Monetary and Macro-Prudential Policies: An Integrated Analysis*

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Abstract This paper studies monetary and macro-prudential policies in a simple model with both a nominal rigidity and a financial friction that give rise to price and financial stability objectives. We find that lowering the degree of nominal rigidity or increasing the strength of the interest rate response to inflation is always welfare increasing in the model, despite a tradeoff between price and financial stability that we document. Even though crises become more severe as the economy moves toward price flexibility, the cost of the nominal rigidity is always higher than the cost of the financial friction in welfare terms in the model. We also find that macro-prudential policy implemented by augmenting traditional monetary policy with a reaction to debt is always welfare increasing despite making crises more severe. In contrast, implementing macro-prudential policy with a separate tax on debt is always welfare decreasing despite making crises relatively less severe. The key difference lies in the behaviour of the nominal exchange rate, that is more depreciated in the economy with the tax on debt and increases the initial debt burden.

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1 Introduction

The recent financial crisis has raised fundamental questions on the role and objectives of monetary policy. For instance, Taylor (2009) argued that excessively lax monetary policy before the crisis contributed to its occurrence and severity. A large literature is emerging that responds to this idea by designing monetary policy rules that curtail growth in credit or asset prices.\(^1\) In contrast, others believe that the crisis was the result of regulatory failures, and financial stability should be pursued by macroprudential policy, not monetary policy. For example, Svensson (2010) argues that monetary policy should continue to focus squarely on macroeconomic objectives (i.e., price and output stability).

The contribution of this paper is to study monetary and macroprudential policies in a framework in which there is a scope for both macroeconomic and financial stability. In doing so, the model developed in this paper represents a departure from most of the existing literature that has focused on one objective at a time (notable exceptions are Cesa-Bianchi and Rebucci, 2011, Fornaro, 2011 and Unsal, 2011). In particular, in our model a financial stability objective arises because financial crises are endogenous events captured, from a model perspective, by the situation in which the credit constraint becomes strictly binding.\(^2\) The advantage of our approach is that it allows us to study the implications of “conventional” monetary policy for financial stability (broadly defined by the frequency and the severity of crises) and to examine the extent to which monetary policy can be used in a precautionary manner to guard against the occurrence of such events.

This paper builds upon two distinct strands of literatures. The first is the extensive literature on the design of monetary policy rules to achieve macroeconomic stability in the face of nominal frictions (e.g., Woodford, 2003). This New-Keynesian literature has proposed a policy framework (inflation targeting) that performs well at stabilizing output and inflation fluctuations using interest rate rules. The second is a literature that has emerged since the great recession and focuses on designing stabilization policies before and after a financial crisis in environments with credit constraints that bind only occasionally (Benigno et al 2009; Bianchi, 2011, Bianchi and Mendoza 2010, Jeanne and Korinek 2011, Korinek 2011). This neo-Fisherian literature works in environments where the non-crisis policy is a seemingly trivial no-action because there are no other frictions in the models. While this approach focuses on the issue of financial stability, it leaves open the question

\(^1\)See below for a partial list of contributions. In addition there is widespread work on such rules at central banks and IFIs.

\(^2\)Given that we do not use the model quantitatively, we do not add additional restrictions on this definition to isolate large events as usually done in the empirical literature. See Benigno et al, 2011 for a detailed discussion.
of how financial stability objectives interacts with macroeconomic stability traditionally defined.

Once we build our model we ask a series of questions about the design of both monetary and macroprudential policies. First, what are the consequences of following a monetary policy rule designed to address the nominal friction in an economy with our financial friction? Second, what are the consequences of adding a macroprudential component to a conventional interest rate rule? Specifically, does this component improve welfare by contributing to macro-financial stability? Third, how well does a two part rule—one targeting inflation and the other targeting debt—do in delivering both macroeconomic and financial stability?

We address these questions from the perspective of a small open economy that borrows from the rest of the world in foreign currency, i.e., a typical emerging market economy. The world lasts for three periods and our economy produces both tradeable and non-tradeable goods. We allow for nominal price rigidities in the tradeable sector while for simplicity prices in the non-tradeable sector are perfectly flexible. Fluctuations in the model are driven by a technology shock to the production of tradeable goods. The key feature of the model is an international borrowing or collateral constraint that depends on the price of a domestically traded asset in fixed supply like in Jeanne and Korinek (2010).

We consider conventional monetary policy in terms of an interest rate rule that includes only inflation. In this context, monetary policy has real effects through multiple channels of transmission: via the nominal rigidity, via the price of the asset, or via the exchange rate; and each of them can have an impact on the tightness of the borrowing constraint, which binds endogenously in the model. Macroprudential policy takes the form of an augmented monetary policy rule that targets also borrowing or a second rule for a tax on borrowing. This is based on the principle that taxing the amount that agents borrow limits the possibility that a crisis might occurs or ameliorates its severity.3

As the model has no closed form solution, we conduct a numerical analysis of its equilibrium under alternative policy rules. The numerical analysis that we report highlights the complex interactions involved in designing macro-prudential policies. The general policy message is that using monetary policy for macro-prudential purposes may be welfare improving despite the adverse trade off between price and financial stability involved. In our framework both an augmented monetary policy rule with a prudential component and an independent macro-prudential tax rule akin to a capital control affect the relative return of domestic versus foreign currency bonds. In the case of the tax rule on debt, borrowing in

3While this statement may be true in some special cases, it is not generally valid. Such a policy may be suboptimal even in the context of a simple neo-Fisherian environment (see Benigno et al, 2010 and 2011 for more details on this).
foreign currency is made relatively more expensive, while in the case of the augmented monetary policy rule domestic interest rates are relatively higher and, as such, intertemporal consumption choices will be directly distorted. Yet, as we shall see, a the two specifications yield very different outcomes from a welfare perspective because of their different implications for the nominal exchange rate.

The specification of the occasionally binding borrowing constraint is crucial for understanding the financial stability implications of monetary policy. In fact the amount that agents borrow depends not only on the price of the collateral but also on the behavior of the nominal exchange rate since the borrowing occurs in foreign currency units. Monetary policy (through domestic nominal interest rate) can influence the borrowing limit of agents by affecting the value of the collateral as well as the nominal exchange rate. While higher nominal interest rates tend to depress the asset price and hence the value of the collateral and tighten the agents’ borrowing limit, they also generate a relatively more appreciated nominal exchange rate that loosens the agents’ borrowing limit. The relative strength of these two opposing effects determines the extent to which traditional monetary policy entails a prudential component by curtailing borrowing when interest rate increase. When that is the case, i.e. when traditional monetary policy embeds its own prudential component, an additional policy tool for specific prudential objectives might be redundant or even harmful. This is because the tax is introducing an unnecessary additional distortion in to the economy.

More specifically, the main findings are two. First, we find that lowering the degree of nominal rigidity or increasing the strength of the interest rate response to inflation is always welfare increasing in the model, despite a trade off between price and financial stability that we document. Even though crises become more severe as the economy moves toward price flexibility, the cost of the nominal rigidity is always higher than the cost of the financial friction in welfare terms. Second, we find that conducting macro-prudential policies through an interest rate rule augmented with debt dominates alternative policy regimes from a welfare point of view. The difference lies in the implied behavior of the nominal exchange rate that is relatively more appreciated with the augmented monetary rule.

While these result illustrate the complex interactions at play, there is a robust and common theme across the whole set of results we report. Welfare enhancing policies work by supporting the borrowing (and hence consumption) capacity of the economy, and hence by relaxing the borrowing constraint of our production economy, rather than curtailing it. This is consistent with the result of Benigno at al (2011), who showed that, by allocating productive resources differently in a crisis state, the policy maker can increase borrowing (and
hence consumption) in the economy outside the crisis state while reducing the probability of a financial crisis.

As we noted above, there is an emerging and growing literature that studies augmented interest rate rules with macro-prudential arguments or two-part rules like the one we study in this paper. The basic premise of this literature is that by smoothing cycles in financial variables it may be possible to bring about greater macroeconomic stability. For example, Quint and Rabanal (2011) find that there are reductions in macroeconomic volatility from targeting financial variables, but optimizing the interest rate response to inflation and output is quantitatively more important in reducing macroeconomic volatility. On the other hand, Lambertini, Mendicino and Punzi (2011), find that an interest rate rule augmented with credit growth or house price growth is welfare improving, and that a two-part rules (one for financial stability, one for macroeconomic stability) dominate the one instrument rule in the presence of news shocks in the model. While the results of these exercises are consistent with our main findings, the models are typically are linearized around a deterministic steady state. Hence these exercises can focus only on the regular cyclical fluctuations of the economy. In these environments, therefore, the notion of designing monetary and macro-prudential policies for financial stability is ambiguous. In contrast, in this paper, we build a model in which the constraint binds only occasionally, and there are both crisis and non-crisis states that interact and realize endogenously.

The rest of the paper is organized as follows. In section 2 we set up the model. In section 3 we discuss the model solution and parametrization. In section 4 we report and discuss equilibrium allocations under alternative frictions and policy rules. In section 5 we conclude. An appendix reports key equilibrium conditions of the model.

2 Model

We study a two-country world composed of a small open economy and the rest of the world. For simplicity, we assume that the world economy lasts for three periods (periods 0, 1, and 2). The specification of preferences and parameters is such that there is a one-way interaction between the two economies: the rest of the world affects the small open economy, but the latter does not have any effect on the former. The key difference between the two economies is that households in the small open economy faces a constraint on the amount that they can borrow from abroad. They also face nominal rigidities in their price-setting

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4An earlier literature examined how optimal monetary policy is designed in an environment in which the credit constraint becomes binding unexpectedly and remains binding forever (see for instance Braggion, Christiano and Roldos, 2007).
behavior.

Note that in the model, a financial crisis is defined as the event in which the borrowing constraint is binding (and the corresponding Lagrange multiplier is strictly positive). A key element of the crisis is that it is an endogenous event. Financial stability, therefore, is broadly defined by the frequency and the severity of these events in the model.

2.1 Households

We consider two countries, $H$ (Home) and $F$ (Foreign). The home country is a small open economy that takes prices as given, while the foreign country represents the rest of the world. The world economy is populated with a continuum of agents of unit mass, where the population in the segment $[0; n]$ belongs to country $H$ and the population in the segment $(n; 1]$ belongs to country $F$. We use a * to denote prices and quantities of the foreign country. The home country issues bonds in the foreign currency (held by foreign agents) and hence a * variable will appear in the home country’s budget constraints.

The utility function of a consumer in country $H$ is given by:

$$U_0 = E_0 \left[ \frac{C_0^{1-\rho}}{1-\rho} + \beta \frac{C_1^{1-\rho}}{1-\rho} + \beta^2 \frac{C_2^{1-\rho}}{1-\rho} \right],$$

where $\rho$ is the elasticity of intertemporal substitution and $\beta \in (0, 1]$ is the subjective discount factor. The consumption basket, $C_t$, is a composite good of tradeable and nontradeable goods:

$$C_t \equiv \left[ \omega \frac{1}{\kappa} \left( C_{tT}^{H} \right)^{\frac{\kappa-1}{\kappa}} + (1-\omega) \frac{1}{\kappa} \left( C_{tN}^{F} \right)^{\frac{\kappa-1}{\kappa}} \right]^{\frac{1}{\kappa-1}}. \quad (1)$$

The parameter $\kappa > 0$ is the elasticity of intratemporal substitution between consumption of tradable and nontradable goods, while $\omega$ is the relative weight of tradable goods in the consumption basket. We denote with $P^T$ the price of tradable goods and with $P^N$ the price of nontradable goods. We further assume that tradable goods are a composite of home and foreign produced tradeables ($C^H$ and $C^F$, respectively):

$$C_{tT}^H = \left[ v \frac{1}{\theta} \left( C_{tN}^{H} \right)^{\frac{\theta-1}{\theta}} + (1-v) \frac{1}{\theta} \left( C_{tF}^{F} \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{1}{\theta-1}},$$

where $\theta > 0$ is the intratemporal elasticity of substitution. The parameter $v$ is the relative weight of home tradable goods in $C^T$ and is related to the size of the small economy relative to the rest of the world ($n$) and the degree of openness, $\gamma : (1-v) = (1-n)\gamma$ (see Sutherland,
Foreigners share a similar preference specification as domestic agents with \( v^* = n \gamma \):

\[
C_t^{T^*} = \left[ v^* \frac{1}{\theta} \left( C_t^{H^*}\right)^{\frac{\theta-1}{\theta}} + (1 - v^*) \frac{1}{\theta} \left( C_t^{F^*}\right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}.
\]

That is, foreign preferences for home goods depend on the relative size of the home economy and the degree of openness.

Consumption preferences towards domestic and foreign goods are given by

\[
C^H = \left[ \left( \frac{1}{n} \right)^{\frac{1}{\sigma}} \int_0^n c(z)^{\frac{\sigma-1}{\sigma}} \, dz \right]^{\frac{\sigma}{\sigma-1}}, \quad C^F = \left[ \left( \frac{1}{1-n} \right)^{\frac{1}{\sigma}} \int_1^n c(z)^{\frac{\sigma-1}{\sigma}} \, dz \right]^{\frac{\sigma}{\sigma-1}},
\]

where \( \sigma > 1 \) is the elasticity of substitution for goods produced within a country. \( C^{H^*} \) and \( C^{F^*} \) are specified in the same manner.

Accordingly, the consumption-based price-index for the small open economy can be written as

\[
P_t = \left[ \omega \left( P_t^T\right)^{1-\kappa} + (1 - \omega) \left( P_t^N\right)^{1-\kappa} \right]^{\frac{1}{1-\kappa}},
\]

with

\[
P_t^{\frac{1}{1-\sigma}} = \left[ v \left( P_t^{H^*}\right)^{1-\theta} + (1 - v) \left( P_t^{F^*}\right)^{1-\theta} \right]^{\frac{1}{1-\theta}},
\]

where \( P^H \) is the price sub-index for home-produced goods expressed in the domestic currency, and \( P^F \) is the price sub-index for foreign produced goods expressed in the domestic currency:

\[
P^H = \left[ \left( \frac{1}{n} \right)^{\frac{1}{\sigma}} \int_0^n p(z)^{1-\sigma} \, dz \right]^{\frac{1}{1-\sigma}}, \quad P^F = \left[ \left( \frac{1}{1-n} \right)^{\frac{1}{\sigma}} \int_1^n p(z)^{1-\sigma} \, dz \right]^{\frac{1}{1-\sigma}}.
\]

The law of one price holds (for tradeable goods): \( p(h) = Sp^*(h) \) and \( p(f) = Sp^*(f) \), where \( S \) is the nominal exchange rate (i.e., the price of foreign currency in terms of domestic currency). Our preference specification implies that \( P^H = SP^{H^*} \) and \( P^F = SP^{F^*} \), while \( P^T \neq SP^{T^*} \), since

\[
P^{T^*} = \left[ v^* \left( P_t^{H^*}\right)^{1-\theta} + (1 - v^*) \left( P_t^{F^*}\right)^{1-\theta} \right]^{\frac{1}{1-\theta}}.
\]

We define the real exchange rate as \( RS \equiv SP^*/P \). Note that because of our small open economy assumption (i.e., \( n \to 0 \)) \( P^{F^*} = P^* \), which implies that \( RS = SP^{F^*}/P \). Thus, nothing that occurs in the small open economy will affect the rest of the world.

The period budget constraints, expressed in units of domestic currency, for the home
country are:

\[ Q_0 A_1 + P_0 C_0 + B_1 + S_0 B_1^* = B_0 (1 + i_{-1}) + S_0 B_0^* (1 + i_{-1}^*) + A_0 (D_0 + Q_0) + W_0 L_0 + F_0 \]

\[ Q_1 A_2 + P_1 C_1 + B_2 + S_1 B_2^* = B_1 (1 + i_0) + S_1 B_1^* (1 + i_0^*) + A_1 (D_1 + Q_1) + W_1 L_1 + F_1 \]

\[ P_2 C_2 = B_2 (1 + i_1) + S_2 B_2^* (1 + i_1^*) + A_2 D_2 + W_2 L_2 + F_2 \]

where we denote with \( A_{t+1} \) the individual asset holding at the end of period \( t \), \( Q_t \) is the price of the asset in units of domestic currency, with \( D_t \) the exogenous dividend from holding the asset at time \( t \), \( W_t \) is the wage rate at time \( t \), \( L_t \) is the amount of total labor supplied at time \( t \), \( F_t \) are firms’ profit, and \( i_t \) is the nominal interest rate from holding debt \( B_t \) at time \( t \). We denote with \( B_t \) the amount of domestic-currency denominated bonds (which is traded only within the small open economy) and with \( B_t^* \) the foreign-currency denominated bond which is traded internationally. In writing the budget constraint we used the fact that \( B_3 = Q_2 = 0 \).

The collateral constraints are expressed as limits on foreign borrowing:

\[ S_0 B_1^* \geq -\psi Q_0 A_1 \]

\[ S_1 B_2^* \geq -\psi Q_1 A_2 \]

\[ S_2 B_3^* \geq 0. \]

It is now evident that, for given asset holding \((A_1 \text{ and } A_2)\), asset price and exchange rate appreciation increase the value of the collateral and allow agents to borrow more.

The dependence of the borrowing constraint from both exchange rate and asset price is behind the interplay between monetary policy and financial crises in the model. As we shall describe below, the determination of both prices is affected by the design of monetary policy both when the constraint is binding and when it is not.

**Intratemporal Consumption Choices** The intratemporal first order conditions determines how the household allocate their consumption expenditure among the different goods:

\[ C^N = \omega \left( \frac{P^N}{P} \right)^{-\kappa} C, -C^r = (1 - \omega) \left( \frac{P^r}{P} \right)^{-\kappa} C \]

with

\[ C^H = v \left( \frac{P^H}{P} \right)^{-\theta} C^T, -C^F = (1 - v) \left( \frac{P^F}{P} \right)^{-\theta} C^T \]
and
\[
c(h) = \left[ \frac{p(h)}{P^H} \right]^{-\sigma} C^H = v \left[ \frac{p(h)}{P^H} \right]^{-\sigma} \left[ \frac{P^H}{P^T} \right]^{-\theta} C^T
\]
\[
c(f) = \left[ \frac{p(f)}{P^F} \right]^{-\sigma} C^F = (1 - v) \left[ \frac{p(f)}{P^F} \right]^{-\sigma} \left[ \frac{P^F}{P^T} \right]^{-\theta} C^T
\]

There are corresponding conditions for the foreign economy and given our preference specification, the total demands of the generic good \( h \), produced in Home country, and of the good \( f \), produced in Foreign country, are respectively:

\[
y^d(h) = \left[ \frac{p(h)}{P^H} \right]^{-\sigma} [C^H + C^{H*}]
\]
and
\[
y^d(f) = \left[ \frac{p^*(f)}{P^*_F} \right]^{-\sigma} [C^F + C^{F*}].
\]

As \( n \to 0 \), we can rewrite our demand equations as:

\[
y^d(h) = \left[ \frac{p(h)}{P^H} \right]^{-\sigma} \left( \frac{P^H}{P^T} \right)^{-\theta} (1 - \omega) \left( \frac{P^T}{P} \right)^{-\kappa} \left[ (1 - \gamma) C + \gamma \left( \frac{P^T}{SP^T} \right)^{\kappa - \theta} \left( \frac{1}{RS} \right)^{-\kappa} C^* \right]
\]
and
\[
y^d(f) = \left[ \frac{p^*(f)}{P^*_F} \right]^{-\sigma} \left\{ \left[ \frac{P^*_F}{P^*_S} \right]^{-\kappa} (1 - \omega)C^* \right\}.
\]

We note here that the demand of home produced goods is affected by movements in two international relative prices: the real exchange rate \((RS)\) and the real exchange rate at the level of tradeable goods \((\frac{SP^T}{P^T})\). If we assume that \( \theta > \kappa \) (the elasticity of substitution among tradeable goods is higher than the one between tradeable and nontradeable), a depreciation of both real exchange rates redirect demand towards home produced goods. Foreign demand on the other hand is not affected by developments in the small open economy and it is determined only by foreign factors.

**Intertemporal Consumption Choices** The intertemporal first order conditions for consumption are then given by:

\[
C_0^{-\rho} = \lambda_0 P_0
\]
\[
\beta C_1^{-\rho} = \lambda_1 P_1
\]
\[
\beta^2 C_2^{-\rho} = \lambda_2 P_2.
\]
where we have denoted with $\lambda_t$ the multipliers on the period budget constraints. Using the expression for the Lagrange multiplier from the previous conditions we can write the first order conditions for foreign-currency denominated bond holdings as:

$$\sum\frac{C_0}{P_0} = S_0\mu_0 + \beta E_t \left[ S_1\frac{C_1}{P_1} (1 + \hat{i}) \right]$$

$$\sum\frac{C_1}{P_1} = S_1\mu_1 + \beta E_t \left[ S_2\frac{C_2}{P_2} (1 + \hat{i}) \right].$$

where $\mu_t$ denotes the Lagrange multiplier on the collateral constraints. From the first order conditions for domestic-currency denominated bond holdings we can retrieve the familiar Euler equations:

$$\frac{1}{(1 + i_0)} = E_t \left[ \beta\frac{C_1}{P_1} \right]$$

$$\frac{1}{(1 + i_1)} = E_t \left[ \beta\frac{C_2}{P_2} \right].$$

Using the expression for the Lagrange multiplier from the previous conditions we can then rewrite the first order conditions for the asset holdings as:

$$\frac{C_0}{P_0}Q_0 = \mu_0 \psi Q_0 + E \left[ \frac{C_1}{P_1} (D_1 + Q_1) \right]$$

$$\frac{C_1}{P_1}Q_1 = \mu_1 \psi Q_1 + E \left[ \frac{C_2}{P_2} D_2 \right].$$

Finally, by rearranging these conditions, we have:

$$Q_i = \frac{\lambda_{i+1} (D_{i+1} + Q_{i+1})}{\lambda_i - \mu_i \psi} \quad t = 0, 1.$$

All else being equal, this expression shows that when the constraint binds agents have an extra incentive to buy the asset and use it as collateral since the asset price is increasing in $\mu_t$. In fact, the previous equation is almost identical to a standard asset price condition in which the price of an asset is equal to the the expected present discounted value of future dividends. The discount is now given by the term $\frac{\lambda_{i+1}}{\lambda_i - \mu_i \psi}$ and differs from the standard one (i.e. $\frac{\lambda_{i+1}}{\lambda_i} = \frac{1}{(1+i)}$) only because of the multiplier associated with the credit constraint. This implies that, in general (both when the constraint is binding and when is not), the discount factor is going to be higher, other things being equal, since agents take into account the shadow value of relaxing the credit constraint by purchasing an extra unit of the asset.
Whenever the collateral constraint binds or it is expected to bind at a future date. Equations (8) and (9) thus highlight the first channel of interaction between monetary policy and the credit constraint: the asset price is given by the present discounted value of dividends and more aggressive monetary policy in normal time reduces the asset price and hence the value of the collateral.

No-arbitrage implies the following modified version of international parity condition:

\[
E_t \left[ \frac{C^{-\rho}}{P_1} (1 + i_t) \right] = \left[ \mu_0 + E_t \left[ \frac{C^{-\rho}}{P_1} \frac{S_1}{S_0} (1 + i^*) \right] \right]
\]

(10)

and

\[
E_t \left[ \frac{C^{-\rho}}{P_2} (1 + i_1) \right] = \left[ \mu_1 + E_t \left[ \frac{C^{-\rho}}{P_2} \frac{S_2}{S_1} (1 + i^*) \right] \right]
\]

(11)

The international parity conditions are now modified to take into account the possibility that the constraint is binding (\(\mu_t > 0\)) or might be binding in the future. Equations (10) and (11) determine a second channel of interaction between monetary policy and the borrowing constraint operating via the nominal exchange rate. When the constraint binds, agents reallocate their wealth towards domestic assets, and in particular towards domestic currency bonds. This generates an increase in the real return on domestic currency bonds through an expected appreciation of the nominal exchange rate or an increase in the domestic nominal interest rate. This in turn implies that, when the constraint is binding, a relatively more aggressive monetary policy is coupled with a relatively more appreciated currency, which tends to relax the constraint. When the constraint is not binding, a similar mechanism operates: for given future exchange rate, a more aggressive monetary policy is accompanied by a more appreciated exchange rate.

To summarize, in normal times, monetary policy affects the borrowing capacity of agents (i.e., the possibility that the constraint might be binding) through two channels. Higher interest rates can increase the borrowing capacity by appreciating the nominal exchange rate while they decrease it by lowering the asset price that serve as a collateral. The relative strength of these two channels determines the extent to which monetary policy entails an indirect prudential component that reduces the amount of foreign currency-denominated borrowing of the small open economy, and hence contributes to a reduction in the frequency and the severity of financial crises.

2.2 Firms

Our economy is a two-sector economy that produces tradeables and non-tradeables goods. We assume that only domestic agents hold shares in home firms. Firms in the tradeables
sector operate in a monopolistic competitive environment and face a technology that might prevent them from adjusting prices in period 0 and 1. In period 2, prices are fully flexible for all firms. On the other hand, firms in the non-tradeables sector operate under decreasing return to scale in a competitive environment.

In the non-tradeable sector, firms produce according to the following production function:

\[ Y_t^N = z_t^N (L_t^N)^\delta \]

where \( z_t^N \) is the sector-specific productivity shock, \( L_t^N \) is the amount of labor employed in the non-tradeables sector and \( \delta < 1 \) is the return to scale parameter. The profit of non-tradable firms, \( \pi_t^N \), is given by:

\[ \pi_t^N = P_t^N z_t^N (L_t^N)^\delta - W_t L_t^N. \]

From the maximization problem of non-tradeables firms we obtain the following standard first order condition:

\[ W_t = P_t^N z_t^N \delta (L_t^N)^{\delta - 1}. \tag{12} \]

In the tradable sector the firms’ production function is linear in labor:

\[ y_t(h) = z_t^T L_t^T(h) \]

with \( z_t^T \) denoting a sector-specific productivity shock. These firms operate in a monopolistic competitive market and face a technology constraint that prevents them from adjusting prices every period. In particular, we assume that only a fraction \( (1 - \alpha) \) can change price in period 0 and 1, while prices are fully flexible in period 2.\(^5\)

Starting from period 2, we write the individual firm problem as:

\[ \pi_2(h) = p_2(h) y_2(h) - W_2 \frac{y_2(h)}{z_2^T}, \]

where

\[ y_2(h) = \left( \frac{p_2(h)}{F_{H,2}} \right)^{-\sigma} Y_{H,2} \]

is the total demand faced by the individual firm for the single differentiated good. Period 2’s maximization problem renders that the optimal price is a mark-up over nominal marginal

\(^5\)Here we also assume that when firms can reset prices they have observed the relevant uncertainty.
Given that all firms in period 2 face the same marginal cost, the optimal price is the same across firms \( p_2(h) = P_2^H \), with

\[
1 = \frac{\sigma}{\sigma - 1} \frac{W_2}{P_2^H z_2^T}.
\]

Consider now firm pricing in period 0 and 1. In period 0 only a fraction \((1 - \alpha)\) of firms can reset prices taking into account that prices might be fixed in period 1. So the maximization problem is given by

\[
\max_{E_0} \left[ \pi_0^T + \beta \alpha Q_{0,1} \pi_1^T \right] = \left[ p_0(h) \tilde{y}_0(h) - W_0 \frac{\tilde{y}_0(h)}{z_0^T} \right]
+ \beta \alpha Q_{0,1} \left[ z_1^T p_0(h) \tilde{y}_1(h) - W_1 \frac{\tilde{y}_1(h)}{z_1^T} \right],
\]

where

\[
\tilde{y}_0(h) = \left( \frac{\tilde{p}_0(h)}{P_{H,0}} \right)^{-\sigma} Y_{H,0},
\]
\[
\tilde{y}_1(h) = \left( \frac{\tilde{p}_0(h)}{P_{H,1}} \right)^{-\sigma} Y_{H,1}
\]

are the total demands that the individual firm face in period 0 and 1, conditional on the choice of price in period 0, while \( Q_{0,1} \) is the nominal stochastic discount factor between period 0 and 1. The first order condition for the individual firm’s maximization problem yields:

\[
\tilde{p}_0(h) = \frac{\sigma}{\sigma - 1} \frac{E_0 \left( \frac{W_0 \tilde{y}_0(h)}{z_0^T} + \beta \alpha Q_{0,1} \frac{W_1 \tilde{y}_1(h)}{z_1^T} \right)}{E_0 (\tilde{y}_0(h) + \beta \alpha Q_{0,1} \tilde{y}_1(h))}
\]

By using (14), we can rewrite the above condition as:

\[
\frac{\tilde{p}_0(h)}{P_0^H} = \frac{\sigma}{\sigma - 1} \frac{E_0 \left( \frac{W_0}{z_0^T} P_{H,0} Y_{H,0} + \beta \alpha Q_{0,1} \frac{W_1}{z_1^T} P_{H,1} Y_{H,1} \right) \left( \Pi_1^H \right)^{1+\sigma} Y_{H,1}}{E_0 \left[ Y_{H,0} + \beta \alpha Q_{0,1} \left( \Pi_1^H \right)^{\sigma} Y_{H,1} \right]}
\]

with \( \Pi_1^H = \frac{P_1^H}{P_0^H} \) denoting gross inflation from period 0 to period 1. \( P_0^H \) is the aggregate price index for the home produced goods given by

\[
(P_0^H)^{1-\sigma} = (1 - \alpha) \tilde{p}_0(h)^{1-\sigma} + \alpha \left( P_{-1}^H \right)^{1-\sigma},
\]
that can be rewritten as
\[
\left( \frac{1 - \alpha (\Pi_0^H)^{\sigma-1}}{1 - \alpha} \right)^{\frac{1}{1-\sigma}} = \frac{\tilde{p}_0(h)}{P_0^H},
\tag{17}
\]
with \( \Pi_1^H \equiv \frac{P_1^H}{P_0^H} \).

A similar problem arises in period 1 in which only a fraction of firms \((1 - \alpha)\) can reset prices. Since prices can be reset for every firm in period 2, the pricing problem in period 1 is the same as in the flexible price case:
\[
\tilde{p}_1(h) = \frac{\sigma}{\sigma - 1} \frac{W_1}{z_1^t}
\tag{18}
\]
with the aggregate price index for the home produced goods in period 1 given by
\[
\left( P_1^H \right)^{1-\sigma} = (1 - \alpha)\tilde{p}_1(h)^{1-\sigma} + \alpha \left( P_0^H \right)^{1-\sigma}
\]
that can be rewritten as:
\[
\left( \frac{1 - \alpha (\Pi_0^H)^{\sigma-1}}{1 - \alpha} \right)^{\frac{1}{1-\sigma}} = \frac{\tilde{p}_1(h)}{P_1^H}
\tag{19}
\]

It is now useful to examine how the credit constraint interacts with firm behavior in the presence of nominal rigidities. The interaction between the credit constraint and nominal rigidities is direct in period 0 and indirect in period 1 and 2, since in period 1 and 2 firms reset prices at the flexible price level. In period 0, a binding constraint, or an expected binding constraint in period 1, reduces aggregate demand and tends to lower domestic producer inflation other things being equal, compared to an economy in which there is no borrowing constraint. In period 1 and 2, the effect is indirect through the endogenous state variable \( B_t^* \) that determines the household debt position at the beginning of period \( t \). Indeed, the lower the level of debt accumulated in the previous period, the lower are the resources available to household for spending in the current period, given the level of other variables. Thus, other things being equal, higher debt implies lower demand and lower domestic producer inflation.

Inflation, in turn, also determines an inefficient allocation of resources between tradable and non-tradable goods that can influence the tightness of the borrowing constraint. To see this, note that the pricing decisions in period 0, 1 and 2 can be summarized in terms of the following equations:
\[
\left(1 - \alpha \left(\Pi_0^H\right)^{\sigma-1}\right)^{\frac{1}{1-\alpha}} = \frac{\sigma}{\sigma - 1} E_0 \left(\frac{P_0^N z_0^N \delta (L_0^N)^{\delta-1}}{z_0^1 P_0^H} Y_{H,0} + \beta_0 Q_{0,1} \frac{P_0^N z_0^N \delta (L_0^N)^{\delta-1}}{z_0^1 P_{H,1}^N} \left(\Pi_1^H\right)^{1+\sigma} Y_{H,1}\right)
\]

(20)

for period 0;

\[
\left(1 - \alpha \left(\Pi_1^H\right)^{\sigma-1}\right)^{\frac{1}{1-\alpha}} = \frac{\sigma}{\sigma - 1} \frac{P_1^N z_1^N \delta (L_1^N)^{\delta-1}}{P_1^H z_1^1}
\]

(21)

for period 1, and

\[
1 = \frac{\sigma}{\sigma - 1} \frac{P_2^N z_2^N \delta (L_2^N)^{\delta-1}}{P_2^H z_2^1}
\]

(22)

for period 2, where \(Q_{0,1} = \frac{1}{1+\alpha}\).

Note now that, from (21), positive inflation determines an inefficient allocation of resources between tradable and non-tradable goods. Indeed, inflation creates a wedge between the relative price of tradable goods over non-tradable goods and their marginal rate of transformation. When inflation is positive resources tend to shift towards the non-tradables sector, implying a decline in tradable production, other things being equal. Through this affect, the possibility that the borrowing constraint binds increases by increasing the amount agents need to borrow in order to enjoy a given level of tradable consumption. Note however that positive inflation might also imply higher nominal interest rates through the monetary policy rule, which as we described above, affects the borrowing capacity of agents through the effects on asset prices and the nominal exchange rates.

### 2.3 Monetary and prudential policies

We model monetary policy with a simple interest rate rule that reacts only to domestic producer inflation:

\[
(1 + i_t^{TR}) = \beta^{-1} \Pi \left(\frac{\Pi_t^H}{\Pi}\right)^{\phi_w},
\]

(23)

in which the target inflation \(\Pi_t\) is time invariant and set equal to zero. An alternative is to include in the rule the CPI inflation rate that indirectly includes also changes in the nominal exchange rate. This, however, in our model, might have prudential effects to the extent to which the exchange rate enters also the leverage constraint.

First, we consider an augmented interest rate rule with an explicit macro-prudential
argument in period zero in addition to the inflation term. We include the level of aggregate borrowing as a share of total consumption expenditure. More formally, the alternative rule is:

\[(1 + i_t) = \beta^{-1} \Pi \left( \frac{\Pi_t}{\Pi} \right)^{\phi_x} \left( 1 - \frac{S_tB_{t+1}^*}{P_tC_t} \right)^{\phi_{B^*}} \text{ for } B_{t+1}^* < 0 \quad (24)\]

where \((1 + i_t^{TR}) = \beta^{-1} \Pi \left( \frac{\Pi_t}{\Pi} \right)^{\phi_x} \) is the hypothetical level of the interest rate that would prevail if \(\phi_{B^*} = 0\), which is used below for the purpose of explaining how macro-prudential policy works in our model. This rule says that, all else being equal, the nominal interest rate in period \(t\) is higher the higher the level of aggregate borrowing in domestic currency as a share of consumption spending. When \(\phi_{B^*} = 0\) the nominal interest rate will be the same as in (22). When instead \(\phi_{B^*} \neq 0\) nominal interest rates are higher than in the standard rule for a given amount of debt, and as such the interest payment on debt increases, constraining current spending.

The relatively higher current interest rate also provides an incentive to reduce current period borrowing. From our set of equilibrium conditions, in fact, we can see that (24) affects the intertemporal margin in (6) and (7) by tilting the profile of consumption towards future consumption as opposed to present consumption and reducing the amount that agents want to borrow other things being equal. In fact the Euler equation in period 0 becomes:

\[
\frac{1}{(1 + i_t^{TR}) \left( 1 - \frac{S_0B_1^*}{P_0C_0} \right)^{\phi_{B^*}}} = E_t \left[ \beta \frac{C_{1}\rho}{P_1} \frac{P_0}{C_0^{-\rho}} \right] \quad (25)
\]

In this case, the international parity condition becomes

\[
\left( 1 - \frac{S_0B_1^*}{P_0C_0} \right)^{\phi_{B^*}} E_t \left[ \frac{C_{1}\rho}{P_1} (1 + i_0^{TR}) \right] = \left[ \mu_t + E_t \left[ \frac{C_{1}\rho}{P_1} \frac{S_t}{P_0S_0} (1 + i^*) \right] \right]
\]

since the augmented rule is based on aggregate debt and agents take it as given when they allocate their wealth between home and foreign currency bonds. Thus, macro-prudential monetary policy makes domestic borrowing relatively more expensive compared to foreign borrowing and affects directly the intertemporal allocation of consumption of households (see (25)).

\footnote{The fact that the second argument in the interest rate rule is active only in period zero is crucial for its performance.}
Second, we also consider a separate macro prudential policy rule which is a tax on the amount that the economy borrows in the aggregate. This second tool acts simultaneously and independently from the interest rate tool. As in the previous case, we allow for this macro-prudential tool only in period 0 since in our three-period economy the constraint might be binding only in period 1. In this case, the budget constraint in period 0 becomes:

\[ Q_0 A_1 + P_0 C_0 + B_1 + S_0 B_1^*(1 - \tau_0^*) = B_0 (1 + i_{-1}) + S_0 B_0^*(1 + i_{-1}^*) + A_0 (D_0 + Q_0) + W_0 L_0 + F_0 + T_0 \]

where \( B_1^*(1 - \tau_0^*) \) is the after-tax borrowing proceeding available for consumption, and \( T_0 \) is a lump-sum transfer from the government (with the government that follows a balanced budget rule \( T_0 = -S_0 B_1^* \tau_0^* \)). Our macro-prudential tax rule is then given by:

\[
(1 - \tau_0^*) = (1 - \frac{S_1 B_{t+1}^*}{P_t C_t})^{\phi_{0^*}} \quad \text{for} \quad B_{t+1}^* < 0,
\]

which implies that after-tax borrowing proceedings decreases with the level of debt.

Similarly to the case of the augmented interest rate rule above, this tax applies when the economy is borrowing from the rest of the world. The intertemporal margin that now is distorted is the Euler equation for foreign bonds:

\[
S_0 \frac{C_0^{-\rho}}{P_0} (1 - \tau_0^*) = S_0 \mu_1 + \beta E_t \left[ S_1 \frac{C_1^{-\rho}}{P_1} (1 + i^*) \right]
\]

and the international parity condition becomes similar to the one in the augmented Taylor rule case:

\[
(1 - \tau_0^*) E_t \left[ \frac{C_1^{-\rho}}{P_1} (1 + i_0) \right] = \mu_0 + E_t \left[ \frac{C_1^{-\rho}}{P_1} S_1 (1 + i^*) \right].
\] (26)

Here macro-prudential policy alters the relative return of domestic and foreign bonds by making foreign currency denominated borrowing return relatively more expensive compared to the case in which monetary policy is augmented by a macro-prudential component. The main difference with respect to the previous case is that now there is no intertemporal distortion in the consumption profile across time. In fact in this case (6) holds:

\[
\frac{1}{(1 + i_0^{TR})} = E_t \left[ \frac{\beta}{\frac{P_0}{P_1}} \frac{C_1^{-\rho}}{C_0^{-\rho}} \right].
\]

So, with our formulation, an independent macro-prudential policy acts directly on the quantity that agents borrow and reduces the net amount that they borrow but it does not distort the intertemporal consumption choice.
3 Model parametrization and solution

Our three-period is calibrated at annual frequency for a small open economy with an ini-
tial negative net foreign asset position. Examples of such countries are emerging markets
economies like Hungary, South Korea, Mexico and Brazil in 1990s and the 2000s. We in-
terpret period zero as the short-run, period one as the medium-run, and period two as the
long-run or the steady-state.

We choose the parameter values with the model in which there are both frictions, the
nominal rigidities and the borrowing constraint, as a reference. The specific parametriza-
tion chosen largely draws on the existing literature and three empirical features of these
economies: the net foreign asset position that is typically negative (e.g., Lane and Milesi-
Ferretti, 2007), the probability of a financial crisis that is relatively small (e.g., Benigno et
al., 2011), and their leverage that is moderate (Fernandez and Gulan, 2012).

The tradeable sector technology level, $\zeta^T$, is the only source of uncertainty in the model
and it is a Markov process that can take on two values (low or high). We label the low
state as bad or normal and the high state as good or boom. The model is initialized in the
bad/normal state, and our parametrization is such that the constraint will bind in period
1 when the technology switches to the good/boom in the economy with price rigidity and
the borrowing constraint.\footnote{The analysis is most relevant when the economy is a normal state but is vulnerable and a small shock,
either positive or negative, could trigger a crisis.} In the exercises that follow we compare different economies in
which we allow for flexible prices and/or no borrowing constraint while keeping the other
structural parameters constant. By changing the structure of the economy, the properties
of the solution also change. So the constraint may bind in both states, in neither state, or
in the opposite state than in the in the benchmark case.

While we seek a parametrization that is as realistic as it is feasible for the benchmark
case, we do not contend that our three-period model is a realistic laboratory economy. In
particular, even in the absence of uncertainty, the model has a dynamic with excessively
large changes over time in the nominal variables. This is partly driven by the fact that the
negative net foreign asset position must be repaid in full within three periods and partly by
the terminal condition for the nominal exchange rate, given endowments and preferences.
In light of this, we do not use the model to make quantitative statements, but rather only
to study the interaction between its two frictions and the alternative policies regimes that
we consider.\footnote{We discuss the main results without taking deviation from these deterministic allocations for ease of
interpretation and transparency.}

Table 1 reports the specific parameter values we chose, the shocks’ process, and the
initial and terminal conditions. The Markov process takes values 0.9 or 1.1 with transition matrix:

\[ p = \begin{bmatrix} 0.9 & 0.1 \\ 0.1 & 0.9 \end{bmatrix}. \]

The conditional probability of staying in each state is 0.9, while the unconditional probability of each state is 0.5, and that the autocorrelation of the process is 0.8. The implied standard deviation, given the transition matrix, is 7.5 percent, which is slightly above the annualized value of aggregate TFP volatility for Mexico (Benigno 2011, and Mendoza, 2010). This shock hits the economy in period 0 and in period 1, so that the economy has two possible outcomes in period 1 and four outcomes in period 2.

We choose these parameters so that the probability of changing state is 0.1. Thus, this conditional probability is equal to the probability of a binding constraint—our definition of a financial crisis. Therefore, from the perspective of period zero, we have an unconditional probability to remain in the bad/normal state of 0.5 and a 0.1 chance of entering a financial crisis despite the realization of a positive shock. This implies that we have crises approximately 5 percent of the times if we were to simulate the model for a large number of periods. By comparison, the unconditional probability of a financial crisis in Mexico since 1980 is 10 percent per year, which is close to other empirical estimates in the literature (see Benigno et al, 2011 for a discussion). In other words, our crisis probability is smaller, but the size of the trigger of the crisis is slightly larger than in Mexico data.  

Note here that the probability of the crisis cannot be used as a measure of financial stability in the model. Because the Markov shock process has only two states, the probability at time 0 that the constraint binds at time 1 is exogenous in the model and coincides with the probability that the economy switches from the bad/normal state in period 0 (in which it is initialized) to a good/boom state in which the constraint binds in period 1. However, the value of the credit multipliers is endogenous and, when it is positive, indicates the presence and the severity of the crisis. As we noted above, we measure financial stability with the value of the borrowing multipliers, which change endogenously depending on the structure of our model economies.

The relative weight of non-tradable goods is set to 0.32076, close to the value of Benigno et al (2012) and Mendoza (2002). The size parameter \( n = 0 \) to capture the concept of a small open economy that cannot influence the rest of the world and the degree of openness \( \gamma \) is set at 0.40 (Mexico openness before the 1994-95 crisis) which together yields a value for the relative weight of home tradable goods \( v \) of 0.6. The elasticity of substitution between

\[ 10 \text{ The results reported are robust to changes in the parameters of the Markov process in the ranges discussed. All experiments not reported are available from the authors on request.} \]
tradable and non-tradable goods, $\kappa$, is set to 0.5 a customary value in the literature. The elasticity of substitution between home and foreign tradeable, $\theta$, is 2. This is a relatively low value (i.e., a short term elasticity) but well within the range of the empirical estimates for macroeconomic data.\(^\text{11}\)

The elasticity of substitution within home tradeable goods is set to 6 to yield a mark up of 20%, which is a conventional value assumed in the New-Keynesian literature. The labor share parameter $\delta$ is set to 0.75, slightly higher than usually assumed but not outside a plausible range of values if we consider self-employment. The intertemporal substitution and risk aversion are set $\rho = 0.5$, implying a risk aversion of 2, which is a standard value. The foreign interest rate ($i^*$) and the discount rate ($\beta$) are set at .03 and .96 respectively, which are also standard values.

The Calvo parameter controlling the degree of nominal rigidity is set to $\alpha = 0.38$. This is the value of $\alpha$ that would correspond to the unconditional probability of changing prices of one year if we interpret our model at a annual frequency. This is consistent with the typical value of .75 in quarterly, infinite horizon models that implies full price adjustment within 4 quarters. The coefficient in the interest rate rule on domestic producer inflation is set to $\dot{\phi}_\pi = 1.5$, which is a standard value. The coefficients on macro prudential policy are set at $\dot{\phi}_{B^*} = 0.05$ in the augmented interest rate rule and to $\phi_{B^*} = \phi_{B^*} = -0.05$ in the tax rule. These values are of the same order of magnitude of the taxes on certain forms of capital inflows that Brazil recently introduced.

The parameter $\psi$ of the collateral constraint is set to a value such that the constraint is never binding in period 0 (e.g., 1,000), and to 1.1 in period 1. This is slightly above the value of .9 for Mexico’s prime corporations reported by Fernandez and Gulan (2012), who construct a novel data set on leverage in emerging markets.

For given $\psi$, the initial net foreign asset position and the exogenous dividend process are set to achieve a certain target for the average debt-to-income ratio in the model.\(^\text{12}\) The dividend is constant in nominal terms over time and set to $D_0 = D_1 = D_2 = 0.012$. The initial stock of debt in foreign currency is set to $B^*_0 = -.43$. With these values, in the benchmark economy with sticky prices and the borrowing constraint, we obtain a average debt-to-income ratio of about 40 percent, which is close to the value for Mexico in the 1990s and 2000s.\(^\text{13}\)

\(^{11}\)The main results of the paper are robust to moving both $\kappa$ and $\theta$ toward one. We find similar results, with smaller nominal fluctuations in the deterministic equilibrium of the model by making the non-tradable sector as an endowment rather than production sector by assuming a value for $\delta$ arbitrarily close to zero. We cannot not solve the model for values of $\kappa$ and $\theta$ much above 1 and 2, respectively.

\(^{12}\)Averages of the endogenous variables of the model are computed over time and weighting across states with the conditional probabilities of the states of the Markov process.

\(^{13}\)While the values for the dividend and the initial level of debt produce a dividend-to-income ratio of
Finally, foreign prices are constant and normalized to 1: \( P^* = P_0^{F*} = P_1^{F*} = P_2^{F*} = 1 \). The terminal net foreign asset position in foreign currency is zero (i.e., \( B_3^* = 0 \)), while the terminal exchange rate level is \( S_2 = 1 \).

Despite its relative simplicity, the model we set up has no closed form solution and must be solved numerically. We solve a fully non-linear version without resorting to approximation techniques. Specifically, the model’s core non-linear equilibrium conditions (including the resource constraint of the tradable sector derived in appendix) are solved for all states of the economy simultaneously with the Matlab function \textit{fsolve}, for given initial and terminal conditions, and the state of the tradeable sector technology shock \( Z^T \). Like Benigno et al. (2011), we convert the complementary slackness conditions for the borrowing constraint into a single nonlinear equation following Garcia and Zangwill (1981). When the default initial condition does not yield a solution we employ a homotopy method to find the solution of the model—see again Garcia and Zangwill (1981). The model can have multiple equilibria. We ruled out equilibria with negative nominal interest rates.\(^{14}\) The results we report are robust to change the initial conditions.

We evaluate alternative policy rules by comparing welfare. This is computed as the ex ante value of the lifetime utility:

\[
V = \frac{C_0^{1-\rho}}{1-\rho} + p_{11} \frac{C_{1,1}^{1-\rho}}{1-\rho} + p_{12} \frac{C_{1,2}^{1-\rho}}{1-\rho} + p_{11}p_{11} \frac{C_{2,11}^{1-\rho}}{1-\rho} + p_{11}p_{12} \frac{C_{2,12}^{1-\rho}}{1-\rho} + p_{12}p_{21} \frac{C_{2,21}^{1-\rho}}{1-\rho} + p_{12}p_{22} \frac{C_{2,22}^{1-\rho}}{1-\rho},
\]

where \( C_0 \) is total consumption at time zero, \( C_{i,j} \) is the total consumption in period 1 in state \( i \) with \( i = 1, 2 \), \( C_{2,ij} \) is the total consumption in period 2 if state \( i \) realized in period 1 and state \( j \) realizes in period 2, and \( p_{i,j} \) with \( i,j = 1, 2 \) are the transition probabilities of the Markov process above, in which state 1 is the negative one.

4 Alternative monetary and macro-prudential policy rules

In this section we study the equilibrium allocation under alternative specifications for the frictions in the model and the monetary and macro-prudential policy rules. We consider four alternative specifications of our small open economy model that helps to provide intuition on how nominal rigidities and the borrowing constraint work and interact in the model.
The first is a frictionless version that provides a benchmark (even though is not necessarily a Pareto efficient economy). The second is a flexible price economy with the borrowing constraint that is comparable to the models in the Neo-Fisherian literature on financial stability. The third is a sticky price economy without the financial friction that is a three period version of a typical small open economy New Keynesian model. Finally, we consider the economy with both nominal and financial frictions.

We consider three alternative macro prudential regimes. The first is a traditional monetary policy regime without any prudential component. Traditional monetary policy is implemented by means of an interest rate rule with coefficient of 1.5 on inflation.\footnote{See Ghironi and Cavallo (2002) for an analysis of alternative interest rate rules in small open economies under flexible prices.} The second is a two-instrument regime with the same traditional monetary policy rule and a tax rule on debt in period 0 with a reaction coefficient of 0.5 as a macro-prudential policy tool. The third is an interest rate rule that responds to both inflation and debt in period 0 with coefficients of 1.5 and 0.5, respectively.

### 4.1 Flexible price allocations

Table 2 describes the equilibrium allocation as well as the associated welfare for a subset of relevant flexible price cases. The first two columns describe economies without and with the borrowing constraint, respectively. The third column describes a flexible price economy with the borrowing constraint and the tax rule on debt. The fourth column describes an economy with a monetary policy rule augmented with debt.

As we can see from Table 2, the borrowing constraint reduces lifetime utility relative to the frictionless economy. The frictionless economy is on a debt repayment path with consumption that is roughly constant over time and across states, and a current account surplus of similar magnitude in all periods and states (experiment 1). The initial debt (constant across experiments in units of foreign currency), in fact, needs to be repaid in full in period 2 (i.e., $B_2^* = 0$).

The constrained economy consumes more tradable goods than the unconstrained economy in period 0 and less tradable goods in both states of the world in period 1 (experiment 2). This is despite that borrowing in foreign currency is lower than the unconstrained economy in period 0. The constrained economy also has a higher price level (and hence inflation) in period 0 and higher inflation in period 1 in both states. Interest rates are also uniformly higher in the constrained economy in both period 0 and 1, but the exchange rate is more depreciated in both periods. The asset price is higher in both period 0 and period
1.

The constrained economy has to consume less and produce more in period 0 and 1 to meet the borrowing constraint. For this reason, the exchange rate falls more than in the unconstrained economy to help external adjustment, despite the higher interest rates. The asset price is more appreciated despite higher interest rates as the binding borrowing constraint in both states provides an extra incentive to hold the asset as we saw in equation (8) and (9).

The introduction of a tax rule on debt along with a traditional interest rate rule decreases welfare in the constrained economy with flexible prices (experiment 3). The key difference is the path of the interest rates that is tilted in both states, with higher rates in period 0 and lower rates in period 1 than in the economy with the constraint and no debt tax. This tilt depreciates the exchange rate in period 0 and appreciates it in period 1 in both states relative to the case with only traditional monetary policy. Borrowing in foreign currency is lower and the crisis is less severe than in the absence of the tax on debt. But this comes about via a more depreciated exchange rate that increases the domestic currency value of the initial debt and hence its burden. As a result overall consumption is lower in period 0.

The interest rate rule augmented with debt, instead, increases utility relative to the benchmark with the borrowing constraint. The augmented interest rate rule tilts the interest rate path in the opposite direction: interest rates are lower than in the case of traditional monetary policy in period 0, and higher in the bad state in period 1 when the exchange rate is under relatively more pressure. This helps the exchange rate depreciation in the state in which the constraint is more binding. As a result, the crisis is less severe in the bad state. This also permits larger borrowing in foreign currency at period 0, higher tradable consumption in period 0, and higher overall consumption in period 0 and 1.

4.2 Sticky price allocations

Table 3 compares a set of economies with sticky prices, both with and without the borrowing constraint, and with the constraint and the prudential tax rule on debt and the augmented interest rate rule.

The economy with price rigidity without constraint has a smooth consumption and debt repayment path over time similar to the flexible price economy without the constraint (experiment 1). Since prices are sticky, following a shock, tradable prices cannot adjust to allocate efficiently resources. Inflation and interest rates are lower than in the flexible price economy.

\[\text{Note here that in this case the borrowing constraint binds in both states of the tradable productivity process, but the constraint is more severe in the bad state than in the good one.}\]
allocation both in period 0 and 1. As prices cannot adjust efficiently the nominal exchange rate depreciates more than under flexible prices in period 0. Agents borrow less in foreign currency, since they face a higher debt burden associated with a nominal exchange rate that is more depreciated. This will reduce consumption in both period 0 and period 1, and hence lowers welfare.

The economy with sticky prices and the borrowing constraint has a higher asset price but a more depreciated exchange rate than the one without constraint. Borrowing in foreign currency is lower but the debt burden as a share of national income is higher. A higher debt burden translates into higher inflation and interest rates in period zero and lower consumption and welfare.

A tax on debt reduces welfare and works like in the flexible price case by tilting the interest rate path. With tax on debt interest rates are higher in period zero and lower in the good state of period 1, but higher in the bad state of in period 1, relative to the benchmark case without prudential policy. Consistent with this pattern, inflation is higher at time zero and in the bad state of period 1, but lower in the good state of period 1. The exchange rate is more depreciated and the asset price is lower in period zero. As a result, borrowing in foreign currency and consumption in period zero are lower than in the baseline case. Nominal rigidities therefore do not alter the functioning of macro-prudential policy via the tax debt in comparison with the flexible price case discussed above.

Augmenting the monetary policy rule with debt also works in manner similar to the case of flexible prices. Interest rates are tilted in the opposite direction, and are lower in period zero and higher in the good state of period 1, with a consistent inflation pattern. The exchange rate is relatively more appreciated in period zero than in the benchmark case with only traditional monetary policy. As a result, the economy can support a higher level of debt in foreign currency and consumption in period zero, even though the asset price is lower.

4.3 Sensitivity

We now conduct sensitivity analysis to understand how key features of the economic environment and the policy regime affect economic outcomes in the model. We consider a set of five experiments, each of which makes one parameter vary. We change the level of initial debt, the degree of nominal rigidity, the inflation coefficient in the interest rate rule, and the debt coefficient in the debt rule and the augmented interest rate rule. We examine how each change impacts on overall utility, the amount that agents borrow in foreign currency in period 0 (before the constraint might bind), tradable consumption in period zero, the
values of the multipliers on the collateral constraint in the two states, the nominal exchange rate, producer price inflation, the nominal interest rate, and the asset price, all in period 0. We focus on period 0 (before the constraint might bind) because this is the period in which precautionary behavior, which is the focus of prudential policy, can take place.

We first vary the initial condition on the amount of outstanding debt ($B_0^*$) (Figure 1). We note that as the amount of initial debt decreases, welfare rises. This is intuitive since, as we noted above, the economy is on an adjustment path in which debt has to be repaid in full at the end of period 2. As the initial debt position declines, agents consume more tradables and borrow less in period 0, and there is a threshold level of initial debt beyond which the constraint is never binding in period 1.

Interestingly the price level and the nominal interest rate in period 0 are non-monotonic with respect to the borrowing constraint. When the constraint binds in period 1, less debt is associated with lower inflation and nominal interest rate in period 0. The opposite occurs when the constraint does not bind in period 1: lower debt is associated with higher nominal interest rates and inflation in period 0. This reflects the behavior of producer price inflation, with a higher debt being associated with a tighter constraint. The latter requires higher production, higher marginal costs, and higher hence inflation and interest rates. When the constraint is not binding, instead, inflation increases with lower debt. We also note that the asset price falls despite the decline in the interest rate when the constraint binds, driven by the effect of the credit multiplier. The exchange rate instead appreciates even if the interest rates fall because there is a smaller need to adjust externally with lower debt.

In the second experiment we vary the degree of nominal price rigidity (Figure 2). In this case, as the degree of nominal rigidity increases, utility is lower despite lower borrowing and a looser constraint. In other words, higher price rigidity is associated with cases in which the financial constraint binds less tightly, but this trade off is not strong enough to be registered in terms of utility. In particular, there is a threshold of nominal rigidity below (above) which the constraint is never (always) binding in period 1. This threshold alters the slope of the utility change, but does not lead to a reversal. The exchange rate depreciates and the asset price appreciates, driven by lower interest rates, which in turn is consistent with a lower price level and inflation in period zero.

We next examine the effects of changing $\phi_\pi$, the inflation coefficient in the traditional monetary rule in which there is a similar trade off. By altering the strength of the monetary response to inflation the behavior of the economy mirrors that found increasing the degree of nominal rigidity. As the reaction towards inflation becomes more aggressive (i.e. interest rates are higher) the credit multipliers becomes positive and their value increase with higher $\phi_\pi$. In fact, while the exchange rate appreciates, asset prices decrease with higher nominal
interest rates. The effect of an appreciated exchange rate reduces the initial debt burden (positive wealth effect) while the combined effect of asset price decline and appreciated exchange rate increases the borrowing capacity of agents. At the same time, higher reaction toward inflation reduces domestic producer inflation and reduces the inefficiency created by nominal rigidities. In utility terms, this second channel dominates so that higher $\phi_\pi$ is associated with higher welfare despite the fact that the crisis is more severe with a more aggressive traditional monetary policy.

In the last two experiments we first increase the coefficients on debt in the tax rule and in the augmented interest rate rule. Not surprisingly when the coefficient on the debt is higher in the tax rule, agents reduce their foreign borrowing and there is a threshold above which the constraint is never binding. Despite this, utility declines with the magnitude of the tax on debt as the distortions introduced in terms of lower consumption dominates the benefit of limiting the severity of the crisis. With a larger tax on debt, inflation and interest are higher, the exchange rate depreciates and and the asset price decline.

On the other hand, with the augmented interest rate rule, the utility increases monotonically with the strength of the debt reaction. With a larger debt reaction in the interest rate rule, borrowing increases, while inflation and the interest rate decline. The exchange rate appreciates and the asset price decline. Like the cases in which we increased the degree of price rigidity or the strength of the inflation reaction, there is a trade off between the severity of the crisis and the level of inflation, but not strong enough to induce a utility reversal over the portion of the parameter space explored.

In sum, these results highlight the important role of the nominal exchange rate for prudential policy and the interaction between production and consumption decisions in determining welfare. While the tax on debt may reduce the severity of financial crisis, it tends to depreciate the exchange rate and to constraint borrowing capacity. In contrast, augmenting the interest rate rule with debt, helps to keep the exchange rate more appreciated and to support borrowing even though it produces more severe financial crises in both states of the world. Welfare enhancing policies in the model work by supporting the borrowing (and hence consumption) capacity of the economy; thus relaxing the borrowing constraint, rather than curtailing it.\footnote{These results are consistent with the findings of Benigno (2010, 2011), who showed that, by allocating productive resources differently in a crisis state, the policy maker can increase borrowing (and hence consumption) in the economy outside the crisis state while also reducing the probability of a financial crisis.}
5 Conclusions

In this paper we propose a model with a nominal rigidity and an occasionally binding collateral constraint. We then study their general equilibrium interaction under alternative monetary and macro-prudential policy regimes. Both frictions are specified in a manner that is consistent with two separate strands of literature that have focused on macroeconomic and financial stability separately: the well known New-Keynesian (e.g., Woodford, 2003) and the New-Fisherian literature (e.g., Mendoza, 2010), respectively.

We find that in our model there are trade offs between macroeconomic and financial stability but they are not large enough to affect the utility ranking of alternative policy regimes. Lowering the degree of nominal rigidity or increasing the response of interest rates to inflation is always welfare improving even though crises might become relatively more severe with more aggressive monetary policy or more price flexibility. We also find that a separate tax rule on debt is always welfare reducing while adding a reaction to debt to a traditional interest rate rule is always welfare increasing.

Even though the framework that we propose is simplified in many dimensions, the analysis in the paper also highlights the complex and non-linear interaction between nominal rigidities and financial frictions. We take our study as a preliminary investigation on this complex interaction: the results reported suggest that the cost and the role of the financial friction are limited. One reason may be that in this class of models crises do not have persistent effects. Another possibility is that crises in our model do not restrict the set of policy options (i.e. there is no zero lower bound on nominal interest rate in our analysis).
References


[15] Lambertini, Mendicino and Punzi (2011), "Leaning Against Boom-Bust Cycles in Credit and Housing Prices" manuscript.


A Appendix: the equilibrium conditions

In this appendix we list the equilibrium conditions for our general model. Equilibrium in non-tradeable goods market requires:

$$z_t^N(L_t^N)^\delta = C_t^N$$  \hspace{1cm} (27)

In determining the goods market equilibrium condition for tradeable we use the assumptions that labor is in fixed labor supply and is normalized to 1,

$$L_t = L_t^N + \frac{1}{n} \int_0^n l_t^T(z)dz = 1, \hspace{1cm} (28)$$

that domestic bonds are traded only among domestic household, and the asset that serves as a collateral is in fixed supply. Firms’ profits are given by

$$F_t = P_t^N z_t^N (L_t^N)^\delta - W_t L_t^N + \frac{1}{n} \int_0^n \left( p_t(z)y_t(z) - W_t \frac{y_t(z)}{z_t^N} \right) dz$$

$$= P_t^N C_t^N - W_t L_t^N + P_t^H Y_t^H - W_t \frac{1}{n} \int_0^n l_t^T(z)dz.$$

Assuming that domestic-currency denominated bonds are trades only among domestic households we have

$$\int_0^n B(i)di = 0.$$

As the asset $A$ is in fixed supply $A_{t+1} = A_t = 1$. So the resource constraint in the tradeable sector becomes:

$$P_t^H C_t^H + P_t^F C_t^F + S_t B_{t+1}^* = S_t B_t^*(1 + i_{t-1}^*) + D_t + P_t^H Y_t^H, \hspace{1cm} (29)$$

where $D_t$ is the dividend flow from holding the fixed asset and it is assumed to be exogenously given. By using the demand equation for tradeable goods, we can then rewrite the resource constraint for tradeables by as:

$$P_t^T C_t^T + S_t B_{t+1}^* = S_t B_t^*(1 + i_{t-1}^*) + D_t + P_t^H Y_t^H.$$

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Table 1. Model Parameters, Initial Conditions, And Stochastic Process

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<tr>
<th>Structural parameters</th>
<th>Values</th>
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<td>Share of firms resetting prices</td>
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Table 2. Allocations under Alternative Policy Rules: Flexible Prices

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<td>Borrowing (nominal level, foreign currency)</td>
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<td>Average debt-to-income ratio 2/</td>
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1/ Inflation coefficient set to 1.5 in all experiments.
   Debt coefficient in the tax rule and in the augmented interest rate rule set to 0.05.
2/ Average across states and over times in period -1, 0, and 1.
### Table 3. Allocations under Alternative Policy Rules: Sticky Prices

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<th>Debt Borrowing Constraint</th>
<th>Unconst.</th>
<th>Const.</th>
<th>Low</th>
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<tr>
<td>Prudential policy 1/</td>
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<td>None</td>
<td>None</td>
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<tr>
<td>Experiment number (1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
</tbody>
</table>

| Utility                   | 5.22577 | 5.21950 | 5.21779 | 5.22093 |
| Credit multiplier         |         |         |         |         |
| Period 1, bad state       | 0.00000 | 0.00000 | 0.00000 | 0.00047 |
| Period 1, good state      | 0.00000 | 0.06620 | 0.06327 | 0.06792 |
| Consumption               |         |         |         |         |
| Period 0                  | 1.02508 | 1.02117 | 1.01902 | 1.02310 |
| Period 1, bad state       | 0.98289 | 0.98295 | 0.98298 | 0.98263 |
| Period 1, good state      | 1.09441 | 1.05786 | 1.05970 | 1.05678 |
| PPI Inflation (% per period) |       |         |         |         |
| Period 0, level           | 1.21270 | 1.21274 | 1.21275 | 1.21273 |
| Period 1, good State      | 20.85490| 21.01989| 21.01800| 21.02101|

| Nominal Interest Rate (% per period) |         |         |         |         |
| Period 0, level                | 33.54562| 33.55176| 33.55345| 33.55023 |
| Period 1, bad State            | 33.48369| 33.48732| 33.48982| 33.48644 |
| Period 1, good State           | 32.86066| 33.13282| 33.12970| 33.13467 |

| Nominal Exchange Rate (% per period; + is a depreciation) |         |         |         |         |
| Period 0, level                | 0.59541 | 0.59926 | 0.60134 | 0.59734 |
| Period 1, bad state            | 29.59599| 28.76032| 28.31309| 29.23518|
| Period 1, good state           | 30.20371| 38.25511| 37.34988| 38.95396|

| Nominal Asset Price (% per period) |         |         |         |         |
| Period 0, level                  | 0.01592 | 0.01597 | 0.01597 | 0.01592 |
| Period 1, bad state              | -41.84619| -42.02787| -42.01924| -41.79315|
| Period 1, good state             | -41.57348| -37.30859| -37.51376| -36.95941|

| Borrowing (nominal level, foreign currency) |         |         |         |         |
| Period 0                               | -0.25365| -0.25112| -0.24936| -0.25215 |
| Period 1, bad state                    | -0.01462| -0.01259| -0.01117| -0.01320 |
| Period 1, good state                   | -0.04566| -0.01329| -0.01329| -0.01330 |

| Initial debt-to-income ratio (in percent) |         |         |         |         |
| Period 0                                | -50.28710| -50.29871| -50.32121| -50.30229|

| Average debt-to-income ratio 2/          |         |         |         |         |

1/ Inflation coefficient set to 1.5 in all experiments. Debt coefficient in the tax rule and in the augmented interest rate rule set to 0.05.
2/ Average across states and over times in period -1, 0, and 1.
Figure 3: Inflation
Figure 4: Debt Tax
Figure 5: Debt Coefficient