Monetary and Macro-prudential Policies: An Integrated Analysis[1]

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Abstract

This paper studies the interaction between monetary and macro-prudential policies in a simple model with both nominal and financial frictions. The nominal friction gives rise to a conventional monetary policy objective emphasized in the New Keynesian literature. The financial friction, in the form of an occasionally binding collateral constraint, gives rise to a financial stability objective. We study how rules developed for the nominal rigidity perform in a model that also has the financial friction. We then study how two alternative macro-prudential regimes perform. The first is a macro-prudential adjusted monetary policy. The second is a two-part rule–a standard Taylor rule

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and a tax rule on the amount that the economy borrows. There are three main findings. First, contrary to standard New Keynesian wisdom, in an economy with the nominal rigidity and the financial friction, a relatively accommodative monetary policy may be welfare improving, suggesting a role for positive inflation in this environment. By the same token, we find that there may be a trade off between macroeconomic and financial stability with a relatively aggressive monetary policy. Second, macro-prudential policy is most effective in our model (from a welfare ranking point of view) when it is designed in terms of macro-prudential augmented interest rate rules rather than through an independent tax rule on debt. Third, independent macro-prudential tax rules on debt can be welfare reducing when monetary policy is accommodative. The same tax policy rule however can be welfare increasing when monetary policy is aggressive toward inflation as in this case it helps to address the possible trade off between macroeconomic and financial stability.

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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 macro-prudential 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 the interaction between monetary and macro-prudential 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 since financial crises are endogenous events captured, from a model perspective, by the situation in which the credit constraint becomes binding. The advantage of our approach is that it allows us to study the implications of "conventional" monetary policy design 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 in the presence of nominal rigidities. The

1. In addition there is widespread work on such rules at central banks and IFIs.

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 of how financial stability objectives interact with macroeconomic stability traditionally defined.

Once we build our model we ask a series of questions about the design of both monetary and macro-prudential 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 macro-prudential component to a conventional Taylor 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? A common feature of all these questions is the role that monetary policy can play as part of a macro-prudential policy toolkit and we address these questions from the perspective of a small open economy that borrows from the rest of the world in foreign currency at a given interest rate. The world lasts for three periods and our small open economy is a two-sector production economy of tradable and non-tradable goods. We allow for nominal price rigidities in the tradable sector while for simplicity prices in the non-tradable sector are perfectly flexible. Fluctuations in the model are driven by a technology shock to the production of tradable 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 and affects the inter-temporal choices of domestic household like in Jeanne and Korinek (2010).

Monetary policy in this framework 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 this framework. In this context, we consider conventional monetary policy in terms of an interest rate rule that includes only inflation and an augmented monetary policy rule that targets also the amount that agents borrow (a macro-prudential augmented interest rate rule). Independent macro-prudential policy is similarly modeled as a tax rule on domestic agents' borrowing, based on the principle that taxing the amount that agents borrow limits the possibility that a crisis might occurs or ameliorates its severity[1]. As the model has no closed form solution, we conduct a numerical analysis of its equilibrium under alternative policy rules aimed at understanding the interaction between the policy design and the behavior of the economy.

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 is not necessarily welfare improving and the interaction between prudential policy and traditional monetary policy is crucial. In our framework both a macro-prudential monetary policy rule and an independent macro-prudential tax rule affect the relative return of domestic versus foreign currency bonds. In the case of the tax rule on debt, borrowing in 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, inter-temporal consumption choices will be directly distorted. Yet, as we shall see, the two specifications yield very different outcomes from a welfare perspective.

Second, 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

1. While this statement may be true in some special cases, it is not generally true. Such a policy is suboptimal even in the context of a simple neo-Fisherian environment (see Benigno et al., 2010 and 2011 for more details on this).

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 increases. 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 into the economy.

More specifically, we have three main findings. First, we find that an accommodative monetary policy, defined as a smaller coefficient on inflation in the interest rate rule, dominates an aggressive rule in welfare terms, in the economy with sticky prices and the collateral constraint. This is contrary to the typical welfare ranking that arises when we consider the same policies in an economy with only sticky prices. This result suggests that in economies with financial frictions, positive inflation might be optimal from a welfare point of view (e.g., Greenwald, Michael and Joseph Stiglitz, 1993).[1] This also shows that traditional monetary policy may face a trade off between macroeconomic and financial stability depending on its design rather the nature of the shock that buffets the economy (e.g., Woodford, 2011).

Second, we find that the scope for macro-prudential policies depends crucially on the design of the traditional component of monetary policy. When monetary policy is aggressive macro-prudential policy is always welfare improving, regardless of how it is implemented (in terms of augmenting the interest rate rule with debt or by adding an independent tax rule on debt). However, when monetary policy is relatively accommodative, macro-prudential policy is welfare improving only if implemented through an augmented interest rate rule, while it is welfare decreasing if conducted through an independent tax rule. This is because, with both the nominal rigidity and the financial friction, the separate distortion introduced by the tax rule on debt helps only when there

1. Along this line of argument, Koening (2011) argues that inflation targeting may contribute to financial instability by concentrating risk in a world with nominal debt.

is a trade off between macroeconomic and financial stability induced by the traditional component of monetary policy. And the latter emerges only when the traditional component of monetary policy is accommodative.

Third, conducting macro-prudential policies through an interest rate rule augmented with a prudential argument dominates alternative policy regimes from a welfare point of view. The main feature of this regime is to produce, all else equal, relatively higher interest rates when borrowing is higher in normal times, and no interference with the interest rates when the occasional crisis occurs. An aggressive traditional monetary policy instead, would react strongly to inflation in both normal and crisis times. This suggests that the non-linear feature of the augmented interest rate rule is key to understand its positive welfare properties.

An important caveat to these results is that they may depend on both the model specification and the parameter values adopted[1]. They are therefore illustrative of the complex interactions at play rather than definitive. A robust and common theme across the whole set of results we report, however, is that 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 et 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[2]. The basic premise of this literature is that by smoothing cycles in financial variables it may be possible to bring about

1. Conducting the analysis reported in the paper with a more realistic calibration is work in progress.
2. Braggion, Christiano and Roldos (2007) examine how optimal monetary policy is designed in an environment in which the credit constraint becomes binding unexpectedly and remains binding forever.

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. The models in these exercises typically have many shocks and frictions and are linearized around a deterministic steady state. Hence they 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 smaller model in which the constraint binds only occasionally and there are both crisis and non-crisis states that interact and realize endogenously. We then study how monetary and macro-prudential policies should be designed and interact in such environment.

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 parameterization. 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 face a constraint on the amount that they can borrow from abroad. They also face nominal rigidities in their price-setting behavior.

In this 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.[1] This feature of the model resembles the debt-deflation mechanism as in Fisher (1933) since, in a crisis, when the constraint binds, there is feedback loop between asset prices and the tightness of the borrowing constraint, which amplifies the effect of negative shocks and magnifies bust dynamic in credit and asset prices.

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. We will use a * to denote prices and quantities of the foreign country. Note that 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 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.

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 ρ is the elasticity of intertemporal substitution and $\beta \in (0,1]$ is the subjective discount factor. The consumption basket, Ct, is a composite good of tradable and non-tradable goods:

1. Financial stability, therefore, is broadly defined by the frequency and the severity of these events in the model.

$$C_t \equiv \left[\omega^{\frac{1}{R}} \left(C_t^T \right)^{\frac{R-1}{R}} + (1-\omega)^{\frac{1}{R}} \left(C_t^N \right)^{\frac{R-1}{R}} \right]^R \qquad (1)$$

The parameter k>0 is the elasticity of intra-temporal substitution between consumption of tradable and non-tradable goods, while ω is the relative weight of tradable goods in the consumption basket. We denote with PT the price of tradable goods and with PN the price of non-tradable goods. We further assume that tradable goods are a composite of home and foreign produced tradable (CH and CF, respectively):

$$C_t^T = \left[\nu^{\frac{1}{\theta}} (C_t^H)^{\frac{\theta-1}{\theta}} + (1-\nu)^{\frac{1}{\theta}} (C_t^F)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} ,$$

where $\theta > 0$ is the intra-temporal elasticity of substitution. The parameter υ 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, $\gamma : (1-\nu) = (1-n)\gamma$ (see Sutherland, 2004). Foreigners share a similar preference specification as domestic agents with $\nu^* = ny$:

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

That is, foreign consumer's 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

$$C^H = \left[\left(\frac{1}{n} \right)^{\frac{1}{\sigma}} \int_0^n c(z)^{\frac{\sigma-1}{\sigma}} dz \right]^{\frac{\sigma}{\sigma-1}} , C^F = \left[\left(\frac{1}{1-n} \right)^{\frac{1}{\sigma}} \int_n^1 c(z)^{\frac{\sigma-1}{\sigma}} dz \right]^{\frac{\sigma}{\sigma-1}} , \qquad (2)$$

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:

$$P_t = \left[w\left(P_t^T\right)^{1-R} + (1-w)\,(P_t^N)^{1-R} \right]^{\frac{1}{1-R}} \ ,$$

with

$$P^T = \left[v\left(P_t^H\right)^{1-\theta} + (1-v)\,(P_t^F)^{1-\theta} \right]^{\frac{1}{1-\theta}} \ , \qquad (3)$$

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:

$$P^H = \left[\left(\frac{1}{n}\right) \int_0^n p(z)^{1-\sigma} dz \right]^{\frac{1}{1-\sigma}} \ , P^F = \left[\left(\frac{1}{1-n}\right) \int_n^1 p(z)^{1-\sigma} dz \right]^{\frac{1}{1-\sigma}} \qquad (4)$$

The law of one price holds (for tradable 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 we define the real exchange rate as $RS \equiv SP^* / P$. Note that because of our small open economy assumption $(i.e., n \rightarrow 0)$ $P^{F*} = P^*$, which implies that $RS = SP^{F*} / P$. Thus, nothing that occurs in the small open economy will affect the rest of the world.

$$p^{T*} = \left[v^* \left(P_t^{H*}\right)^{1-\theta} + \left(1 - v^*\right) \left(P_t^{F*}\right)^{1-\theta} \right]^{\frac{1}{1-\theta}} \qquad (5)$$

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 it 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:

$$S_0 B_1^* \geq -\psi Q_0 A_1$$
$$S_1\ B_2^* \geq -\psi Q_1 A_2$$
$$S_2 B_3^* \geq 0.$$

We can rewrite the borrowing constraints in period 0 and 1 as:

$$B_1^* \geq -\frac{-\psi Q_0 A_1}{S_0}$$
$$B_2^* \geq -\frac{-\psi Q_1 A_2}{S_1}$$

It is now evident that, for given asset holding (A_1 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.

Intra-temporal Consumption Choices The intra-temporal first order conditions determine how the household allocate their consumption expenditure among the different goods:

$$C^{N}=w\left(\frac{P^{N}}{P}\right)^{-R}C,-C^{T}=(1-w)\left(\frac{P^{T}}{P}\right)^{-R}C$$

with

$$C^{H}=v\left(\frac{P^{H}}{P^{T}}\right)^{-\theta}C^{T},-C^{F}=(1-v)\left(\frac{P^{F}}{P^{T}}\right)^{-\theta}C^{T}$$

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:

$$y^{d}(h)=\left[\frac{p(h)}{P_{H}}\right]^{-\sigma}\left[C^{H}+C^{H*}\right]$$

and

$$y^{d}(f)=\left[\frac{p*(f)}{P_{F}^{*}}\right]^{-\sigma}\left[C^{F}+C^{F*}\right]$$

With $(1-\nu)=(1-\mathrm{n})\gamma$ and $\nu^{*}=n\gamma.$ As $n\rightarrow 0$, we can rewrite our demand equations as:

$$y^{d[\,]}(h)=\left[\frac{p(h)}{P_{H}}\right]^{-\sigma}\left(\frac{P^{H}}{P^{T}}\right)^{-\theta}(1-w)\left[\frac{P^{T}}{P}\right]^{-R}\left[(1-\gamma)C+\gamma\left(\frac{p^{T}}{SP^{T*}}\right)^{R-\theta}\left(\frac{1}{Rs}\right)^{-R}C^{*}\right]$$

and

$$y^d(f)=\left[\frac{P^*(F)}{p_f^*}\right]^{-\sigma}\left\{\left[\frac{p_f^*}{p^*}\right]^{-R}(1-w)C^*\right\}$$

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 tradable goods $\left(\frac{SP^{T*}}{P^T}\right)$. If we assume that $\theta > k$ (the elasticity of substitution among tradable goods is higher than the one between tradable and non-tradable), 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.

Inter-temporal Consumption Choices the inter-temporal 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 λ_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:

$$S_0\frac{C_0^{-\rho}}{P_0}=S_0\mu_0+\beta E_t\left[S_1\frac{C_1^{-\rho}}{P_1}(1+i^*)\right]$$
$$S_1\frac{C_1^{-\rho}}{P_1}=S_1\mu_1+\beta E_t\left[S_2\frac{C_2^{-\rho}}{P_2}(1+i^*)\right]$$

where μ_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:

$$\frac{1}{(1+i_0)}=E_t\left[\beta\frac{C_1^{-\rho}}{P_1}\frac{P_0}{C_0^{-\rho}}\right] \qquad (6)$$

$$\frac{1}{(1+i_1)}=E_t\left[\beta\frac{C_2^{-\rho}}{P_2}\frac{P_1}{C_1^{-\rho}}\right] \qquad (7)$$

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

$$\frac{C_0^{-\rho}}{P_0}Q_0=\mu_0\psi Q_0+E\left[\frac{C_1^{-\rho}}{P_1}(D_1+Q_1)\right] \qquad (8)$$

$$\frac{C_1^{-\rho}}{P_1}Q_1=\mu_1\psi Q_1+E\left[\frac{C_2^{-\rho}}{P_2}D_2\right] \qquad (9)$$

$$Q_t=\frac{\lambda_{t+1}(D_{t+1}+Q_{t+1})}{\lambda_t-\mu_t\psi}\ t=0{,}1$$

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 μ_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 expected present discounted value of future dividends. The discount is now given by the term $\left(\frac{\lambda_{t+1}}{\lambda_t-\mu_t\psi}\right)$ and differs from the standard one $\left(i.e. \frac{\lambda_{t+1}}{\lambda_t}=\frac{1}{(1+i_t)}\right)$ 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:

$$E_t\left[\frac{C_1^{-\rho}}{P_1}(1+i_0)\right]=\left[\mu_0+E_t\left[\frac{C_1^{-\rho}}{P_1}\,\frac{S_1}{S_0}(1+i^*)\right]\right] \qquad (10)$$

and

$$E_t\left[\frac{C_2^{-\rho}}{P_2}(1+i_1)\right]=\left[\mu_1+E_t\left[\frac{C_2^{-\rho}}{P_2}\,\frac{S_2}{S_1}(1+i^*)\right]\right] \qquad (11)$$

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 serves as 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 tradable and non-tradable goods. We assume that only domestic agents hold shares in home firms. Firms in the tradable 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-tradable sector operate under decreasing return to scale in a competitive environment.

In the non-tradable 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, $\mathrm{L}_{\mathrm{t}}^{\mathrm{N}}$ is the amount of labor employed in the non-tradable sector and $\delta < 1$ is the return to scale parameter. The profit of non-tradable firms π_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-tradable firms we obtain the following standard first order condition:

$$W_t = P_t^N \, z_t^N \, \delta \left(L_t^N \right)^{\delta - 1} \quad (12)$$

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.[1]

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

$$y_2(h) = \left(\frac{P_2(h)}{P_{H,2}} \right)^{-\sigma} Y_{H,2}$$

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 cost:

$$p_2(h) = \frac{\sigma}{\sigma - 1} \frac{W_2}{z_2^T} \qquad (13)$$

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

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

1. Here we also assume that when firms can reset prices they have observed the relevant uncertainty.

where

$$\bar{y}_0(h)=\left(\frac{\bar{p}_0(h)}{P_{H,0}}\right)^{-\sigma} Y_{H,0}, \qquad (14)$$

$$\bar{y}_1(h)=\left(\frac{\bar{p}_0(h)}{P_{H,1}}\right)^{-\sigma} Y_{H,1} \qquad (15)$$

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:

$$\tilde{p}_0(h)=\frac{\sigma}{\sigma-1}\;\frac{E_0\left(\frac{W_{0\bar{y}0}(h)}{z_0^T}+\beta\alpha Q_{0,1}\frac{W_{1\bar{y}1}(h)}{z_1^T}\right)}{E_0(\tilde{y}_0(h)+\beta\alpha Q_{0,1}\tilde{y}_1(h))}$$

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

$$\frac{\tilde{p}_0(h)}{P_0^H}=\frac{\sigma}{\sigma-1}\;\frac{E_0\left(\frac{W_0}{z_0^{\backslash T}P_{H,o}}Y_{H,0}+\beta\alpha Q_{0,1}\frac{W_1}{z_1^T P_{H,1}}\left(\prod_1^H\right)^{1+\sigma}Y_{H,1}\right)}{E_0\left[Y_{H,0}+\beta\alpha Q_{0,1}\left(\prod_1^H\right)^{\sigma}Y_{H,1}\right]} \qquad (16)$$

with $\prod_l^H \equiv \frac{P_l^H}{P_o^H}$ denoting gross inflation from period 0 to period 1. P_o^H is the aggregate price index for the home produced goods given by that can be rewritten as that can be rewritten as:

$$(P_0^H)^{1-\sigma}=(1+\alpha)\tilde{p}_0(h)^{1-\sigma}+\alpha(P_{-1}^H)^{1-\sigma}$$

$$\left(\frac{1-\alpha\left(\prod_0^H\right)^{\sigma-1}}{1-\alpha}\right)^{\frac{1}{1-\sigma}}=\frac{\tilde{p}_o(h)}{P_0^H}, \qquad (17)$$

with $\prod_{l}^{H} \equiv \frac{P_{0}^{H}}{P_{-1}^{H}}$.

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:

$$\tilde{P}_{1}(h) = \frac{\sigma}{\sigma-1}\frac{W_{1}}{z_{1}^{T}} \qquad (18)$$

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:

$$\left(\frac{1-\alpha\left(\prod_{1}^{H}\right)^{\sigma-1}}{1-\alpha}\right)^{\frac{1}{1-\sigma}} = \frac{\tilde{p}_{1}(h)}{P_{1}^{H}} , \qquad (19)$$

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:

(20)

$$\left(\frac{1-\alpha\left(\prod_0^H\right)^{\sigma-1}}{1-\alpha}\right)^{\frac{1}{1-\sigma}}=\frac{\sigma}{\sigma-1}\frac{E_0\left(\frac{P_0^N z_0^N \delta(L_0^N)}{z_0^T P_0^H}Y_{H,0}+\beta\alpha Q_{0,1}\frac{P_1^N z_1^N \delta(L_1^N)^{\delta-1}}{z_1^T P_{H,1}}\left(\prod_1^H\right)^{1+\sigma}Y_{H,1}\right)}{E_0\left[Y_{H,0}+\beta\alpha Q_{0,1}(\prod_1^H)^{\sigma}Y_{H,1}\right]}$$

for period 0;

$$\left(\frac{1-\alpha\left(\Pi_1^H\right)^{\sigma-1}}{1-\alpha} \right)^{\frac{1}{1-\sigma}} = \frac{\sigma}{\sigma-1} \frac{P_1^N z_1^N \delta(L_1^N)^{\delta-1}}{P_1^H z_1^T} \qquad (21)$$

for period 1, and

$$1 = \frac{\sigma}{\sigma-1} \frac{P_2^N z_2^N \delta(L_2^N)^{\delta-1}}{P_2^H z_2^T} \qquad (22)$$

for period 2, where $Q_{0,1} = \frac{1}{1+i_0}$.

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-tradable 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:

$$(1+i_t^{TR}) = \beta^{-1}\,\overline{\Pi}\left(\frac{\Pi_t^H}{\overline{\Pi}}\right)^{\phi_\pi} , \qquad (23)$$

in which the target inflation $\overline{\Pi}_t$ is time invariant and set equal to zero.[1] Macro-prudential policy is modeled in two different ways, consistent with alternative proposals in the ongoing policy debate.

First, we consider an augmented interest rate rule with an explicit macro-prudential argument in period zero in addition to the inflation term.[2] We include the level of aggregate borrowing as a share of total consumption expenditure. More formally, the alternative rule is:

$$
\begin{aligned}
(1+i_t) &= \beta^{-1}\,\overline{\Pi}\left(\frac{\Pi_t}{\overline{\overline{\Pi}}}\right)^{\phi_\pi}\left(1-\frac{S_t B^*_{t+1}}{P_t C_t}\right)^{\phi_{B^*}} \quad for\ \ B^*_{t+1}<0 \\
&= (1+i^{TR}_t)\left(1-\frac{S_t B^*_{t+1}}{P_t C_t}\right)^{\phi_{B^*}}
\end{aligned}
\tag{24}
$$

where $(1+i^{TR}_t)=\beta^{-1}\,\overline{\Pi}\left(\frac{\Pi_t}{\Pi}\right)^{\phi\pi}$ 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 (23). 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 inter-temporal margin in (6) and (7) by tilting the profile of consumption towards future consumption as opposed to

1. 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.
2. As we shall see, the fact that the second argument in the interest rate rule is active only in period zero is crucial for its performance.

present consumption and reducing the amount that agents want to borrow other things being equal. In fact the Euler equation in period 0 becomes:

$$\frac{1}{(1+i_0^{TR})\left(1-\frac{S_0 B_1^*}{P_0 C_0}\right)^{\phi_{B*}}} = E_t\left[\beta \frac{C_1^{-\rho}}{P_1}\frac{P_0}{C_0^{-\rho}}\right] \tag{25}$$

In this case, the international parity condition becomes

$$\left(1-\frac{S_0 B_1^*}{P_0 C_0}\right)^{\phi_{B*}} E_t\left[\frac{C_1^{-\rho}}{P_1}(1+i_0^{TR})\right] = \left[\mu_0 + E_t\left[\frac{C_1^{-\rho}}{P_1}\frac{S_1}{S_0}(1+i^*)\right]\right]$$

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 inter-temporal allocation of consumption of households [see (25)].

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:

$$(1-\tau_0^*) = \left(1-\frac{S_t B_{t+1}^*}{P_t C_t}\right)^{-\phi_{B*}} \quad for\ B_{t+1}^* < 0,$$

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 inter-temporal 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:

$$(1-\tau_0^*)E_t\left[\frac{C_1^{-\rho}}{P_1}(1+i_0)\right] = \left[\mu_0 + E_t\left[\frac{C_1^{-\rho}}{P_1}\frac{S_1}{S_0}(1+i^*)\right]\right]. \qquad (26)$$

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 inter-temporal distortion in the consumption profile across time. In fact in this case (6) holds:

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

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 inter-temporal consumption choice.

3. Model Parametrization and Solution

The model is parameterized in the simplest possible manner as we do not attempt to use it quantitatively but rather to provide examples of the possible interactions between the two frictions in the models and the alternative policies we consider. In fact, the three- period structure of the model imposes terminal conditions for the net foreign position and asset prices that require sharp and unrealistic movements in most endogenous variables between periods. Moreover, the exercises we run require that, for given initial conditions, the structural parameters stay constant across different policy regimes. But alternative policy regimes have very different properties, making it difficult to find a common set of structural parameter values for which we can solve the model under a reasonably large set of policy experiments. For instance, while in our baseline case the borrowing constraint binds only in one state in period one, alternative specifications of monetary and macro-prudential policy result in the constraint binding in neither states or both states in period one. The highly non-linear nature of the model also adds a degree of complexity in finding a suitable parametrization. Nonetheless, to the extent possible, in doing our numerical examples, we borrow parameter values from the literature.[1]

Table 1 reports the chosen parameter values, the shocks' process, and the initial conditions. The tradable sector technology shock Z_T is a two-state Markov process that can take two values, either 0.9 or 1.1 (bad and good state, respectively) with transition matrix:

$$p = \begin{bmatrix} 0.4 & 0.6 \\ 0.4 & 0.6 \end{bmatrix}$$

The shock hits the economy in period 0 and in period 1, so the economy has two possible states in period 1 and four states in period 2. The unconditional standard deviation of this process is 9.6.

The elasticity of substitution between tradable and non-tradable goods and between home and foreign tradable goods is set to one for simplicity. The relative weight of non- tradable goods is set to 0.5. As a result, tradable and non-tradable consumption are always the same in units of consumption. The

1. Conducting the analysis reported in the paper with a more realistic calibration is work in progress.

size parameter n=0 and the degree of openness γ is.25 (a common value for a small open economy) which together yields a value for the relative weight of home tradable goods ν of .75. The elasticity of substitution within home tradable goods is set to 6 to yield a markup of 20%, which is a conventional value. The labor share parameter δ 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 ρ =1, as in Jeanne and Korinek (2010).

The nominal rigidity parameter is set somewhat arbitrarily to α = 0.5. This is below the typical value around .75 used in quarterly, infinite horizon models and imply that half of the firms can adjust prices in period 0. The coefficient in the interest rate rule on domestic producer inflation is set to $\phi_\pi = 1.5$. When we use a more aggressive reaction parameter toward domestic producer, inflation is $\phi_\pi = 2$. The coefficients on macro prudential policy are set at $\phi_{B^*} = 0.02$ in all cases.

The parameter ψ of the collateral constraint is set to a value such that the constraint is never binding in period 0, and to 2.267 in period 1, so that the constraint binds in at least one state in the baseline case. We then keep the structural parameters of the model constant across experiments and change only the policy rules. When we change the policy rule, the constraint may bind in both states or in neither state, nor the value of the credit multipliers, when they are positive, indicate the severity of the crisis. Financial stability, therefore, measured by the value of the collateral multiplier, varies endogenously with alternative policy rules in the models. Note however that, 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 state in period 0 (in which it is initialized) to state in which the constraint binds in period 1. Therefore, the probability of the crisis cannot be used as a measure of financial stability in the model.

The exogenous dividend process is constant in nominal terms over time and set to $D_0 = D_1 = D_2 = 0.5$. The foreign interest rate and the discount rate are constant and such that $\beta = 1/(1+i^{*}) = 1$, like Jeanne and Korinek (2010) for comparability in the case in which prices are flexible. Foreign prices are also constant and normalized to 1: $P^{*} = P_{0}^{F*} = P_{1}^{F*} = P2_{0}^{F*} = 1$. The terminal exchange rate level is S2 = 1. All allocations are initialized with $B_{0}^{*} = -3.76$ in the negative state (state 1). Note however that the value of initial debt in either domestic currency or unit of consumption wills differ across experiments endogenously playing an important role in behavior of the economy under alternative policy rules. In fact, all else being equal, the higher the value of debt entering period t, the smaller the amount of resources available for consumption in period t and $t + i$ $(i=1,2)$.

Despite its relative simplicity, the model we set up has no closed form solution and will 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 solve, for given initial and terminal conditions and the state of the tradable sector technology shock Z^{T}. Like Benigno et al. (2011), we convert the complementary slackness conditions for the collateral constraint into a single nonlinear equation following Garcia and Zangwill (1981). In a few cases, in which the default initial condition does not yield a solution we employ a homotopy method to generate better initial conditions that lead to the solution of the model–see again Garcia and Zangwill (1981).

We evaluate alternative policy rules by comparing welfare. This is computed from as the ex-ante value of the expected 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 the total consumption at time zero, $C_{1,i}$ 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 and the monetary and macro-prudential policy regimes. In total we analyze 24 different allocations: four specifications of the economic frictions, times three macro-prudential regimes, times two traditional monetary policy regimes. And Table 2 describes the equilibrium allocation as well as the associated welfare for a subset of relevant cases.[1]

We consider four alternative specifications of the two frictions in the model. The first is a frictionless version of our three-period, small open economy model that helps to provide intuition of how the two frictions work and interact in our model. The second is a flexible price economy with the financial friction that is comparable to the models in the Neo-Fisherian literature on financial stability–e.g., Benigno et al. (2010, 2011), Jeanne and Korinek (2010, 2011) and Bianchi and Mendoza (2011). The third is a sticky price economy without the financial friction that corresponds to a three period version of the traditional New Keynesian framework. Finally, we consider the economy with both nominal and financial frictions. Note here that even the frictionless version of our small open economy is not necessarily Pareto efficient.

We consider three alternative macro prudential regimes. The first is the case in which there is only traditional monetary policy, and hence no prudential policy. The second is a two-instrument regime with the same traditional interest rate rule and a tax on debt as a macro prudential policy rule. The third is an interest rate rule that responds to both inflation and debt.

Finally, we consider only two traditional monetary policy regimes, a relatively accommodative, and a relatively aggressive one. Traditional monetary policy is implemented by means of a simple interest rate rule that responds only to inflation, and the two regimes are differentiated by the strength of the

1. All experiments not reported are available from the authors on request.

inflation response. Note therefore that in all four economies above there is a traditional monetary policy component implemented by means of an interest rate rule.[1]

As a general caveat to our analysis, we note from the outset that the results we report in Table 2 and discuss below should not be seen as general properties of our model economy as they may depend on both the model specification adopted and the parameter values chosen, but rather as examples illustrating the rich and complex interaction between asset prices, consumption and production decisions on the one hand, and monetary and prudential policies on the other. A robust and common feature of the different cases we discuss, however, is that welfare enhancing policies work by supporting the borrowing (and hence consumption) capacity of the economy, and thus by relaxing the borrowing constraint of our production economy.

4.1. Flexible Price Allocations

The first there columns of Table 2 compare flexible price allocations. The first two columns of Table 2 compares the allocation of two flexible price economies, with a relatively accommodative traditional monetary policy (i.e., an interest rate rule that responds only to inflation with a 1.5 coefficient), with and without the collateral constraint. The third column of Table 2 adds to this comparison a flexible price economy with the constraint and both an accommodative traditional monetary policy and prudential tax rule on debt. As we can see the borrowing constraint reduces lifetime utility relative to the unconstrained economy, while adding the prudential tax on debt in period zero along with the traditional interest rate rule increases utility slightly in the case of flexible prices (even if traditional monetary policy is relatively less aggressive or more accommodative). These results are consistent with some of the findings in the Neo-Fisherian literature on financial stability–e.g., Jeanne and Korinek (2010, 2011) and Bianchi and Mendoza (2011).

In particular, the presence of the borrowing constraint decreases utility by hampering consumption smoothing over time and across states. The model has

1. See Ghironi and Cavallo (2002) for an analysis of interest rate rules in small open economies under flexible prices.

three periods, and there is initial debt (constant across experiments in units of foreign currency) that needs to be repaid in full in period $2\,(i.e., B_3^* - 0)$. This implies that, as we can see from experiment 1 in Table 2, the frictionless economy is on a debt repayment path with a current account surplus in all periods and states, and tradable consumption that are roughly constant over time and across states. With the borrowing constraint instead (experiment 2), consumption is not constant over time and across states, and is much lower in both periods and states than without the constraint.

Note here that the borrowing constraint binds in the good state of the tradable productivity process, as we can see from the value of credit multiplier. With the realization of the positive state in period 1, the physical amount of tradable output increases and puts downward pressure on producer price inflation and the nominal exchange rate. The interest rate falls, driven by the monetary rule, but not enough to support the asset price that in equilibrium falls in this case. As a result, the borrowing capacity of the economy meets its limit. Interestingly, however, the level of borrowing at which the constraint binds in period 1 is much higher than the equilibrium level in the economy without constraint. This is because the interest rate (and the asset price) in the constrained economy are much lower (higher) than in the unconstrained one allowing for a much larger borrowing capacity. At the same time, the exchange rate is more depreciated in the constrained economy requiring a larger borrowing capacity in equilibrium.

The introduction of a tax rule on borrowing along with a traditional interest rate rule increases welfare in the constrained economy with flexible prices (experiment 3 in Table 2). This is achieved by inducing a relatively less pro-cyclical allocation of borrowing over time and across states relative to the economy with constraint but without the tax rule on debt. In fact, in equilibrium, tradable consumption (and the current account surplus) is higher (lower) in period zero and in the bad state in period 1. A higher interest rate in period 0, other things being equal, also induces a relatively more appreciated nominal exchange rate in period 0 that makes the initial debt burden easier to repay over time, and hence also permits more consumption in period 0. Note here also that the borrowing multiplier in the good state, when the constraint binds, is lower than the case without the tax rule on debt, suggesting that the crisis is less costly in this case when it occurs.

4.2. Sticky Price Allocations

Columns 4 to 9 in Table 2 compare 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. The first three economies (experiments 4-6) have relatively accommodative traditional monetary policy–i.e., a pure inflation targeting rule with a 1.5 coefficient on inflation, with inflation measured by the PPI index, i.e., $(\prod_t^H)$ as in the first three experiments with flexible prices. The second three (experiments 7-9) have a more aggressive traditional monetary policy with a 2.0 reaction to inflation.

The economy with price rigidity without constraint (experiment 4) has a smooth path of tradable consumption similar to the flexible price economy without constraint (experiment 1). Period 1 inflation, which stems from higher marginal costs associated with higher domestic production necessary to repay the initial debt, is lower than in the frictionless case. The nominal interest rate is also lower in this case. The exchange rate is more depreciated and the initial debt burden is consequently larger. As a result, the overall profile of tradable consumption is lower than with flexible prices. Thus, the nominal rigidity friction reduces welfare by requiring a more depreciated exchange rate with accommodative policy relative to the flexible price allocation.

When we examine economies with sticky prices and the borrowing constraint but no tax rule on debt, however, we note that a relatively less aggressive monetary policy can induce allocations that may have higher welfare ranking than the corresponding flexible prices ones (experiment 5 and 8 in Table 2). One interpretation is that, with higher inflation, there is less pressure on the current nominal exchange rate to depreciate because interest rates are higher and support it relative to the corresponding case with flexible prices. A relatively less depreciated currency increases agents borrowing capacity in period 0, allowing them to consume more. This suggests that, with multiple distortions, inflation might be welfare- enhancing.

In sharp contrast to these results, with a more aggressive traditional monetary policy (see experiments 7-9), a trade off emerges between macroeconomic and financial stability. While stabilizing inflation more aggressively in response to shocks, a more aggressive traditional monetary policy can make financial crises more frequent and more severe (as measured by the values of the borrowing multipliers that are now positive in both states and are one order of magnitude larger in the positive one compared to the case of relatively accommodative monetary policy). The asset price is much higher in this economy in period zero and in period 1 in the good state, while the nominal exchange rate tends to be relatively more depreciated. As a result, the economy experiences a higher current account surplus and lower consumption in period 0 and is much more volatile in period 1 because the constraint ends up binding in both states of the world. By comparison, there is no such a trade off in the sticky price economies without borrowing constraint, and the more aggressive reaction to inflation induces higher welfare in those cases, consistent with traditional New-Keynesian results (see experiments 4 and 7, respectively).

Alternative macro-prudential regimes also interact with the traditional component of monetary policy in a rich and non-linear way (experiments 6 and 9 in Table 2). For instance, conducting macro-prudential policies with a tax rule on debt is welfare increasing when monetary policy is aggressive because it helps resolve the trade off we described above (experiment 9), but it is welfare decreasing with a more accommodative policy (experiment 6). When the traditional component of monetary policy is more accommodative (aggressive), a tax rule on debt will make foreign borrowing relatively more (less) expensive compared to the domestic ones in period 0, leading to a more (less) depreciated currency that worsens (improves) the initial debt position, and hence has negative (positive) impact on consumption.

Perhaps surprisingly, the trade off between monetary and financial stability seemingly disappears when prudential policy is implemented adding debt to the interest rate rule (experiments 10 and 11). With both aggressive and accommodative reaction to inflation, these policy rules remove the constraint in both states and achieve a level of welfare just below the level in the corresponding unconstrained economies with sticky price (experiments 4 and 7). The key to interpreting this result is to note that this rule augments the interest rate rule with debt only in period zero, so that the debt target does not interfere with the interest rate setting when the occasional crisis occurs in period

1. An aggressive traditional monetary policy, instead, reacts strongly to inflation in both normal and crisis times and, in equilibrium, induces excessively low interest rates in both period 0 and 1 (experiment 8). This in turn leads to a pattern of asset price behavior in period zero that is inferior from a welfare perspective compared to the one with the prudential component in the interest rule (experiment 11). This suggests that the non-linear feature of the prudential interest rate rule is the key to its good welfare properties.

5. Conclusions

In this paper we set up a model with both a nominal rigidity and an occasionally binding financial friction. 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, which 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 a model with both the nominal rigidity and the financial friction a policy of price stability may be dominated by a policy in which inflation is positive (in producer inflation terms), and that there might be a trade off between macroeconomic and financial stability when the traditional component of monetary policy is aggressive. This suggests that traditional monetary policy may face a trade off between macroeconomic and financial stability depending on its design rather the nature of the shock that buffets the economy. We also find that a separate tax rule on debt is welfare improving only when there is such a trade off between macroeconomic and financial stability, which is (not) the case when the traditional component of monetary policy is aggressive (accommodative). Adding a debt component to a traditional interest rate rule is always welfare increasing when both model frictions are active regardless of the nature of the traditional component of monetary policy. The crucial ingredient to the success of this rule, however, is its non-linear specification manner as the debt argument is active in the rule only in period zero.[1]

The analysis in the paper also highlights the difficulties of reaching general and definitive conclusions on the design of macro-prudential policies as the interactions with the traditional component of monetary policy are complex and highly non-linear. From a practical perspective, our results suggest that booming small open economies might need macro prudential policies if they run a monetary policy with an aggressive traditional component, but might not stand to gain much if the traditional component of their monetary policy is already accommodative.

1. A similar result (not reported) in fact obtains with a non-linear traditional interest rule.

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Appendix: The Equilibrium Conditions

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

$$z_t^N \left(L_t^N\right)^{\delta} = C_t^N \qquad (27)$$

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

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

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

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

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

Assuming that domestic-currency denominated bonds are traded 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 tradable sector becomes:

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

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 tradable goods, we can then rewrite the resource constraint for tradable by as:

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

Table 1: Model Parameters, Initial Conditions, and Stochastic Process

Structural parameters	**Values**
Elasticity of substitution between tradable and non-tradable goods	$k=1$
Relative weight of tradable and non-tradable goods	$\omega=0.5$
Elasticity of substitution between home and foreign tradable goods	$\theta=1$
Relative weight of home tradable goods	$\nu=0.75$
Size	$n=0.0$
Openness	$\gamma=0.25$
Elasticity of substitution within home tradable	$\sigma=6$
Labor share in production	$\delta=0.75$
Credit constraint parameter	$\psi=2.267$
Share of firms resetting prices	$\alpha=0.5$
Intertemporal substitution and risk aversion	$\rho=1$
Discount factor	$\beta=1$
Inflation coefficient	$\phi_{\pi}=1.5$
Debt coefficient in augmented interest rate rule	$\phi_B=0.02$
Debt coefficient in tax rule	$\phi_B=0.02$
Exogenous variables	**Values**
World real interest rate	$i^*=0$
Technology levels	$z^N=z^T=1$
Dividend	$D_1=D_2=D_3=0.5$
Initial debt position	$B_0^*=-3.76$
Terminal exchange rate level	$S_2=1$
Foreign prices	$P^*=P_0^{F*}=P_1^{F*}=P_2^{F*}=1$
Tradable Productivity Markov Process	
States	{0.9,1.1}
Transition probabilities	{0.4,0.6;0.4,0.6}

Table 2: Allocations under alternative frictions and policy rules

Prices Borrowing Constraint Monetary Policy (Inflation coefficient in interest rule)	Flexible				Sticky			Sticky		Stick	
	Unconst.	Const. 1.5	Const.	Unconst.	Const. 1.5	Const.	Unconst.	Const. 2	Const.	Const. 1.5	Const. 2
Prudential policy	None	None	Debt tax	None	None	Debt tax	None	None	Debt tax	Debt in interest rule	
Experiment number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Utility	-1.94	-5.44	-5.04	-3.87	-3.89	-3.98	-3.57	-6.41	-5.68	-3.82	-3.56
Credit multiplier in bad state	0.0000	0.0000	0.0000	0.0000	0.0000	0.0054	0.0000	0.0161	0.0157	0.0000	0.0000
Credit multiplier in good state	0.0000	0.0784	0.0736	0.0000	0.0084	0.0171	0.0000	0.0847	0.0789	0.0003	0.0000
Consumption											
Period 0	0.507	0.143	0.165	0.251	0.249	0.239	0.290	0.114	0.138	0.258	0.295
Period 1, bad state	0.511	0.333	0.332	0.224	0.224	0.228	0.206	0.248	0.248	0.218	0.196
Period 1, good state	0.546	0.110	0.136	0.302	0.298	0.288	0.331	0.069	0.108	0.306	0.332
Tradable resource constraint in period 0 (in units of consumption)											
Income	0.424	0.626	0.592	0.393	0.396	0.405	0.383	0.871	0.675	0.395	0.385
Tradable consumption	0.254	0.071	0.083	0.125	0.125	0.119	0.145	0.057	0.069	0.129	0.147
Current account	0.171	0.555	0.510	0.268	0.272	0.286	0.238	0.814	0.605	0.266	0.237
Tradable resource constraint in period 1, good state (in units of consumption)											
Income	0.323	0.436	0.435	0.320	0.322	0.341	0.246	0.412	0.411	0.303	0.231
Tradable consumption	0.255	0.167	0.166	0.112	0.112	0.114	0.103	0.124	0.124	0.109	0.098
Current account	0.067	0.269	0.269	0.208	0.210	0.227	0.143	0.288	0.287	0.195	0.133
Tradable resource constraint in period 1, bad state (in units of consumption)											
Income	0.345	0.656	0.621	0.447	0.450	0.465	0.399	0.732	0.666	0.438	0.393
Tradable consumption	0.273	0.055	0.068	0.151	0.149	0.144	0.166	0.035	0.054	0.153	0.166
Current account	0.072	0.601	0.553	0.296	0.301	0.321	0.233	0.698	0.612	0.235	0.227
PPI											
Period 0, level	1.795	1.131	1.159	1.148	1.148	1.147	1.149	1.134	1.131	1.148	1.149
Period 1, % change, bad State	71.3	35.5	33.7	14.9	14.9	14.8	14.9	14.3	14.3	14.9	14.9
Period 1, % change, good State	57.8	-6.1	-4.8	12.3	12.1	11.0	14.3	-7.7	-5.2	13.0	14.4

Table 2: Continued

Prices Borrowing Constraint Monetary Policy (Inflation coefficient in interest rule)	Flexible				Sticky			Sticky		Stick	
	Unconst.	Const. 1.5	Const.	Unconst.	Const. 1.5	Const.	Unconst.	Const. 2	Const.	Const. 1.5	Const. 2
Prudential policy	None	None	Debt tax	None	None	Debt tax	None	None	Debt tax	Debt in interest rule	
Experiment number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Nominal Interest Rate (% per period)											
Period 0, level	140.5	20.2	24.8	23.0	22.9	22.8	31.9	28.6	28.0	23.0	31.9
Period 1, bad state	124.2	57.7	54.7	23.1	23.1	23.1	31.9	30.6	30.7	23.1	32.0
Period 1, good State	98.2	-9.0	-7.2	19.1	18.8	17.0	30.7	-14.7	-10.1	20.1	31.0
Nominal Exchange Rate											
Period 0, level	0.200	0.927	0.894	0.674	0.679	0.707	0.578	0.956	0.930	0.657	0.568
Period 1, level, bad state	0.446	0.634	0.647	0.812	0.812	0.817	0.758	0.778	0.777	0.812	0.758
Period 1, % level, good state	0.505	1.192	1.163	0.840	0.849	0.870	0.765	1.281	1.208	0.833	0.764
Period 1, % change, bad state	123.3	-31.6	-27.7	20.5	19.6	15.5	31.2	-18.6	-16.4	23.6	33.5
Period 1, % change, good state	152.6	28.5	30.1	24.6	25.1	23.0	32.4	34.0	29.9	26.8	34.5
Nominal Asset Price											
Period 1, level, bad state	0.223	0.317	0.323	0.406	0.406	0.411	0.379	0.397	0.397	0.406	0.379
Period 1, level, good state	0.252	0.668	0.646	0.420	0.429	0.445	0.383	0.726	0.677	0.417	0.382
Period 1, % change, bad state	-27.5	-65.9	-63.0	-45.4	-45.7	-45.8	-43.3	-57.1	-55.1	-44.1	-42.3
Period 1, % change, good state	-18.0	-28.2	-26.0	-43.5	-42.7	-41.4	-42.7	-21.7	-23.4	-42.7	-41.9
Borrowing											
Period 0 (nominal level, domestic currency ...	-0.270	-2.284	-2.193	-1.605	-0.617	-1.694	-1.338	-2.352	-2.286	-1.556	-1.308
Period 0 (units of consumption - - S0*B1/P0))	-0.096	-1.053	-0.958	-0.462	-0.469	-0.502	-0.381	-1.540	-1.145	-0.453	-0.376
Period 0 (share of cons. exp.- - S0*B1/P0C0))	-4.7	-184.2	-145.1	-46.0	-47.1	-52.6	-32.8	-338.6	-206.7	-43.8	-31.9
In bad state											
Period 1 (nominal level, domestic currency ...	-0.163	-0.690	-0.705	-0.920	-0.921	-0.932	-0.817	-0.901	-0.899	-0.915	-0.813
Period 1 (units of consumption - - S1*B2/P1))	-0.025	-0.213	-0.215	-0.189	-0.190	-0.206	-0.125	-0.256	-0.255	-0.176	-0.115
Period 1 (share of cons. exp.- - S1*B2)P1C1))	-1.2	-16.0	-16.2	-21.1	-21..2	-22.6	-15.1	-25.8	-25.7	-20.3	-14.7