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Macroprudential Regulation and the Monetary Transmission Mechanism

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Abstract

This 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 and the imposition of an upper limit on banks' leverage ratio. Policy implications are also discussed, in the context of the post-crisis debate on the use of macroprudential tools. 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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Contents

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, Gertler, and Gilchrist (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 devel-

[1] An integrated overview of the recent literature—which, admittedly, is evolving at a rapid pace—is sorely lacking. See the references in Agénor and Alper (2009) for the literature on New Keynesian models with banking and Agénor, Alper, and Pereira da Silva (2010) 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

oped by Agénor and Montiel (2008*a*, 2008*b*) and extended by Agénor and Pereira da Silva (2009). 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, 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.[4] This issue has received some attention in the recent literature, but much of it is based on full-blown numerical models, where the intuition is not always clear. By contrast, we do so in a fairly transparent setting, and this is important to draw 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,

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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 instruments. At the same time, however, we also account for the fact that the financial system in middle-income countries is dominated by banks and that capital markets remain underdeveloped or illiquid. Thus, firms in these countries have no real alternative but to borrow from commercial banks, unlike their counterparts in more developed countries.

[3] As a result, the model is 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 models may end up making unwarranted assumptions about agents'response to a change in the policy environment. See Caballero (2010) for a more detailed discussion.

[4] See Galati and Moessner (2011), Committee on the Global Financial System (2010), Financial Stability Board (2011), and International Monetary Fund (2011) for a general discussion of macroprudential policy tools. Our focus in this paper is on reserve requirements and a leverage ratio.

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

The paper continues as follows. Section II 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 III 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 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. As is now standard, we also assume that the central bank's supply of liquidity is perfectly elastic at a target interest rate. Conceptually, this is just as if monetary policy is implemented through a standing facility.[5] Section IV presents the model's solution and characterizes its steady-state properties under two cases, exogenous and endogenous policy rates. Section V examines the transmission mechanism of monetary and macroprudential policies, namely, increases in the central bank rate and the reserve requirement rate. We show, in particular, that a financial accelerator effect does exist, but it operates in different ways than in Bernanke, Gertler,

[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.

and Gilchrist (2000). We also emphasize how the transmission process of each policy is affected by the nature of the other policy. In Section VI we discuss this issue further, by considering how the transmission mechanism of monetary policy is altered in the presence of another macroprudential tool, a bank leverage ratio. Section VII draws together the policy implications of the analysis, whereas the final section offers some concluding remarks.

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 privatization and cross-border acquisitions have improved in recent years 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 importance as they have in advanced economies.[6]

At the same time, financial market imperfections remain pervasive in

[6] In industrial countries, non-banks (hedge funds, commodities funds, private equity groups, and money market funds) have become essential sources of credit. 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 agains 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 conventional banking. Even in industrial countries, they also haven't reached a critical mass of borrowers to be considered serious alternatives to bank finance.

most of these countries. These imperfections cover a broad spectrum.[7] 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.[8] With poor regulation of corporate governance and weak financial accounting 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, bankruptcy procedures for liquidating the assets

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

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

of firms in default are weak and inefficient in many developing countries.[9] 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.[10]

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.[11] As documented by the Inter-American Development Bank (2004) 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.

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,

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

[10] 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.

[11] See Barth et al. (2004, 2008). In some cases inadequate supervision and porous regulations is 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.

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.[12]

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.[13] We now turn to the description of a model that we believe provides a significant step in this direction.

3 A Simple Dynamic Model

As noted earlier, the model builds on the static framework developed by Agénor and Montiel (2008*a*, 2008*b*) and its extensions in Agénor and Pereira da Silva (2009). In what follows we describe the behavior of the four types of agents that populate the economy, firms, households, a commercial bank,

[12] As documented in Agénor and Alper (2009), there is evidence that the cost channel may be significant in some industrial countries as well. See also Fernandez-Corugedo (2011).

[13] 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 (2011).

and the central bank.[14]

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. 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, we will assume that loans contracted for the purpose of financing working capital (which are short-term in nature), are 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.[15] 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 denotes output and N_t the quantity of labor employed. The production function 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.

[14] We abstract from the government for simplicity.

[15] 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.

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, inclusive of interest payments.

Suppose 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. 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 '~' 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

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

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.

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 $I' < 0$.[16]

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

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

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 below to a third order, thereby precluding the use of phase diagrams. In addition, given that the risk premium in equation (22) below depends on the flow, rather than the stock, of credit for investment, and that borrowing from the central bank is determined residually (with no feedback effect on interest rates), it is easy to verify that the resulting dynamic system is recursive, with π_t and either i_t^L or i_t^R being determined independently of (7).[17]

3.2 Households

Households supply labor inelastically, 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 assumed to be positively related to the nominal interest

[16] Throughout the analysis, and given the continuous time setting of the model, we assume that expectations are static, that is, expected and actual inflation rates are equal. See Agénor and Bayraktar (2010) for evidence on inflation inertia in middle-income countries.

[17] With a govenrment bond rate determined through the equilibrium condition of the money market, as in Agénor and Alper (2009) for instance, the system would no longer be recursive.

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:

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

where C_t denotes real private expenditure and $\psi > 0$. 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 $\alpha_0, \alpha_2 > 0$.[18] 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*b*)) and the assumption that households cannot borrow directly from banks to smooth consumption.[19] In addition, we assume that inflation generates a

[18]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.

[19]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.

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 assumption is consistent with the buffer stock theory of saving, according to which households adjust their savings to reach or maintain a wealth target (see 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.

We will discuss later the possibility that macroprudential policy, by affecting the safety of the banking system, may affect the (expected) rate of return on deposits and thus consumption. Note also that, given (9), accounting explicitly for a standard, positive wealth effect on consumption would not affect qualitatively the analysis. Indeed, suppose 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 wealth 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 similar.[20]

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:

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

[20] For evidence on wealth effects on consumption in middle-income countries, see Peltonen et al. (2009).

where all variables are measured in nominal terms. Reserves held at the central bank pay no interest and are set in proportion to deposits:

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

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

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, we assume that 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, we assume therefore that the probability of repayment itself, rather than monitoring effort, is the choice variable.

The bank's optimization problem is thus

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

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

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

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 real 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 payment on central bank loans. The last term is monitoring costs, which are increasing in the amount of loans and the level of effort.[21] 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, we also assume that when choosing the lending rate, it takes the total cost of monitoring as given.[22]

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

$$-d_t - [i_t^D - i_t^R(1-\mu)]d' = 0, \tag{14}$$

$$q_t I_t + (q_t i_t^L - i_t^R)I' = 0, \tag{15}$$

$$i_t^L I_t - \frac{V_t}{P_t} - \phi_t q_t I_t = 0, \tag{16}$$

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.[23] Condition (14) yields therefore the desired deposit rate as

$$i_t^{D,d} = \varepsilon^D (1-\mu) i_t^R, \tag{17}$$

[21] A similar quadratic cost function is used in Dell'Arricia et al. (2010) and Allen et al. (2011). However, neither study considers the impact of collateral on monitoring, as we do here.

[22] If the bank internalizes the fact that x_t^M depends indirectly on the loan rate, the term $-\phi_t q_t^2 I'/2$ would appear on the right-hand side of expression (15). Although the key result of a negative effect of the repayment probability on the loan rate (as shown in 18) would be preserved, the solution becomes more complicated with not much additional insights.

[23] 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 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 does not alter qualitatively our analysis.

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 (15) yields the desired loan rate as

$$i_t^{L,d} = (1 + \frac{1}{\eta_L})^{-1} \frac{i_t^R}{q_t}, \tag{18}$$

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.

Condition (16) can be rearranged to give

$$q_t = \phi_t^{-1}(i_t^L - \frac{V_t}{P_t I_t}). \tag{19}$$

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.

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

$$\phi_t = \phi(\frac{V_t}{P_t I_t}). \tag{20}$$

A natural assumption is that 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.[24] This may

[24] See for instance Boot et al. (1991) and Bester (1994) for a discussion of the view that, by increasing borrowers' effort and reducing their incentives to take on excessive risk, collateral reduces moral hazard.

also induce them to be more compliant with bank monitoring requirements. Thus, $\phi' < 0$ and an increase in V_t/P_tI_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 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 (19) and (20) yields therefore

$$q_t = q(i_t^L, \frac{V_t}{P_tI_t}), \tag{21}$$

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

Effective collateral is defined as

$$V_t = \kappa P_t Y_t, \tag{22}$$

that is, the *net* value of collateral pledged by borrowers is a fraction $\kappa \in (0, 1)$ of aggregate output, P_tY_t. Coefficient κ is net in the sense that it is the difference between the 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 (21) and (22) in (18) yields

$$i_t^{L,d} = \varepsilon^L[1 + \theta^L(i_t^L, \frac{\kappa Y_t^s}{I_t})]i_t^R, \tag{23}$$

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

The term $\theta^L()$ may be interpreted therefore 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 of the loan rate and inflation, as discussed subsequently.[25]

We assume that the actual deposit rate adjusts immediately to its optimal value ($i_t^D = i_t^{D,d}$) but that the actual lending rate adjusts only gradually to that value, given in (23). Using a simple partial adjustment equation yields:

$$di_t^L/dt = \lambda^F \left\{ [\varepsilon^L[1+\theta^L(i_t^L, \frac{\kappa Y_t^s}{I_t})]i_t^R - i_t^L \right\}, \tag{24}$$

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 borrowing from the central bank:

$$L_t^B = L_t^F - (1-\mu)D_t. \tag{25}$$

3.4 Central Bank

The central bank sets the refinance rate i_t^R and provides liquidity (at the discretion of 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:

$$L_t^B = M_t. \tag{26}$$

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

$$M_t = Z_t + RR_t. \tag{27}$$

[25] Note also that (23) 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.

Because central bank liquidity is endogenous, the monetary base is also endogenous; equations (26) and (27) 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.

We assume that prices adjust gradually to disequilibria between aggregate demand and aggregate supply. Using again a simple partial adjustment mechanism yields[26]

$$d\pi_t/dt = \lambda^G(C_t + I_t - Y_t^s), \tag{28}$$

where $\lambda^G \geq 0$. The goods market is therefore in continuous equilibrium, and inflation adjusts instantaneously, when $\lambda^G \to \infty$.

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 (26)-(27). 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.

[26] This specification is consistent with Fuhrer and Moore (1995) and has been used in a number of contributions. 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 Solution and Steady State

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

4.1 Exogenous Refinance Rate

With i^R constant, first substitute equations (5) and (6) for output and investment in the desired loan rate equation, (23); this yields

$$i_t^{L,d} = \varepsilon^L \left\{ 1 + \theta^L [i_t^L, \frac{\kappa Y^s(\pi_t; i^R)}{I(i_t^L - \pi_t)}] \right\} i^R. \tag{29}$$

Substituting (29) in (24) yields

$$\frac{di_t^L}{dt} = \lambda^F FF(i_t^L, \pi_t; i^R), \tag{30}$$

where

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

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

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

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 $-I'\tilde{\pi}/\tilde{I} > Y^s_{\pi}\tilde{\pi}/\tilde{Y}^s$, 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.[27] 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 (17) to substitute out for Y^s_t, I_t, C_t, and i^D_t in (28) yields, with $\alpha_0 = 0$,

$$\frac{d\pi_t}{dt} = \lambda^G\{I(i^L_t - \pi_t) - \alpha_2[\varepsilon^D(1-\mu)i^R - \pi_t] - [1-\alpha_1(\pi_t)]Y^s(\pi_t; i^R)\}. \quad (31)$$

Solving this expression yields

$$\frac{d\pi_t}{dt} = \lambda^G GG(i^L_t, \pi_t; i^R, \mu), \quad (32)$$

[27] 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.

where

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

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

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

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

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 three 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 induces households to reduce their propensity to spend on current income. Fourth, it lowers real wages and raises aggregate supply, which in turn stimulates spending.

Thus, consumption may either increase or fall; in what follows we assume that 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. By implication, 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 $GG_{\pi} > 0$.[28]

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

[28] 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 $GG_{\pi} > 0$.

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 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^L_t and π_t. The steady-state equilibrium solutions for these variables can be determined directly from (24) and (28), by setting $di^L_t/dt = d\pi_t/dt = 0$; using (17), these solutions are

$$\tilde{\imath}^L - \varepsilon^L[1 + \theta^L(\frac{\kappa Y^s(\tilde{\pi}, i^R)}{\tilde{I}})]i^R = 0, \tag{33}$$

$$[1 - \alpha_1(\tilde{\pi})]Y^s(\tilde{\pi}, i^R) + \alpha_2[\varepsilon^D(1-\mu)i^R - \tilde{\pi}] + I(\tilde{\imath}^L - \tilde{\pi}) = 0, \tag{34}$$

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

Equation (33) 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 (34) 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.

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.[29] The figure also shows two illustrative adjustment paths (both counter-clockwise, one with cycles), starting from an initial point A at $t = 0$.[30]

4.2 Endogenous Refinance Rate

Suppose now that the policy rate is endogenous and determined by a Taylor-type rule,

$$di_t^R/dt = \chi_1(\pi_t - \pi^T) + \chi_2(C_t + I_t - Y_t^s), \tag{35}$$

where $\chi_1, \chi_2 > 0$ and $\pi^T \geq 0$ is the central bank's inflation target. Thus, 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), suppose now that the loan rate adjusts instantaneously, so that $\lambda^F \to \infty$.[31] Equation (29) can then be solved for the loan rate as a function of the inflation rate and the policy rate:

$$i_t^L = J(\pi_t, i_t^R), \tag{36}$$

[29] 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.

[30] 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 $GG_\pi > 0$.

[31] With $\lambda^F < \infty$, the complete dynamic system in i_t^L, i_t^R, and π_t could be analyzed numerically.

where[32]

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

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

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

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 assumed earlier, the investment effect dominates (that is, $-I'\tilde{\pi}/\tilde{I} > Y^s_\pi \tilde{\pi}/\tilde{Y}^s$) the loan rate will tend to increase ($J_\pi > 0$). 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 (36) in (31) 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

$$\frac{d\pi_t}{dt} = \lambda^G GG(\pi_t, i^R_t; \mu), \tag{37}$$

where now

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

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

[32] Of course, there is a direct link between the coefficients in (30) and those in (36); in particular, $\Omega = -FF_{i^L}$ and $J_x = -FF_x/FF_{i^L}$, for $x = \pi, i^R$.

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

As before, we will assume that 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) (17) and (36) for Y_t^s, I_t, C_t, i_t^D and i_t^L in (35) yields now

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

or equivalently

$$\frac{di_t^R}{dt} = RR(\pi_t, i_t^R; \mu), \tag{38}$$

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 assumed before, the policy rate will unambiguously increase ($RR_\pi > 0$).[33] 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

[33] The Taylor principle requires $RR_\pi > 1$, but here it does not guarantee that the *real* loan rate (which affects investment) increases following an autonomous increase in inflation, to ensure a fall in aggregate demand. The reason is the endogeneity of the risk premium, which depends on the fact that changes in the policy rate have supply-side effects.

cost channel. We will consider again the two 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 (37) and (38) determine the dynamics of inflation and the policy rate. Their steady-state equilibrium solutions are given by

$$[1 - \alpha_1(\tilde{\pi})]Y^s(\tilde{\pi}, \tilde{\imath}^R) + \alpha_2[\varepsilon^D(1-\mu)\tilde{\imath}^R - \tilde{\pi}] - I[J(\tilde{\pi}, \tilde{\imath}^R) - \tilde{\pi}] = 0, \qquad (39)$$

$$\tilde{\pi} = \pi^T. \qquad (40)$$

Equation (39) 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 (40) 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.[34] The initial equilibrium is at point E, 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 of the model (in the vicinity of the steady state) 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

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

in excess demand and stronger inflationary pressures, which in turn lead to further hikes in the policy rate, and so on.[35,36]

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 rate, μ.

5.1 Increase in Refinance Rate

The macroeconomic effects of an 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 a also 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 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 assumed

[35] 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.

[36] 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 (30) and (32) 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 (24).

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 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.[37]

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, $GG_{i^R} = 0$ and curve GG will not 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

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

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 depending on the magnitude of the shift in GG, the economy may converge to either E' or E''. Thus, the speed of adjustment of bank rates do 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 depends 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 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.[38]

The role of the regulatory regime is captured by μ. A high value of the reserve requirement rate lowers the deposit rate and mitigates 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

[38]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.

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 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 (32), 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 therefore shows 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.[39] But in normal times, reserve requirements are fundamentally a prudential tool. During and after the global crisis, there has been growing

[39] 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.

consensus that larger levels of bank reserves could help to absorb liquidity shocks and thereby enhance *systemic* resiliency. 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 (2010)). It is therefore useful to consider the macroeconomic effects of an increase in the required 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 households to shift consumption toward the present, thereby increasing 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. With an exogenous policy rate, FF does not change whereas GG shifts upward. The equilibrium shifts from point E to point E', with both higher inflation and a higher loan rate. Thus, in this setting, a macroprudential policy based on higher reserve requirements is *inflationary*.[40] The reason of course is that, under the assumed monetary policy regime, changes in reserve requirements have no effect on banks' cost of funds. Because the central bank stands ready to provide the funds desired by banks at the given policy rate, increases in reserve requirements leave banks' cost of funds—and therefore their lending rates—

[40] 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.

unaffected while *lowering* the interest rate that represents the opportunity cost of current versus future consumption. With an endogenous policy rate, the central bank now adjusts its policy instrument to choke off the inflationary pressures that tend to develop initially, and as a result, in the long run the inflation rate does not deviate from its target value. However, the initial effect is the same as in the case of an exogenous policy rate, as illustrated in Figure 6: the inflation rate rises initially, and may do so during the whole transition process.

However, as before, suppose that 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 (32) or (37), 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). 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.

6 Monetary Policy with a Leverage Ratio

To further illustrate the links between monetary and macroprudential policy regimes, we now examine how the imposition of a leverage ratio affects the transmission mechanism of monetary policy.[41] For the purpose at hand, it is

[41] A simple leverage ratio was introduced in the Basel III regulatory framework, with the goal of mitigating possible deficiencies in risk measurement and weighting, reducing the

sufficient to focus on the case where the policy rate is exogenous.

Suppose then that the central bank imposes a ceiling on the bank's leverage ratio, which limits (safe and risky) loans to a maximum fraction $\gamma > 0$ of aggregate output, $P_t Y_t^s$. This specification is actually a good approximation if bank capital (which is not explicitly modeled here) moves positively with aggregate economic activity, as for instance in Cecchetti and Li (2008).[42] Thus, the outstanding amount of loans is

$$L_t^F = \min[\gamma P_t Y_t^s, W_t N_t^d + P_t I_t]. \tag{41}$$

We focus in what follows on the case where the regulatory constraint is continuously binding, that is, $L_t^F = \gamma P_t Y_t^s$. Suppose also that in that case the bank adjusts residually the amount of investment loans to meet its leverage ratio. From (7) and (41), the level of investment is thus given by, instead of (6),

$$I_t^C = \gamma Y_t^s - \frac{N_t^d}{1+\pi_t} = \Phi(\pi_t; i^R, \gamma), \tag{42}$$

where

$$\Phi_\pi = \gamma Y_\pi^s - \frac{N_\pi^d}{1+\tilde{\pi}} + \frac{\tilde{N}^d}{(1+\tilde{\pi})^2} \gtrless 0,$$

$$\Phi_{i^R} = \gamma Y_{i^R}^s - \frac{N_{i^R}^d}{1+\tilde{\pi}} \gtrless 0,$$

$$\Phi_\gamma = \tilde{Y}^s > 0.$$

To ensure that $\Phi_\pi > 0$ and $\Phi_{i^R} < 0$, consistent with intuition, we assume

scope for circumventing risk-based capital requirements, and attenuating procyclicality (see Basel Committee on Banking Supervision (2010)). See also Agénor and Pereira da Silva (2010) for a proposition for an incremental, size-based leverage ratio for middle-income countries.

[42] In practice, γ itself could be made a function of the state of the economy, rising during booms and falling during recessions.

that the leverage ratio γ is sufficiently large.[43] However, it is immediately clear that now, in the absence of the cost channel, $\Phi_{i^R} = 0$ and monetary policy has no direct effect on investment, unlike the benchmark case. If so monetary policy operates only through changes in consumption spending, that is, through an intertemporal effect. If this effect itself is relatively low, as suggested by some of the evidence for middle-income countries (see Agénor and Montiel (2008*a*)), monetary policy may have limited ability to affect aggregate demand.

This simple example provides another illustration of how macroprudential regulation may affect the transmission process of monetary policy. At the same time, of course, it suggests that macroprudential policy may have quite a powerful impact on macroeconomic outcomes as well, even when monetary policy loses its effectiveness (in the present case, because of a weak cost channel and a low degree of intertemporal substitution in consumption). Indeed, reducing the leverage ratio serves not only as a prudential measure but also as a macroeconomic policy tool. In that sense, there is complementarity between monetary and macroprudential policies.

7 Policy Implications

The findings in this paper bear 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

[43] As shown below equations (4) and (5), $N^d_\pi = \tilde{N}^d/(1-\alpha)(1+\tilde{\pi})$ and $Y^s_\pi = \alpha\tilde{Y}^s/(1-\alpha)(1+\tilde{\pi})$. Thus, $\gamma Y^s_\pi - N^d_\pi/(1+\tilde{\pi}) = [1/(1-\alpha)(1+\tilde{\pi})][\gamma\alpha\tilde{Y}^s - \tilde{N}^d/(1+\tilde{\pi})]$. For this expression to be positive requires $\gamma\alpha\tilde{Y}^s - \tilde{N}^d/(1+\tilde{\pi}) > 0$, that is, $\gamma > (\tilde{N}^d)^{1-\alpha}/\alpha(1+\tilde{\pi})$. Note that this condition is sufficient, but not necessary, to have $\Phi_\pi > 0$, given that the third term in the definition of Φ_π is positive. A similar reasoning gives $\gamma > (\tilde{N}^d)^{1-\alpha}/\alpha(1+i^R)$, so we assume that γ exceeds the highest of the two values on the right-hand side of these inequalities.

and financial stability. More specifically, in what follows we focus the discussion on two (related) aspects of the debate: *a*) how changes in monetary and macroprudential rules can prevent financial bubbles and promote overall economic stability; *b*) the extent to which these policies should be combined, through a rules-based approach, to achieve these objectives.

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. Therefore, the post-crisis intuition was that macroprudential tools were needed. For instance, typical tools such an upper limit to loan-to-value (LTV) ratios, debt service-to-income caps, reserve requirements, capital ratios or forward-looking provisioning, were increasingly considered to ensure that a financial system could prevent excessively rapid pro-cyclical growth with reflections on asset prices. Similarly, the capacity of monetary policy to mitigate growing system-wide financial risk during the period of Great Moderation of inflation became, and still is, under analysis.

The definition and the workings of the macroprudential component of policy frameworks aimed at achieving financial stability have produced a growing body of literature.[44] Although the definition of financial stability is still elusive, there is broad agreement that the main goal of macroprudential instruments is to reduce systemic risk and ensure a financial sector's resilience against shocks. Thus, central banks have a natural interest in macroprudential policy. It is, as explained earlier, closely associated with their (explicit or implicit) objective of financial stability and its implementation, working through asset and credit markets, and impacting aggregate demand. Hence, it is part of an overall stabilization function that naturally interacts with,

[44] See the references in footnote 3.

and affects the performance of, monetary policy.

As a result, many policymakers have shifted their attention to the design and implementation of macroprudential frameworks. In some cases, it was a revival of relatively traditional tools: for instance, in the past, some central banks in Latin America have used reserve requirements extensively (see Montoro and Moreno (2011)). Reserve requirements were used in a countercyclical fashion to smooth the expansion phase of the cycle and to tighten monetary conditions without attracting capital inflows. During the crisis, reserve requirements were lowered, in order to inject liquidity rapidly in local and foreign currency and restore market activity affected by sudden reversals in capital inflows.

In this context, our analytical framework helped to illustrate the importance of carefully examining the nature of the monetary policy regime and its transmission mechanism under any macroprudential regime before implementing it. Let us examine two cases assuming that the policymaker intends to use a combination of macroprudential (reserve requirements) and monetary policies to achieve macroeconomic (price) stability, that is, low inflation.

Our framework shows that changes in reserve requirements may not have an effect on banks' marginal cost of funds. Under a monetary regime where the central bank stands ready to provide unlimited funding to commercial banks at an exogenous policy rate, increases in reserve requirements have no direct effect on banks' lending rates while lowering deposit rates. As a result of general equilibrium, if there are no significant capital loss effects on consumption, the preference for current versus future consumption may increase, and this in turn may strengthen—rather than dampen—inflationary pressures. We also showed that under an inflation targeting regime with an endogenous, Taylor-type policy rate, the central bank works to reduce inflationary pressures that tend to develop initially and, in the long run the inflation rate converges to its target value. Nevertheless, the initial inflation dynamics is the same as the inflation rate rises initially, and may do so during the whole transition process.

Now let us assume, under our framework, that macroprudential policy (taking again the form of fixing the level of reserves requirements) has a signaling effect regarding the health of the financial sector. This effect could be similar to the one described in Agénor and Pereira da Silva (2009), where higher capital buffers are an indication of strength and affect banks' pricing of deposits. In this setting, what matters for portfolio decisions is the expected real deposit rate; if the signaling effect is strong, consumption may not expand as previously. The transitional dynamics will be now characterized by lower, rather than higher, inflation.

Thus, our framework illustrates well how the impact of macroprudential policy depends on both risk perceptions and the monetary policy regime. It also implies that these policies should be implemented only after assessing its transmission and macroeconomic consequences. Naturally, one might say that our first case (where a positive consumption effect through the change in deposit rate dominates) is extreme. The point is that there needs to be a close analysis of the economy's monetary and financial characteristics before macroprudential tools are implemented.

This observation is important in the post-crisis environment where every single country is now designing and implementing macroprudential guidelines and policies without analyzing first the way they affect the transmission mechanism of monetary policy and the characteristics of their own monetary regime. If the workings of macroprudential tools are only contractionnary (meaning that the first case we discuss does not prevail), the conventional wisdom that both instruments should be combined to improve the contra-cyclical power of both macroprudential and monetary policies will remain. But conventional wisdom has failed us badly in recent years.

8 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. Quite importantly, 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 values to bank borrowing. 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, Gertler, and Gilchrist (2000), namely, the possibility of generating a financial accelerator effect due to endogenous adjustment in borrowing costs.

The model was used to analyze the interactions between monetary and macroprudential policies, including, in the latter case, changes in reserve requirements and the imposition of a leverage ratio. Policy implications were also discussed. We highlighted the fact that understanding how macroprudential tools operate requires improved understanding of the monetary transmission mechanism, and that 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.

The model could be extended in various directions. Our analysis of the macroeconomic effects of a leverage ratio was kept deliberately simple; because we did not explicitly account for bank capital, it operated essentially as a quantitative ceiling on bank credit. A more comprehensive analysis would involve considering explicitly alternative bank capital regimes, perhaps along the lines of Agénor and Pereira da Silva (2009). However, this would not necessarily change the general message of this paper, regarding the impact of macroprudential regimes on the monetary transmission mechanism.

A second limitation of the analysis relates to the fact that 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. We also did not account for the stock market, given the relatively limited role that such markets play in developing countries; however, stock prices affect firms' net worth and could also affect the cost of borrowing—and thus the economy's response to policy shocks.

A third limitation is that at this stage the model is that 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, Alper, and Pereira da Silva (2011*b*)). 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.

Appendix

Consider first the case of an exogenous refinance rate. Taking a linear approximation to (24) and (28) yields

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

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 assumption), 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 (33) and (34),

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

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 downward-sloping.[45]

Consider now the case of an endogenous refinance rate. Taking a linear approximation to (37) and (38) yields

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

[45] 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, $RR_{i^R}, GG_{i^R} < 0$;[46] with $GG_\pi > 0$, for 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 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 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.

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

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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

Figure 1
Equilibrium with Exogenous Refinance Rate

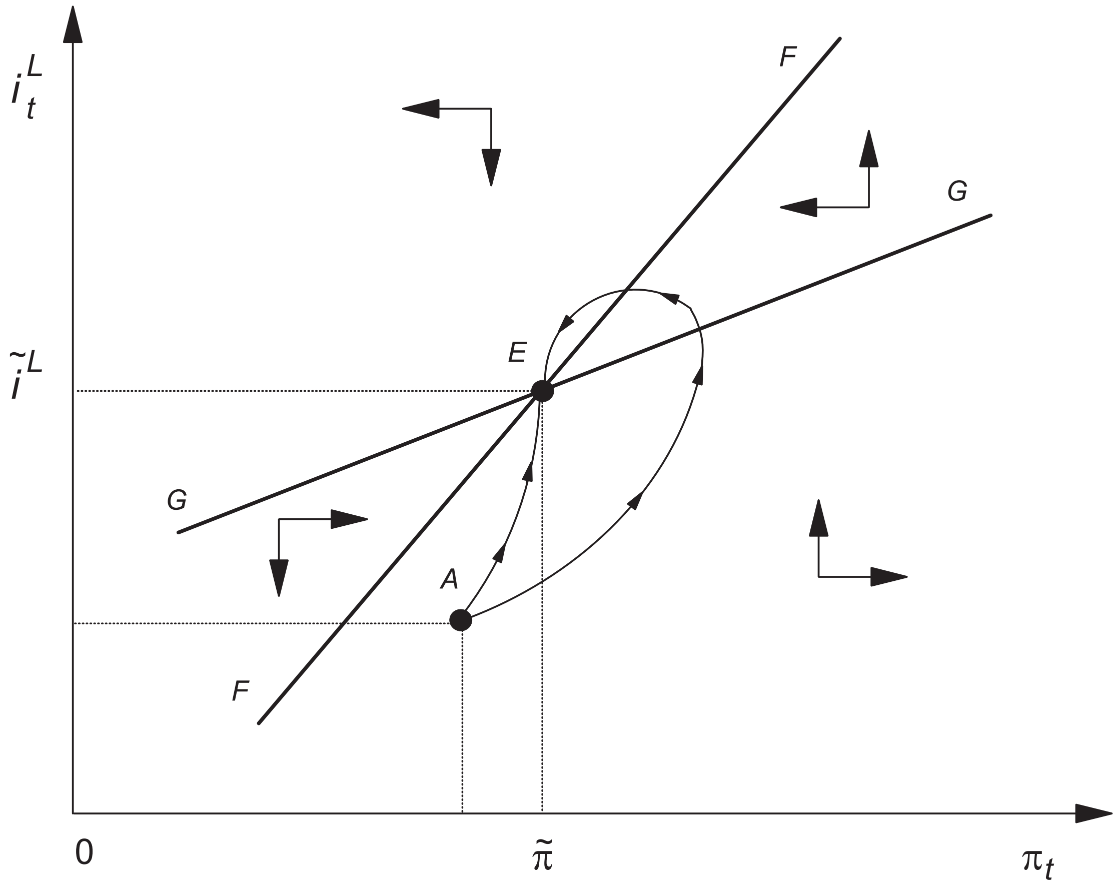


Figure 2
Equilibrium with Endogenous Refinance Rate

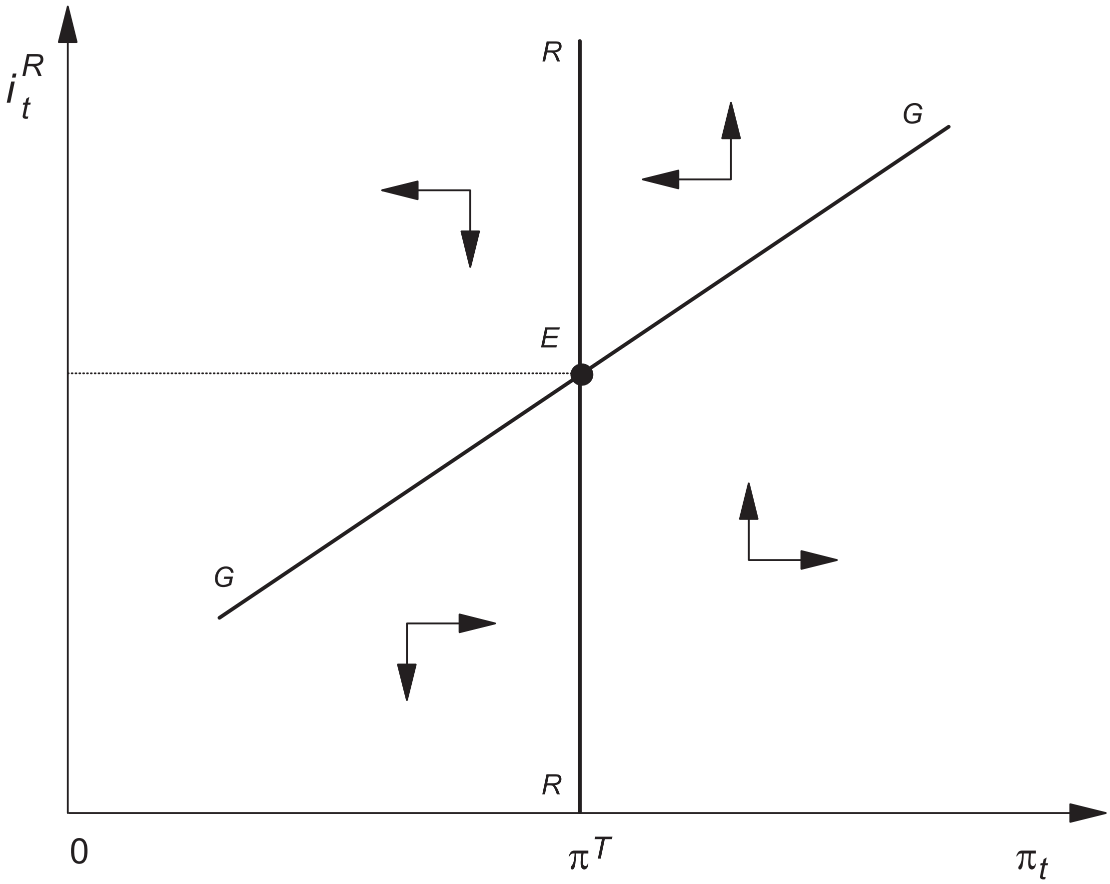


Figure 3
Increase in the Refinance Rate: Mild or No Cost Channel

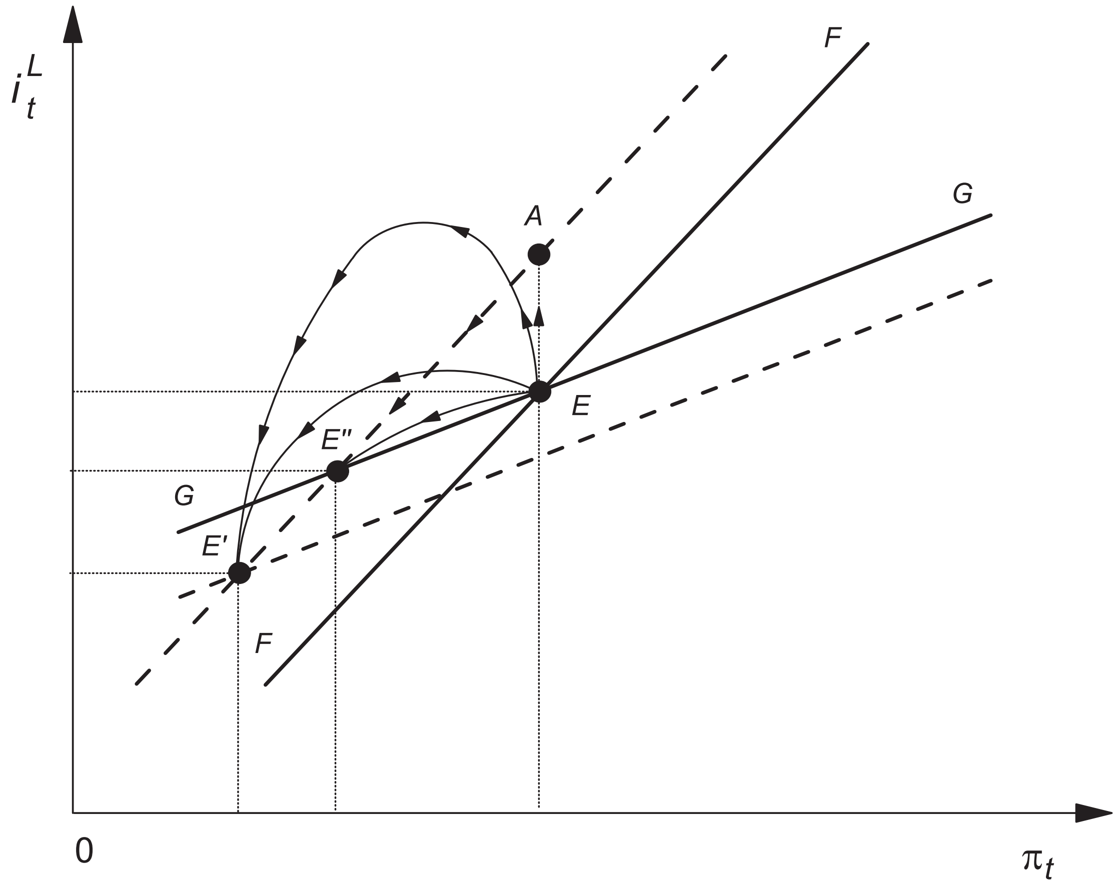


Figure 4
Increase in the Refinance Rate: Strong Cost Channel

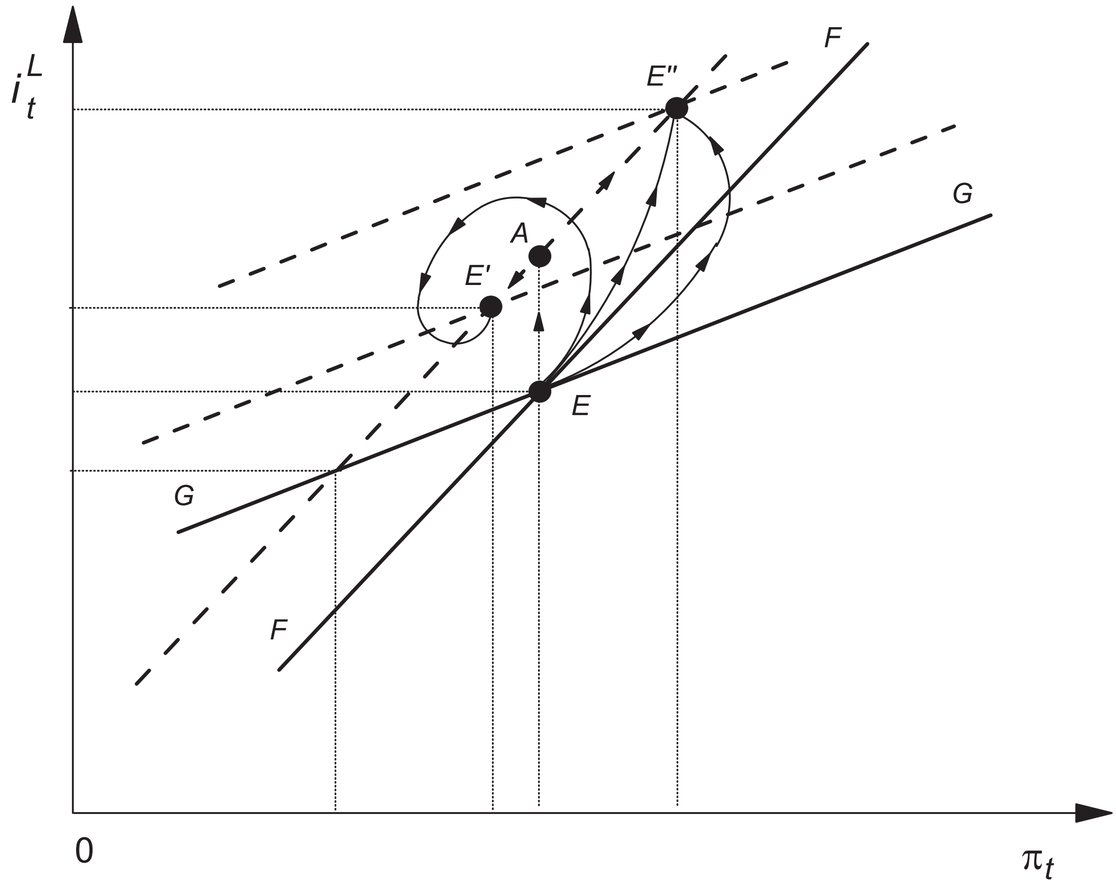


Figure 5
Increase in the Reserve Requirement Rate
(Exogenous Refinance Rate)

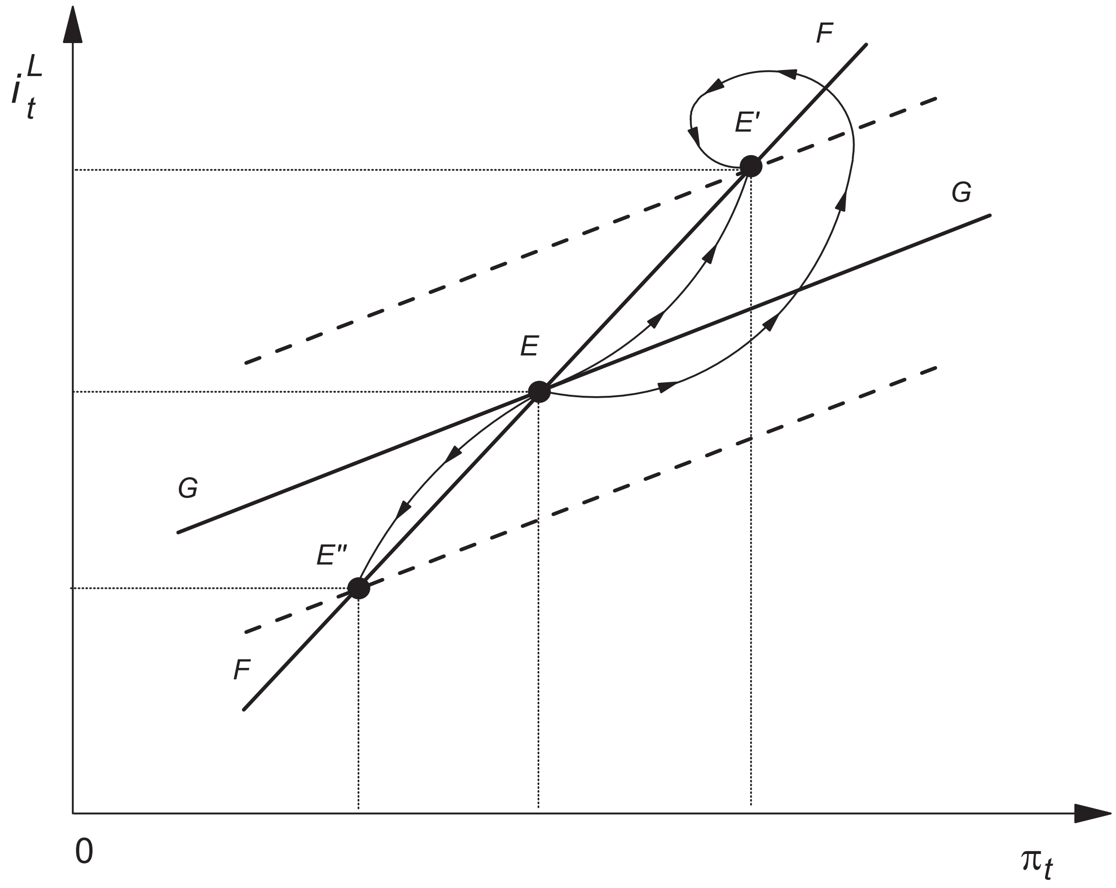
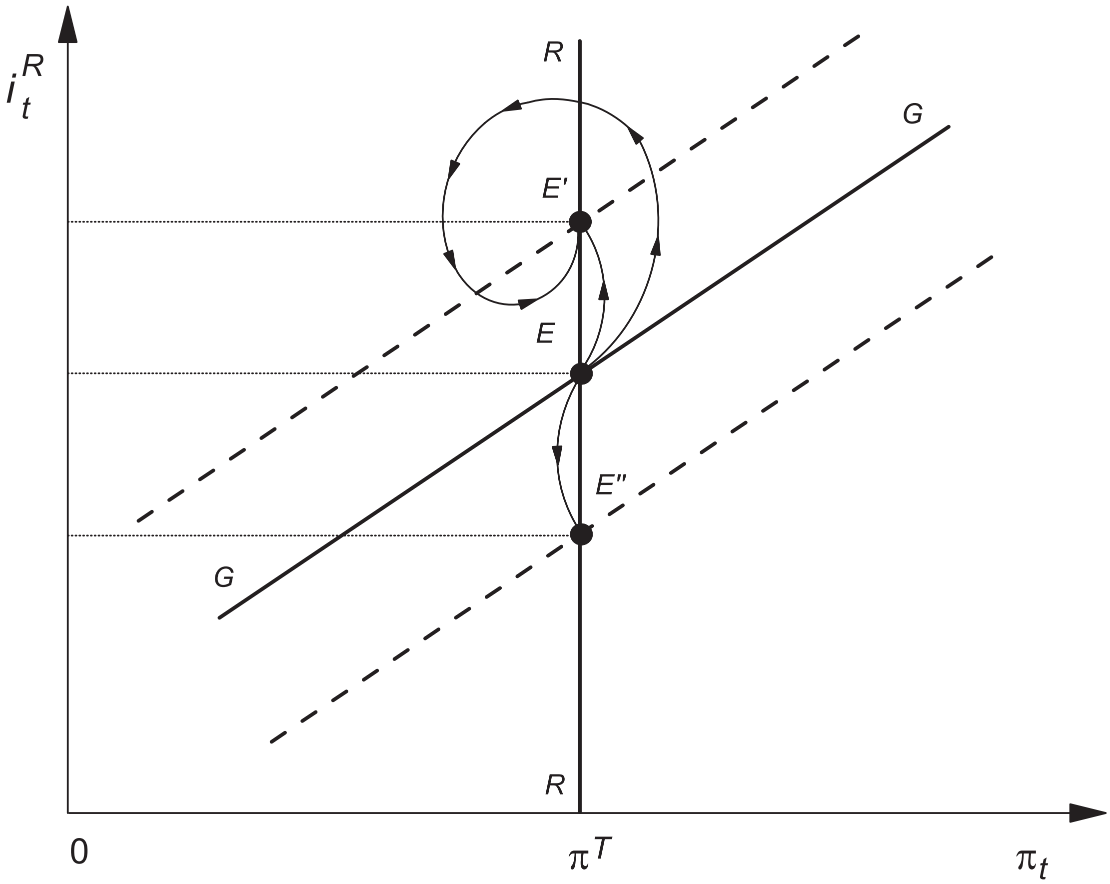


Figure 6
Increase in the Reserve Requirement Rate
(Endogenous Refinance Rate)



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