of private capital accumulation were ignored. Doing so in a nonrecursive manner would increase the order of the dynamic system and would preclude an analytical characterization of the transitional dynamics, but a numerical solution could be implemented. We also did not account for the stock market, given the relatively limited role that such markets continue to play in middle-income countries; however, stock prices do affect firms' net worth and could also affect the cost of borrowing—and thus the economy's response to policy shocks. This extension would also require a numerical analysis to characterize the solution path.

Second, the model assumed that the two sources of funding that banks have access to, deposits and central bank liquidity, are perfect substitutes. This is a natural benchmark case in a model where banks do not hold excess reserves and cannot borrow abroad, whereas the central bank has a perfectly elastic supply of liquidity. With a monopoly bank setting interest rates so as to maximize profits, this is translated into a deposit rate that is a mark-down, adjusted for the reserve requirement rate and a parameter that captures the sensitivity of household demand for deposits, over the refinance rate. This is consistent with the evidence suggesting that deposits are normally the cheapest source of funding for financial intermediaries. As shown earlier, in the model an increase in the reserve requirement rate lowers the deposit rate but has no direct effect on the loan rate, which is determined optimally as a markup over the policy rate. Intuitively, because the return on deposits is lower, households reduce their holdings of that category of assets. However, at the going policy rate, banks simply substitute central bank liquidity for deposits; this has no direct effect on the loan rate or the supply of credit. This result also holds under competitive banking: a higher required reserve ratio makes deposits more expensive from the perspective of the banks but the perfectly elastic supply of central bank liquidity implies that this has no effect on the amount of credit that they supply or the market-determined loan rate. However, with competitive banking a change in the reserve requirement rate does affect the loan rate in the same direction with *imperfect* substitution between funding sources (see for instance Vargas et al. (2010)). Intuitively, the substitution away from deposit funding is now incomplete, and as a result credit supply may fall—implying, all else equal, a rise in the loan rate to maintain equilibrium on the market for loans.

A question that is worth asking, therefore, is whether this result also holds in a model with monopoly banking such as ours, where banks set the loan rate, not the supply of credit. The answer is that it depends on the source of imperfect substitutability between funding sources, which itself can be related to differences in maturities, differences in intermediation costs, or central bank policy. Suppose for instance that the central bank fixes the amount of loans that it provides as a share of household deposits, perhaps because it wants banks to fund their operations mostly by raising resources from the public. The supply of central bank liquidity is thus no longer perfectly elastic, and to avoid any disequilibrium between supply and demand for liquidity it must be assumed also (in a closed economy) that banks hold excess reserves. If these reserves—which are determined residually from the banks' balance sheet constraint—carry some cost that depends on the refinance rate, it is easy to establish that the deposit rate would be lower than otherwise but that the lending rate would remain unaffected. Put differently, even though changes in relative holdings of deposits and central bank borrowing may induce movements in the deposit rate if the two sources of funding loans are imperfect substitutes, the cost of borrowing itself would continue to depend only on the refinance rate and the risk premium.

Alternatively, suppose that producing and managing deposits and loans generate a cost $\Gamma(D_t, L_t^F)$, where the function $\Gamma()$ is strictly increasing, convex, linearly homogeneous, and (by implication of linear homogeneity) $\Gamma_{DL^F} < 0$, that is, a higher volume of deposits lowers the cost of lending—perhaps, as argued by Edwards and Végh (1997), because higher deposits convey more information on potential borrowers, thereby creating economies of scope. In such conditions, the loan rate would indeed depend directly on the reserve requirement rate: because a rise in that rate lowers the deposit rate and thus the level of deposits, it would also raise the cost of producing loans; as a result the equilibrium loan rate would also be higher on impact, and aggregate demand lower. An increase in the required reserve ratio would therefore be *less* procyclical than when $\Gamma() = 0$. The magnitude of this cost complementarity effect, however, would depend on the shape of $\Gamma()$, a function for which limited empirical evidence exists, and other parameters of the model. Put differently, even if economies of scope exist, they may not be strong enough to generate a quantitatively significant direct effect of changes in the reserve requirement rate on the loan rate. A natural extension of our analysis would therefore be to model alternative sources of imperfect substitutability between deposits and central bank borrowing (together with bank excess reserves) and examine quantitatively their implications for the transmission of monetary and macroprudential policies.

Third, as it stands the model does not consider endogenous rules for macroprudential instruments. For instance, we could consider a countercyclical rule relating changes in reserve requirements to changes in credit growth or a leverage indicator. Countercyclical macroprudential rules (in the form of capital buffers and dynamic loan-loss provisions) are part of the Basel III agreement and are being implemented in a number of countries; however, they raise complex implementation issues, which have not yet been fully addressed. Instead, a countercyclical reserve requirement rule may be particularly adequate for middle-income countries, given their institutional weakenesses.

Finally, we only considered the case of a closed economy. While this is sufficient to address the issues that we intended to, there is no doubt that many of the policy questions that middle-income countries confront today require an open-economy setting. For instance, in many middle-income countries the option of tightening monetary policy to fend off inflationary pressures may not be available because raising interest rates may simply encourage capital inflows that could then generate a credit boom. For these countries the only option may be to limit credit growth and excessive risk taking by adopting macroprudential policies (see Agénor et al. (2012) and Agénor and Pereira da Silva (2013)). As noted in the introduction this is precisely what several middle-income countries have done in recent years. Yet, much remains to be done in terms of understanding how these policies perform in an open-economy environment.

How best to deal with these modeling issues, while retaining the simplicity of the model as a tool for thinking about monetary and macroprudential policies, is a matter for future research. However, as they are the findings in this paper do bear already on the debate, initiated in the aftermath of the global financial crisis, about the role of monetary policy and macroprudential regulation—viewed independently and jointly—in achieving macroeconomic and financial stability. Indeed, the global financial crisis revealed that many instruments pertaining to the realm of microprudential supervision did not fulfill their intended objectives of smoothing excessive asset growth and controlling systemic risk. The post-crisis intuition was that macroprudential tools—limits to loan-to-value (LTV) ratios, debt service-to-income caps, reserve requirements, capital ratios or forward-looking provisioning—were needed to mitigate the procyclicality of the financial system, reduce systemic risk and ensure a financial sector's resilience against shocks. Because these tools affect asset and credit markets, and impact aggregate demand, the adoption of an (explicit or implicit) objective of financial stability has led to a series of issues associated with the interaction between maroprudential and monetary policies to ensure economic stability. What our analysis suggests is that policymakers should be careful in designing and implementing macroprudential policies; understanding how macroprudential tools operate requires improved understanding of the monetary transmission mechanism and the effectiveness of monetary policy depends in turn on the macroprudential regime. More generally, designing an effective macroprudential framework requires taking into account its interactions with the monetary policy regime.

Appendix

Consider first the case of an exogenous refinance rate. Taking a linear approximation to (25) and (29) yields

$$\begin{bmatrix} di_t^L/dt \\ d\pi_t/dt \end{bmatrix} = \begin{bmatrix} \lambda^F FF_{i^L} & \lambda^F FF_{\pi} \\ \lambda^G GG_{i^L} & \lambda^G GG_{\pi} \end{bmatrix} \begin{bmatrix} i_t^L - \tilde{\imath}^L \\ \pi_t - \tilde{\pi} \end{bmatrix}. \tag{A1}$$

Let $\mathbf{A}$ denote the matrix of coefficients in (A1). Given that both the inflation rate and the loan rate adjust gradually, stability requires two negative roots. In turn, this requires that the determinant of $\mathbf{A}$ be positive (to exclude roots of opposite signs) and its trace negative (to exclude two positive roots):

$$\text{tr}\mathbf{A} = \lambda^F FF_{i^L} + \lambda^G GG_{\pi} < 0,$$

$$\det\mathbf{A} = \lambda^F \lambda^G (FF_{i^L} GG_{\pi} - FF_{\pi} GG_{i^L}) > 0.$$

Given the signs indicated in the text ($FF_{i^L} < 0$, $FF_{\pi} > 0$, $GG_{i^L} < 0$, and $GG_{\pi} > 0$) both expressions are in general ambiguous. If the loan rate adjusts relatively faster than goods prices (a plausible scenario), then λ^L is relatively high compared to λ^G, and $\text{tr}\mathbf{A} < 0$. In addition, for $\det\mathbf{A} > 0$ we need $FF_{i^L}GG_{\pi} - FF_{\pi}GG_{i^L} > 0$, or equivalently $-FF_{\pi}/FF_{i^L} > -GG_{\pi}/GG_{i^L}$. Now, by definition, from the steady-state conditions (34) and (35),

$$\left.\frac{di_t^L}{d\pi_t}\right|_{FF} = -\frac{FF_{\pi}}{FF_{i^L}} > 0, \quad \left.\frac{di_t^L}{d\pi_t}\right|_{GG} = -\frac{GG_{\pi}}{GG_{i^L}} > 0.$$

Thus, the condition for $\det\mathbf{A} > 0$ is that FF be steeper than GG, as shown in Figure 1.

Note that if $GG_{\pi} < 0$ (case of a strong capital loss effect, as discussed in the text), then $\text{tr}\mathbf{A} < 0$ regardless of the speed of adjustment and $\det\mathbf{A} > 0$, implying that the model is always stable. In that case curve GG is downard-sloping.[47]

Consider now the case of an endogenous refinance rate. Taking a linear approximation to (38) and (39) yields

$$\begin{bmatrix} di_t^R/dt \\ d\pi_t/dt \end{bmatrix} = \begin{bmatrix} RR_{i^R} & RR_{\pi} \\ \lambda^G GG_{i^R} & \lambda^G GG_{\pi} \end{bmatrix} \begin{bmatrix} i_t^R - \tilde{\imath}^R \\ \pi_t - \pi^T \end{bmatrix}. \tag{A2}$$

[47] The condition to avoid cycles is $\det\mathbf{A} < (\text{tr}\mathbf{A})^2/4$. However, this is difficult to evaluate in terms of underlying parameters.

Again, Let **A** denote the matrix of coefficients in (A2); given that both the inflation rate and the policy rate adjust gradually, stability requires two negative roots. In turn, this requires that

$$\text{tr}\mathbf{A} = RR_{i^R} + \lambda^G GG_\pi < 0, \tag{A3}$$

$$\det\mathbf{A} = \lambda^G (RR_{i^R} GG_\pi - GG_{i^R} RR_\pi) > 0. \tag{A4}$$

Given the signs provided in the text, $GG_\pi, RR_\pi > 0$; however, RR_{i^R} and GG_{i^R} depend on the strength of the cost channel. To make further progress we need therefore to consider at least two cases: a "mild" or inexistent cost channel, and a "strong" cost channel. In the first case, $RR_{i^R}, GG_{i^R} < 0$;[48] with $GG_\pi > 0$, for $\text{tr}\mathbf{A} < 0$ requires that λ^G be sufficiently small, and for $\det\mathbf{A} > 0$ we need $-RR_\pi/RR_{i^R} > -GG_\pi/GG_{i^R}$. Now,

$$\left.\frac{di_t^R}{d\pi_t}\right|_{RR} = -\frac{RR_\pi}{RR_{i^R}} > 0, \quad \left.\frac{di_t^R}{d\pi_t}\right|_{GG} = -\frac{GG_\pi}{GG_{i^R}} > 0,$$

which implies that for $\det\mathbf{A} > 0$ RR must be steeper than GG, as shown in Figure 2. This condition always holds, given that RR is vertical. With $GG_\pi < 0$, then $\text{tr}\mathbf{A} < 0$ regardless of the speed of adjustment and $\det\mathbf{A} > 0$, implying that the model is always stable.

Consider now the case of a strong cost channel, in which case $RR_{i^R}, GG_{i^R} > 0$. In that case, as can be inferred from (A3), with $GG_\pi > 0$ the condition $\text{tr}\mathbf{A} < 0$ can never be satisfied. If $\det\mathbf{A} > 0$, then it must be that the two roots are positive. The model is always unstable. With $GG_\pi < 0$, it can be established that $\det\mathbf{A} < 0$, which implies that the two roots are of opposite sign; again, the model is always unstable.

[48] Intermediate cases, where RR_{i^R} and GG_{i^R} are of opposite sign, are ignored for simplicity.

References

Agénor, Pierre-Richard, and Koray Alper, "Monetary Shocks and Central Bank Liquidity with Credit Market Imperfections," *Oxford Economic Papers*, 64 (July 2012), 563-91.

Agénor, Pierre-Richard, Koray Alper, and Luiz Pereira da Silva, "Capital Requirements and Business Cycles with Credit Market Imperfections," *Journal of Macroeconomics*, 34 (September 2012), 687-705.

——, "Capital Regulation, Monetary Policy and Financial Stability," *International Journal of Central Banking*, 9 (September 2013), 193-238.

Agénor, Pierre-Richard, and Nihal Bayraktar, "Contracting Models of the Phillips Curve: Empirical Estimates for Middle-Income Countries," *Journal of Macroeconomics*, 32 (June 2010), 555-70.

Agénor, Pierre-Richard, and Karim El Aynaoui, "Excess Liquidity, Bank Pricing Rules and Monetary Policy," *Journal of Banking and Finance*, 34 (May 2010), 923-45.

Agénor, Pierre-Richard, and Peter J. Montiel, *Development Macroeconomics*, 3rd ed., Princeton University Press (Princeton, New Jersey: 2008*a*).

——, "Monetary Policy Analysis in a Small Open Credit-Based Economy," *Open Economies Review*, 19 (September 2008*b*), 423-55.

Agénor, Pierre-Richard, and Luiz Pereira da Silva, "Reforming International Standards for Bank Capital Requirements: A Perspective from the Developing World," in *International Banking in the New Era: Post-Crisis Challenges and Opportunities*, ed. by S. Kim and M. D. McKenzie, IFR Vol. No 11, Emerald (Bingley: 2010).

——, "Cyclical Effects of Bank Capital Requirements with Imperfect Credit Markets," *Journal of Financial Stability*, 8 (January 2012*a*), 43-56.

——, "Monetary Policy and Credit Growth Gaps," unpublished, University of Manchester and Central Bank of Brazil (October 2012*b*).

——, *Inflation Targeting and Financial Stability: A Perspective from the Developing World*, Inter-American Development Bank (Washington DC: 2013).

Allen, Franklin, Elena Carletti, and Robert Marquez, "Credit Market Competition and Capital Regulation," *Review of Financial Studies*, 24 (April 2011), 983-1018.

Araujo, Aloisio, and Bruno Funchal, "Bankruptcy Law in Latin America: Past and Future," *Economia*, 6 (September 2005), 149-216.

Ariss, Rima Turk, "On the Implications of Market Power in Banking: Evidence from Developing Countries," *Journal of Banking and Finance*, 34 (April 2010), 765-75.

Athanasoglou, Panayiotis P., Ioannis Daniilidis, and Manthos D. Delis, "Bank Procyclicality and Output: Issues and Policies," *Journal of Economics and Business*, 72 (March 2014), 58-83.

Bank of England, “Instruments of Macroprudential Policy,” Discussion Paper (December 2011).

Barth, James, Gerard Caprio, and Ross Levine, “Bank Regulation and Supervision: What Works Best,” *Journal of Financial Intermediation*, 12 (April 2004), 205-48.

——, “Bank Regulations are Changing: For Better or Worse?,” Policy Research Working Paper No. 4646, World Bank (June 2008).

Basel Committee on Banking Supervision, “Basel III: A Global Regulatory Framework for more Resilient Banks and Banking Systems,” Report No. 189, Bank for International Settlements (revised, June 2011).

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist, “The Financial Accelerator in a Quantitative Business Cycle Framework,” in *Handbook of Macroeconomics*, ed. by John B. Taylor and Michael Woodford, North Holland (Amsterdam: 2000).

Bester, Helmut, “The Role of Collateral in a Model of Debt Renegotiation,” *Journal of Money, Credit, and Banking*, 26 (February 1994), 72-86.

Black, Bernard S., Antonio G. de Carvalho. and Érica Gorga, “Corporate Governance in Brazil,” *Emerging Markets Review*, 11 (March 2010), 21-38.

Boot, Arnoud W. A., Anjan V. Thakor, and Gregory F. Udell, “Secured Lending and Default Risk: Equilibrium Analysis, Policy Implications and Empirical Results,” *Economic Journal*, 101 (May 1991), 458-72.

Brunnermeier, Markus K., Thomas M. Eisenbach, and Yuliy Sannikov, “Macroeconomics with Financial Frictions: A Survey,” Working Paper No. 18102, National Bureau of Economic Research (May 2012).

Caballero, Ricardo J., “Macroeconomics after the Crisis: Time to Deal with the Pretense-of-Knowledge Syndrome,” *Journal of Economic Perspectives*, 24 (September 2010), 85-102.

Calvo, Guillermo A., “Staggered Contracts and Exchange Rate Policy,” in *Exchange Rates and International Macroeconomics*, ed. by Jacob A. Frenkel, University of Chicago Press (Chicago, Ill.: 1983).

Cavalcanti, Marco Antonio F.H., “Credit Market Imperfections and the Power of the Financial Accelerator: A Theoretical and Empirical Investigation,” *Journal of Macroeconomics*, 32 (March 2010), 118-44.

Claessens, Stijn, Swati R. Ghosh, and Roxana Mihet, “Macro-Prudential Policies to Mitigate Financial System Vulnerabilities,” *Journal of International Money and Finance*, 39 (December 2013), 153-85.

Coenen, Gunter, and Roland Straub, “Does Government Spending Crowd in Private Consumption? Theory and Empirical Evidence for the Euro Area,” *International Finance*, 8 (December 2005), 435-70.

Committee on the Global Financial System, “Macroprudential Instruments and Frameworks: A Stocktaking of Issues and Experiences," CGFS Paper No. 38, Bank for International Settlements (May 2010).

Dell'Ariccia, Giovanni, Luc Laeven, and Robert Marquez, "Monetary Policy, Leverage, and Bank Risk-Taking," Discussion Paper No. 8199, Centre for Economic Policy Research (January 2011).

Demirguc-Kunt, Asli, Enrica Detragiache, and Thierry Tressel, "Banking on the Principles: Compliance with Basel Core Principles and Bank Soundness," *Journal of Financial Intermediation*, 17 (October 2008), 511-42.

Djankov, Simeon, Oliver Hart, Caralee McLiesh, and Andrei Shleifer, "Debt Enforcement around the World," *Journal of Political Economy*, 116 (December 2008), 1105-49.

Edwards, Sebastian, and Carlos A. Végh, "Banks and Macroeconomic Disturbances under Predetermined Exchange Rates," *Journal of Monetary Economics*, 40 (November 1997), 239-78.

Fernandez-Corugedo, Emilio, Michael McMahon, Stephen Millard, and Lukasz Rachel, "Understanding the Macroeconomic Effects of Working Capital in the United Kingdom," Working Paper No. 422, Bank of England (April 2011).

Fuhrer, Jeffrey C., and Geoffrey R. Moore, "Inflation Persistence," *Quarterly Journal of Economics*, 110 (February 1995), 127-59.

Galati, Gabriele, and Richhild Moessner, "Macroprudential Policy—A Literature Review," *Journal of Economic Surveys*, 27 (December 2013), 846-78.

Galí, Jordi, and Mark Gertler, "Macroeconomic Modeling for Monetary Policy Evaluation," *Journal of Economic Perspectives*, 21 (September 2007), 25-45.

Hurtado, Samuel, "DSGE Models and the Lucas Critique," *Economic Modelling*, forthcoming (September 2014).

Inter-American Development Bank, *Unlocking Credit*, Johns Hopkins University Press (Baltimore, Md: 2005).

International Monetary Fund, "Macroprudential Policy: An Organizing Framework," unpublished, Monetary and Capital Markets Department (March 2011).

Minella, André, and Nelson F. Souza-Sobrinho, "Monetary Policy Channels in Brazil through the Lens of a Semi-Structural Model," *Economic Modelling*, 30 (January 2013), 405-19.

Mohanty, M. S., and Marc Klau, "Monetary Policy Rules in Emerging Market Economies: Issues and Evidence," Working Paper No. 149, Bank for International Settlements (March 2004).

Montoro, Carlos, and Ramon Moreno, "The Use of Reserve Requirements as a Policy Instrument in Latin America," *Quarterly Review*, Bank for International Settlements (March 2011), 53-65.

Moura, Marcelo L., and Alexandre de Carvalho, "What can Taylor Rules Say about

Monetary Policy in Latin America?," *Journal of Macroeconomics*, 32 (March 2010), 392-404.

Orland, Andreas, and Michael W. Roos, "The New Keynesian Phillips Curve with Myopic Agents," *Journal of Economic Dynamics and Control*, 37 (November 2013), 2270-86.

Peltonen, Tuomas A., Ricardo M. Sousa, and Isabel Vansteenkiste, "Wealth Effects in Emerging Market Economies," Working Paper No. 1000, European Central Bank (January 2009).

Pozsar, Zoltan, Tobias Adrian, Adam Ashcraft, and Hayley Boesky, "Shadow Banking," Staff Report No. 458, Federal Reserve Bank of New York (July 2010).

Tornell, Aaron, and Frank Westermann, "Credit Market Imperfections in Middle-Income Countries," in *Financial Market Development in Latin America*, ed. by in Vittorio Corbo, José A. Gonzalez and Aaron Tornell, Stanford University Press (Stanford, Cal.: 2004).

Turnovsky, Stephen J., "Stabilization Theory and Policy: 50 Years after the Phillips Curve," *Economica*, 78 (January 2011), 67-88

Vargas, Hernando, Carlos Varela, Yanneth R. Betancourt, and Norberto Rodríguez, "Effects of Reserve Requirements in an Inflation Targeting Regime: The Case of Colombia," Working Paper No. 587, Central Bank of Colombia (February 2010).

Wen, Yi, "An Analytical Approach to Buffer-Stock Saving under Borrowing Constraints," Working Paper No. 2009-026, Federal Reserve Bank of St. Louis (July 2009).

Woodford, Michael, "Macroeconomic Analysis without the Rational Expectations Hypothesis," NBER Working Paper No. 19368, National Bureau of Economic Research (August 2013).

Table 1
Variable Names and Definitions

Variable	**Definition**
Households	
Z_t	Cash holdings
C_t	Consumption expenditure
D_t	Deposits in commercial bank
Firms	
I_t	Real investment
N_t	Employment
P_t, π_t	Price of produced good, inflation rate
Y_t	Aggregate output
W_t	Nominal wage
Commercial bank	
L_t^F	Bank loans (working capital and investment)
i_t^D, i_t^L	Bank interest rates, deposits and investment loans
q_t	Repayment probability, investment loans
θ^L	Risk premium on investment loans
RR_t	Required reserves
V_t	Effective collateral pledged by borrowers
Central bank	
L_t^B	Loans to commercial bank
M_t	Monetary base
i_t^R	Policy or refinance rate
μ	Required reserve ratio

Table 2
Calibration: Benchmark Parameter Values

Parameter	Value	Definition
Households		
ψ	0.3	Money-in-advance parameter
d_1	0.1	Semi-elasticity of deposits wrt real deposit rate
α_{11}	0.1	Wealth depletion effect on consumption
α_{12}	0.8	Income elasticity of consumption
α_2	0.3	Semi-elasticity of consumption wrt real deposit rate
Firms		
α	0.66	Labor elasticity of output
ψ^L	0.1	Share of the wage bill financed by bank loans
i_1	3.0	Semi-elasticity of investment wrt real loan rate
Commercial bank		
κ	0.2	Share of borrowers' assets used as collateral
Θ_1	2.0	Sensitivity of risk premium to collateral-loan value
Central bank		
μ	0.2	Required reserve ratio
χ_1	1.5	Response of refinance rate to inflation deviations
χ_2	0.5	Response of refinance rate to output gap
π^T	0.02	inflation target
Adjustment speed		
λ^G	0.4	Adjustment parameter, excess demand for goods

Figure 1
Equilibrium with Exogenous Refinance Rate

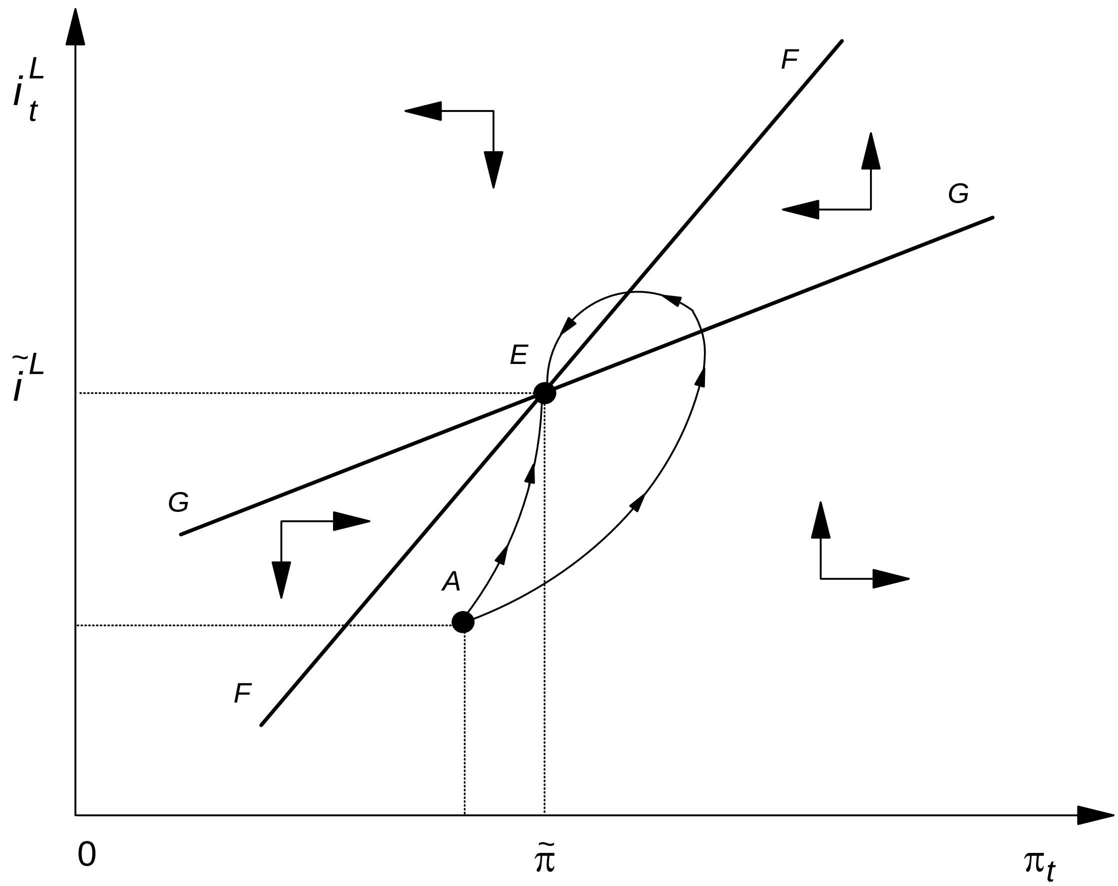


Figure 2
Equilibrium with Endogenous Refinance Rate

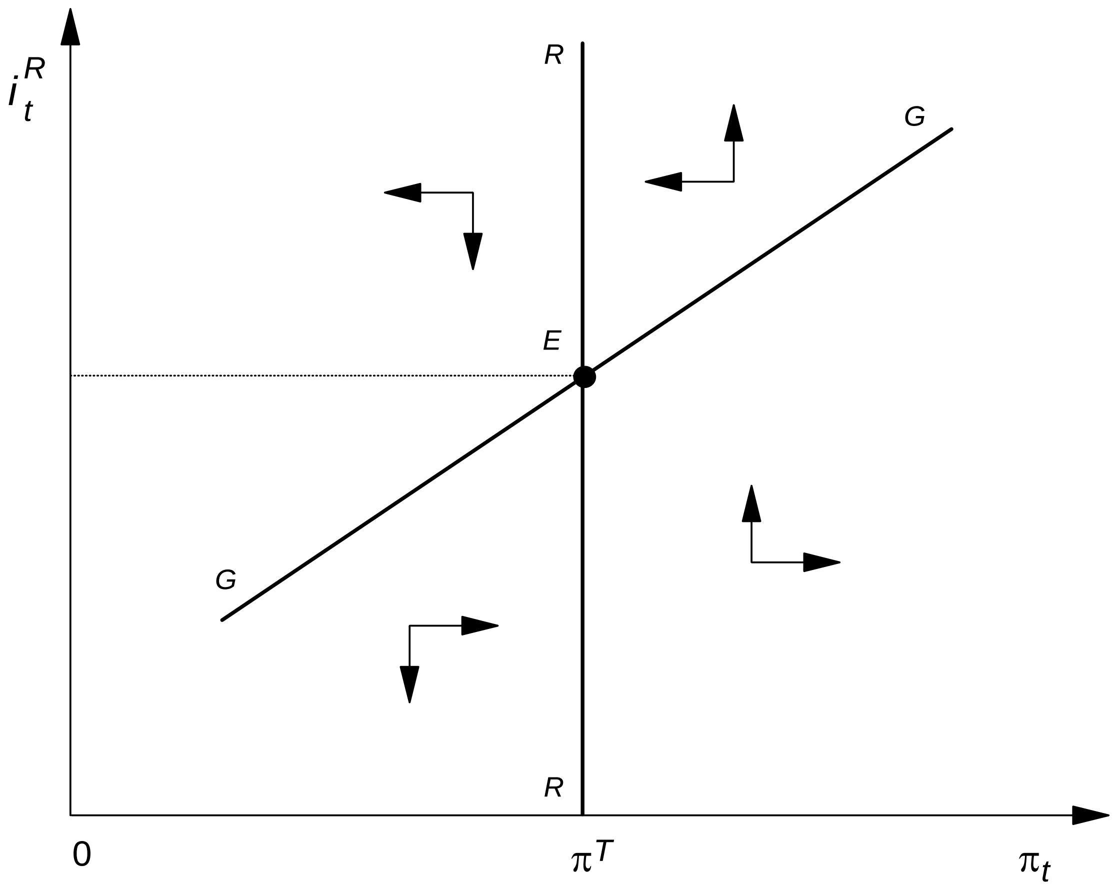


Figure 3

Increase in the Refinance Rate: Mild or No Cost Channel

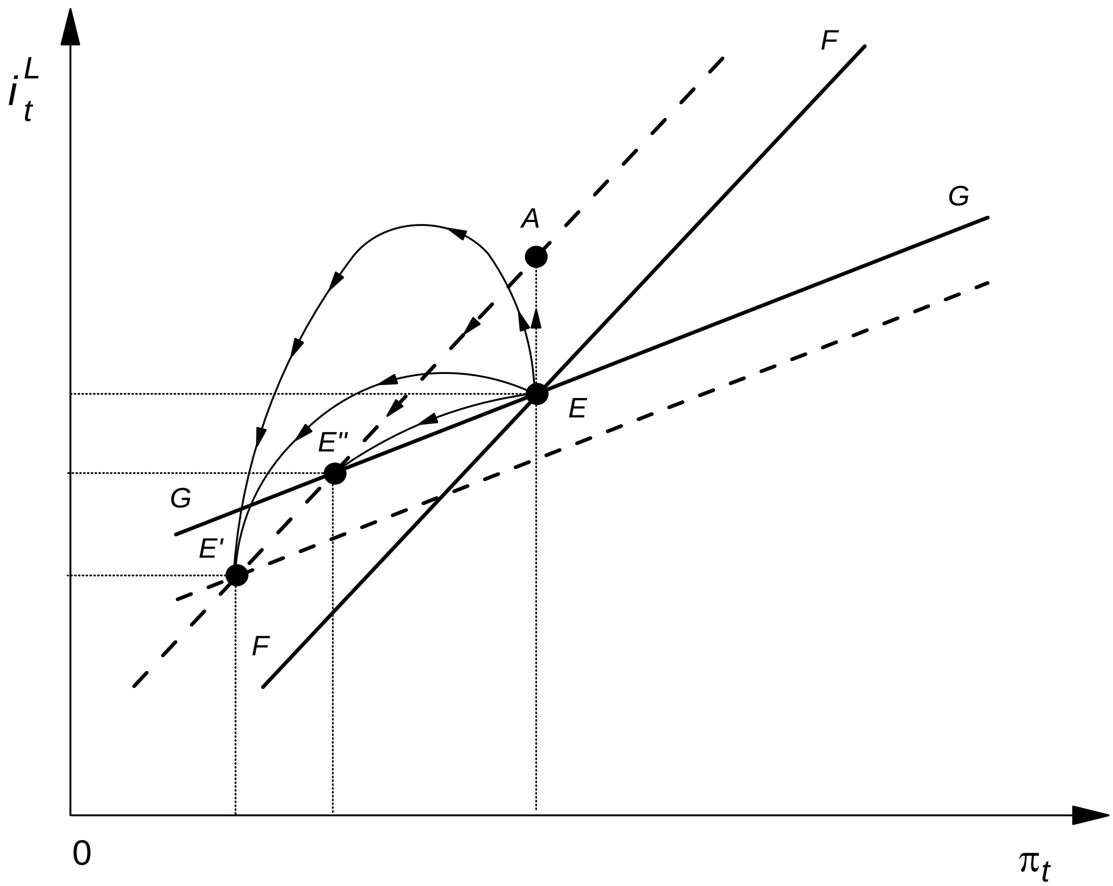


Figure 4

Increase in the Refinance Rate: Strong Cost Channel

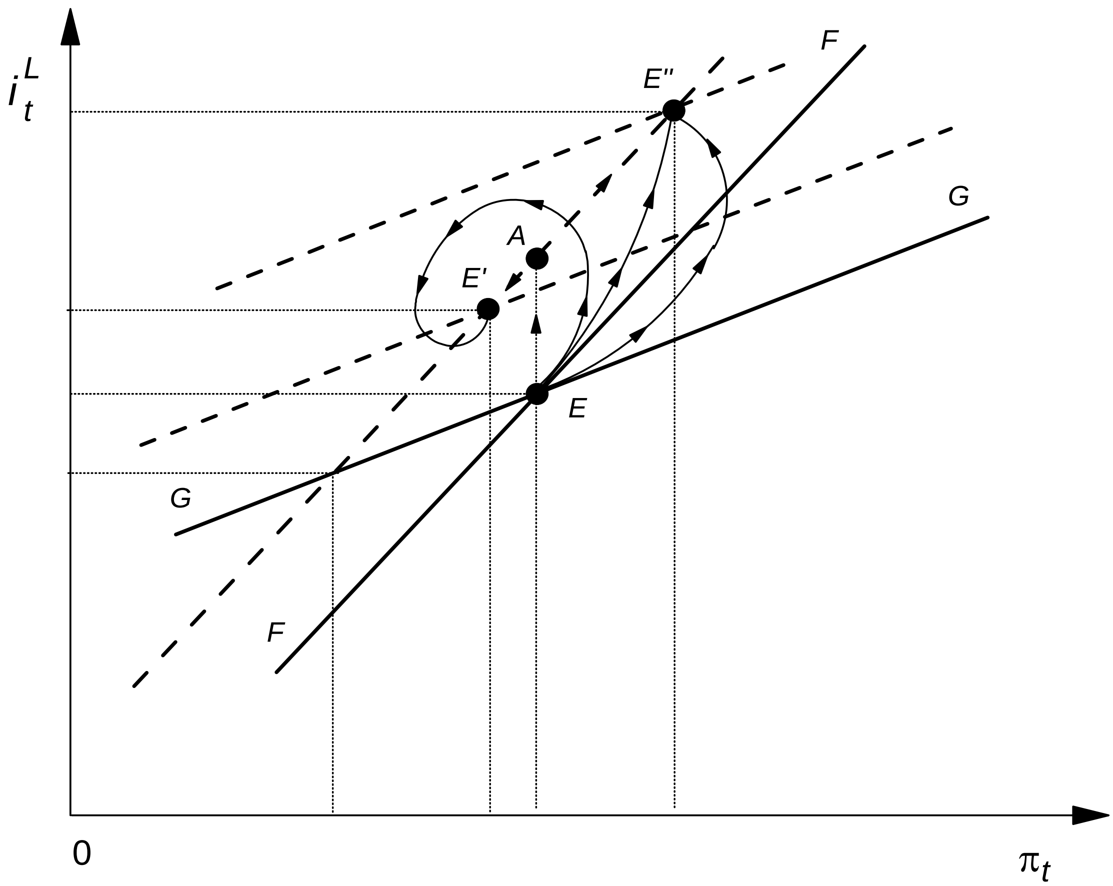


Figure 5
Increase in the Reserve Requirement Rate
(Exogenous Refinance Rate)

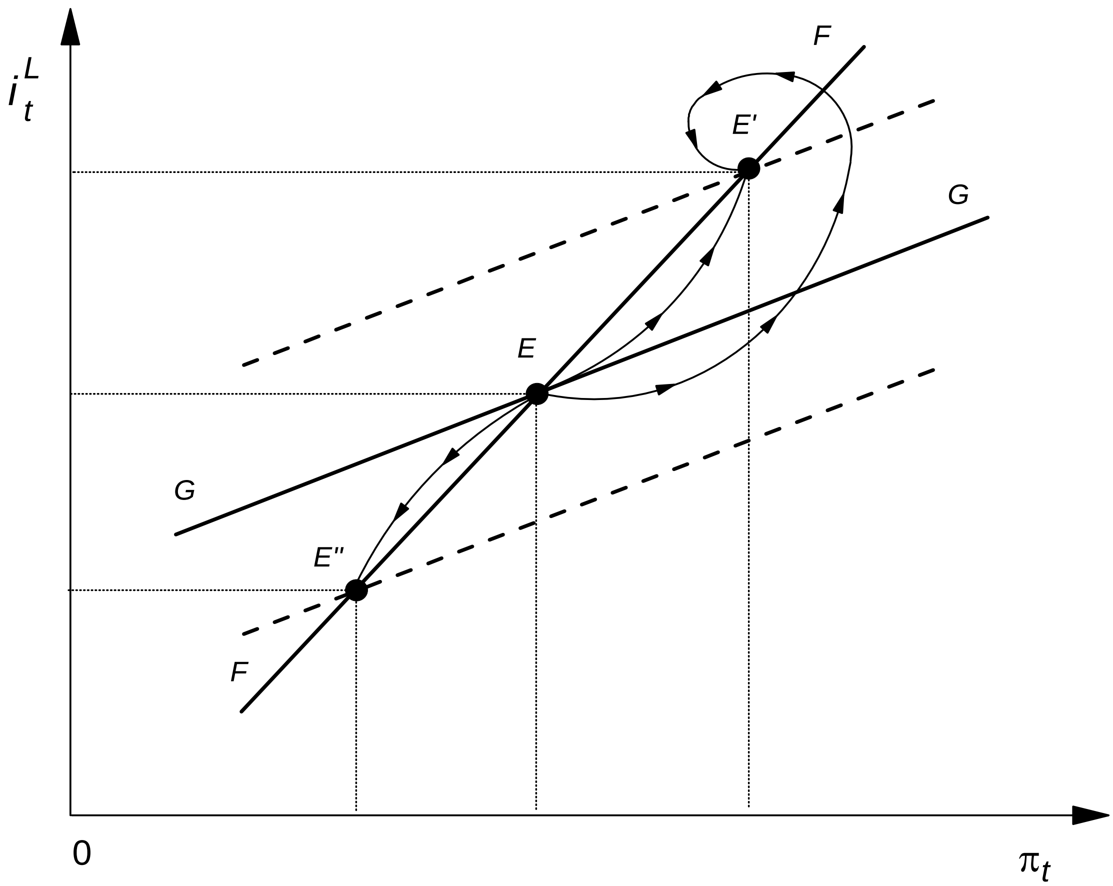


Figure 6
Increase in the Reserve Requirement Rate
(Endogenous Refinance Rate)

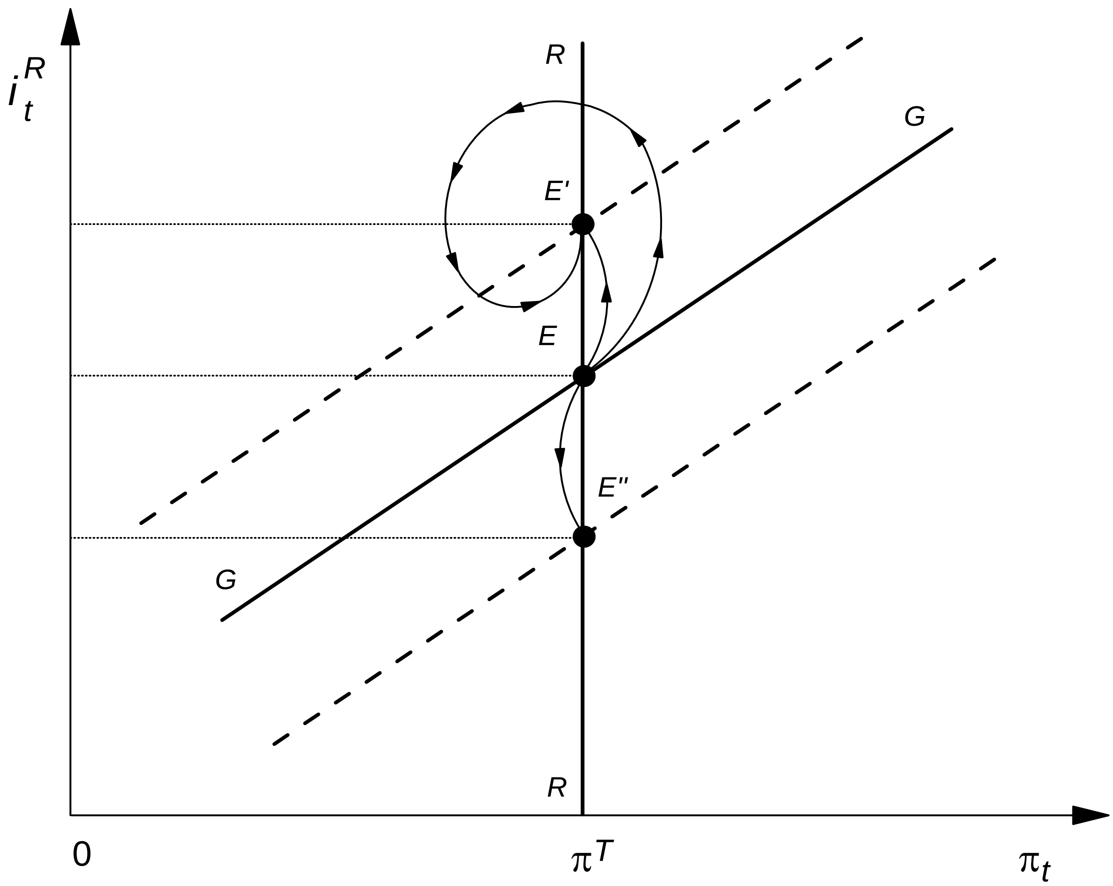
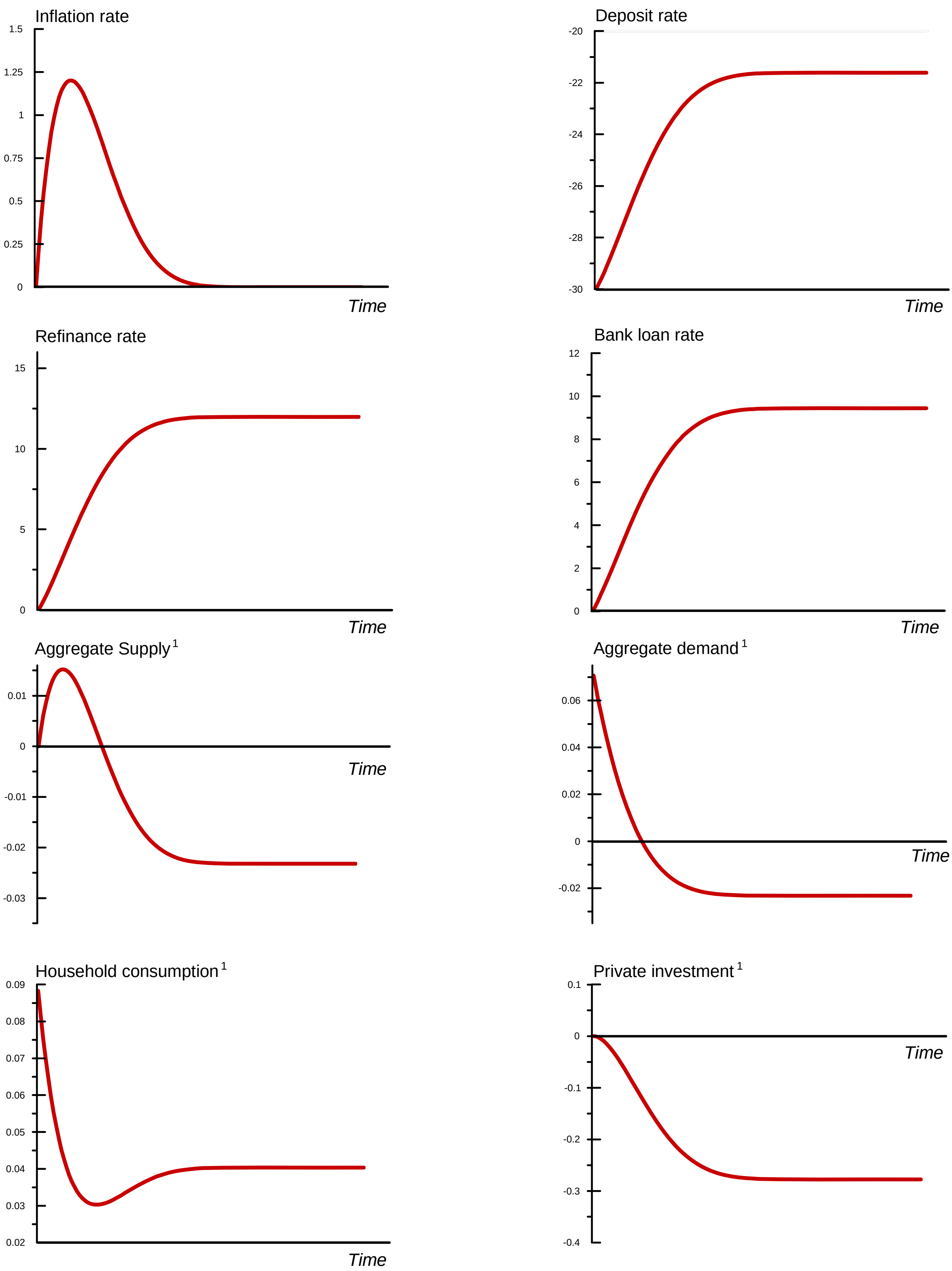


Figure 7
Permanent Increase in the Reserve Requirement Rate: Benchmark Case
(Absolute deviations from baseline in basis points, unless otherwise indicated)

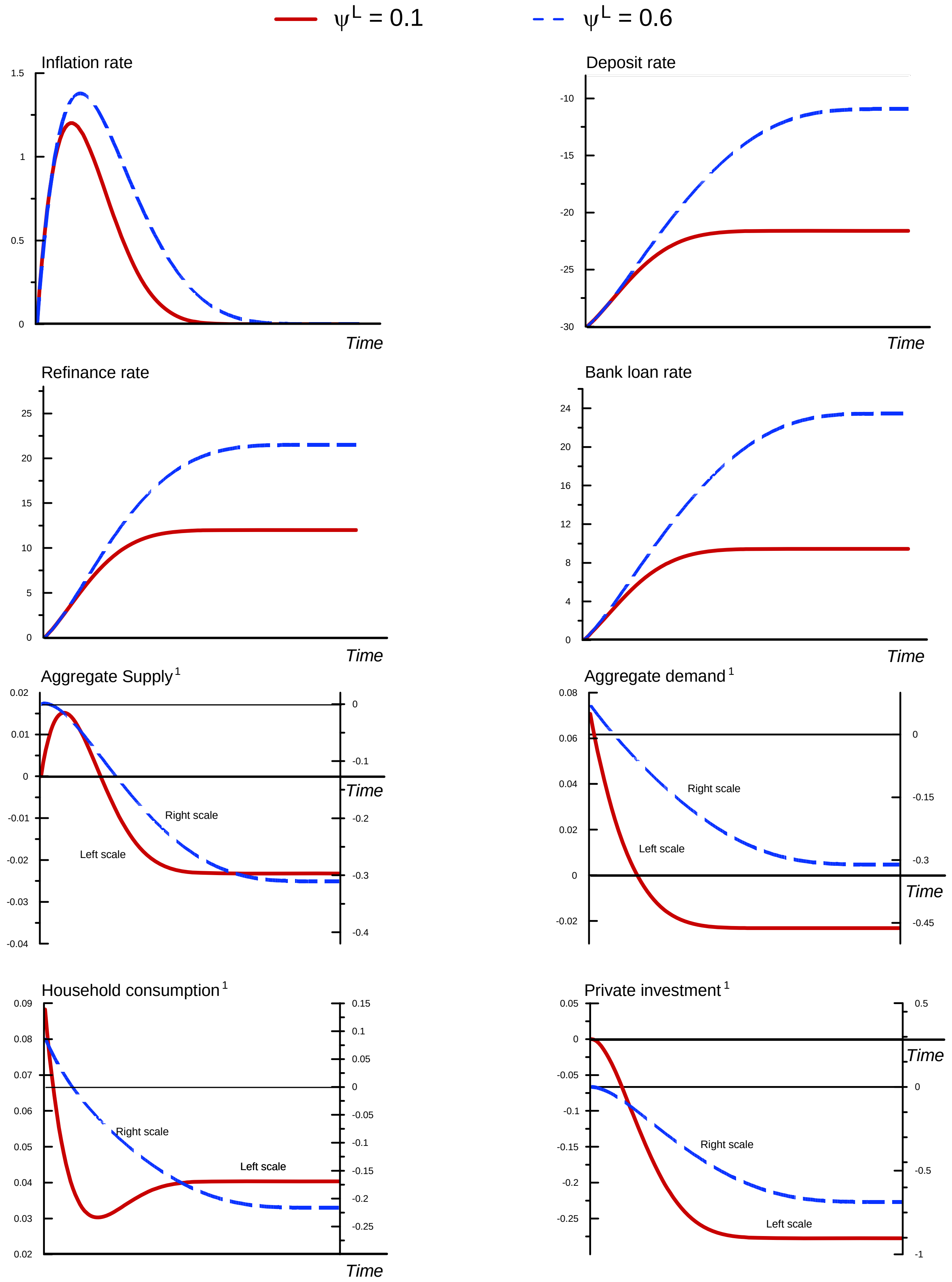


[1] Percentage deviation from baseline.

Figure 8

Permanent Increase in the Reserve Requirement Rate: Sensitivity to the Strength of the Cost Channel

(Absolute deviations from baseline in basis points, unless otherwise indicated)

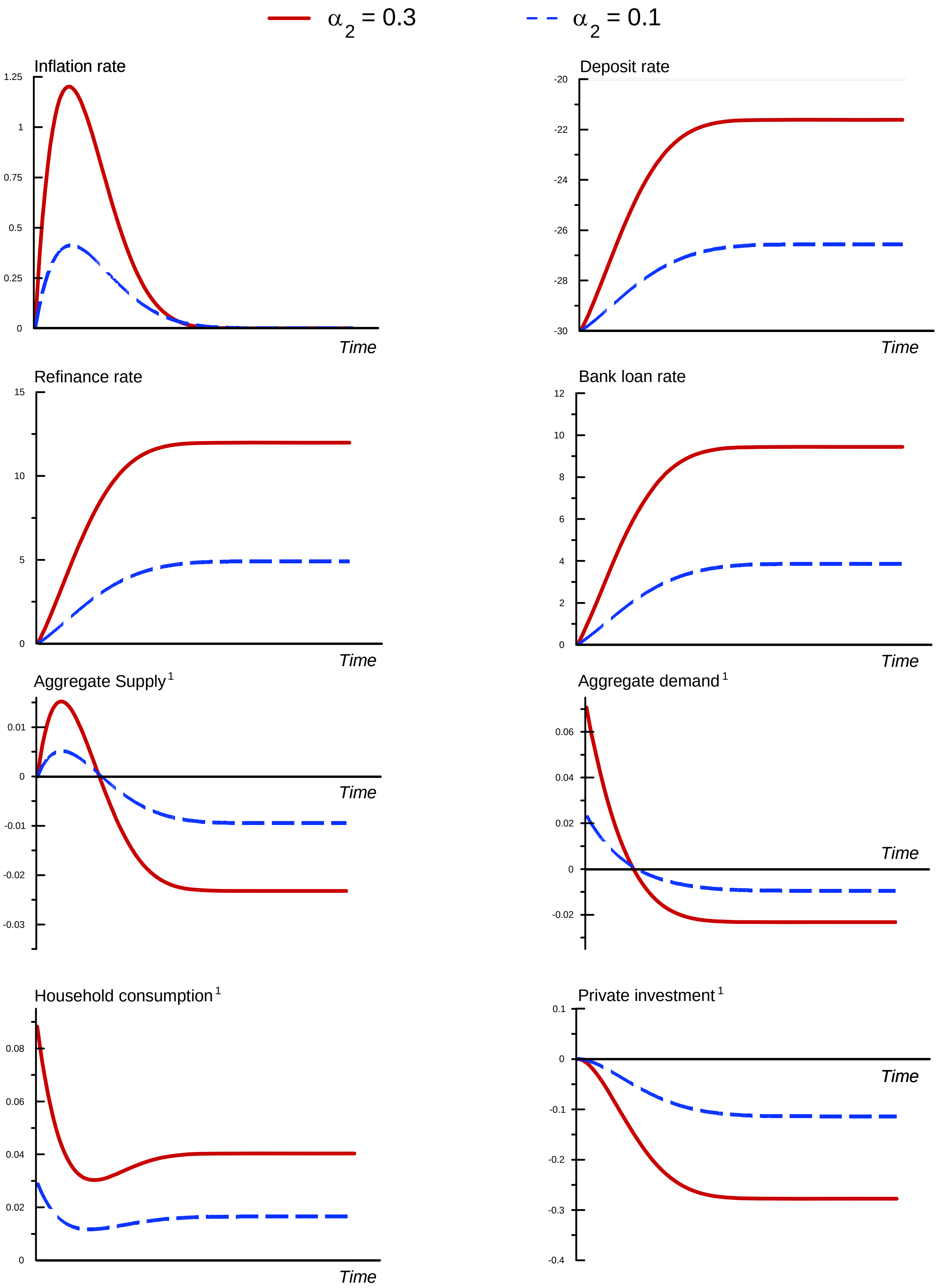


[1] Percentage deviation from baseline.

Figure 9

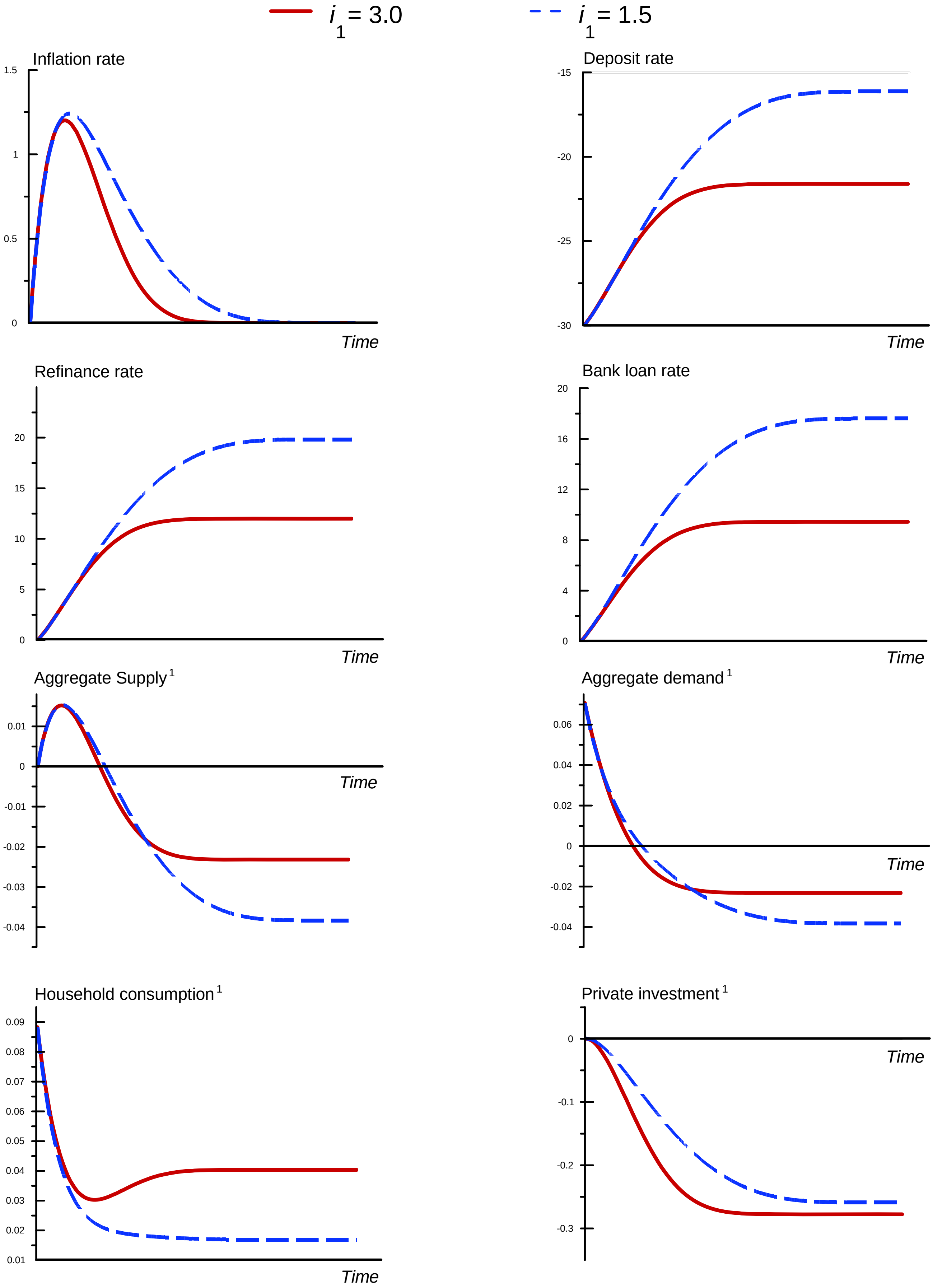
Permanent Increase in the Reserve Requirement Rate:
Sensitivity to Intertemporal Effect

(Absolute deviations from baseline in basis points, unless otherwise indicated)



[1] Percentage deviation from baseline.

Figure 10
Permanent Increase in the Reserve Requirement Rate:
Sensitivity to Investment Elasticity
(Absolute deviations from baseline in basis points, unless otherwise indicated)



[1] Percentage deviation from baseline.