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Gianluca Benigno
London School of Economics

Huigang Chen
JD Power

Christopher Otrok
University of Missouri-Columbia

Alessandro Rebucci
Inter-American Development Bank

Eric R. Young
University of Virginia

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Gianluca Benigno
London School of Economics

Huigang Chen
JD Power

Christopher Otrok
University of Missouri-Columbia and Federal Reserve Bank of St Louis

Alessandro Rebucci
Inter-American Development Bank

Eric R. Young
University of Virginia

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Abstract This paper studies monetary and macro-prudential policies in a simple model with both a nominal and a financial friction. The nominal friction gives rise to conventional monetary policy objectives emphasized in the New Keynesian literature. The financial friction, in the form of a collateral constraint that binds only occasionally, gives rise to the macro prudential objective of either preventing the constraint from binding or mitigating the impact of the constraint when it does bind. The existence of both frictions in the model gives rise to the possibility that focusing on only one friction may exacerbate the distortion created by the other. To study this issue we compare a set of policy rules designed to address either one or both frictions.

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1 Introduction

The recent financial crisis has raised fundamental questions on the objectives of monetary policy. For instance, Taylor (2009) argues that excessively lax monetary policy before the crisis contributed to its occurrence and severity. In contrast, Svensson (2010) argues that monetary policy should continue to focus squarely on macroeconomic objectives (i.e., price and output stability). In this paper we study the interrelationship between the two policy objectives of addressing macroeconomic and/or financial stability.

There is an extensive literature on the design of monetary policy rules to achieve macroeconomic stability in the face of nominal frictions (Woodford, 2003). This New Keynesian literature has proposed policy rules that performs well at stabilizing output and inflation fluctuations using interest rate rules in the presence of nominal rigidities. Since the crisis, a new literature has emerged focusing on stabilization policies before and after a financial crisis in environments with credit constraints that bind only occasionally (Benigno at al 2009, Mendoza and Binachi 2010, Jeanne and Korinek 2010). These papers work in environments where the non-crisis policy is a seemingly trivial no-action policy 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 ones.

Specifically, if a policy maker is following a Taylor rule designed for an economy with no financial friction, could this increase the probability of (or exacerbate the size of) a crisis in response to shocks? Can an adjustment be made to a conventional Taylor rule (e.g. Woodford 2010) to address any trade off between finacial and macroeconomic stability? Or is it best to design two part rules–(one for conventional times and one for when the constraint binds, one for macroeconomic stability and one for finacial stability)? A common feature of all three questions is the role that a monetary policy instrument can play as part of the macroprudential policies toolkit.

In this paper we address these questions in a relatively simple model with nominal and financial frictions that gives rise to both a traditional macroeconomic stabilization role for monetary policy and a more novel financial stability objective. The model is a three-period open economy (small open economy, with tradable and non tradable), but can be re-interpreted as a closed economy with two sectors. The key features are a borrowing/collateral constraint that depends on the price of a domestically traded fixed asset, and firms that cannot change prices every period.

To establish benchmarks and relate our findings to the existing literature, we examine competitive equilibrium allocations of three versions of this economy. The first has only the nominal rigidity, the second only a financial friction, and the third both frictions. By comparing these different allocations we can better understand what allocations different policies might aim to achieve. All three economies are subject to the same technology shock. We could easily study other shocks (interest rates, or shocks to the collateral constraint, etc.) but it is useful to start from the a shock whose transmission is well understood in most macroeconomic models.

We then compare a few alternative policy rules. The first is a pure inflation targeting rule. This allows us to study the role that focusing only on conventional objectives may have in contributing to a crisis. We then add an additional argument to this rule to capture a macro-prudential concern (i.e., Woodford, 2010).

We report three main preliminary findings. First, conditional on the simple model calibration adopted, we find that the welfare cost of the nominal rigidity is larger than the welfare cost of the financial friction. This is consistent with the findings of the existing literature, in which the financial crises generated by the kind of financial friction used are quantitatively small (Mendoza, 2010 and Benigno et al. 2009, 2010, 2011). Second, nominal rigidities, by inducing certain patterns of relative price changes in response to a financial crisis (including in particular a relatively more appreciated real exchange rate) might actually help cope with the financial friction we consider. Third, and in part as a result, we find that that there is no trade off between macroeconomic and financial friction in the model we set up. As a result, macroprudential policies are welfare reducing in this environment.

The rest of the paper is as follows. In section 2 we set up the model. In Section 3 we report and discuss equilibrium allocations under alternative frictions and policy rules. In section 4, we discuss the implications of the analysis and conclude.

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 our 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 borrowing constraint in the amount that they can borrow from abroad and face nominal rigidities in their price-setting behavior.

2.1 Households

We consider two countries, H (Home) and F (Foreign). The home country is the 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, C_t, is a composite good of tradable and non-tradable goods:

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

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

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

where $\theta > 0$ is the intratemporal 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, $\gamma : (1-\upsilon) = (1-n)\gamma$. Foreigners share a similar preference specification as domestic agents with $\upsilon^* = n\gamma$:

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

That is, foreign consumers 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

$$C_H = \left[\left(\frac{1}{n}\right)^{\frac{1}{\sigma}} \int_0^n c\left(z\right)^{\frac{\sigma-1}{\sigma}} dz\right]^{\frac{\sigma}{\sigma-1}}, \quad C_F = \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\sigma}} \int_n^1 c\left(z\right)^{\frac{\sigma-1}{\sigma}} dz\right]^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

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

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

with

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

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:

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

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$P^T = SP^{T*}$, since

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

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

The period budget constraints for the home country are:

$$Q_0A_1 + P_0C_0 + B_1 + S_0B_1^* = B_0\left(1+i_{-1}\right) + S_0B_0^*(1+i_{-1}^*) + A_0\left(D_0+Q_0\right) + W_0L_0 + F_0$$

$$Q_1A_2 + P_1C_1 + B_2 + S_1B_2^* = B_1\left(1+i_0\right) + S_1B_1^*(1+i_0^*) + A_1\left(D_1+Q_1\right) + W_1L_1 + F_1$$

$$P_2C_2 = B_2\left(1+i_1\right) + S_2B_2^*(1+i_1^*) + A_2D_2 + W_2L_2 + F_2$$

where we denote with A_{t+1} the individual asset holding at the end of period t, with D_t the exogenous dividends 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, $\digamma_t$ 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:

$$S_0 B_1^* \geq -\psi Q_0 A_1$$

$$S_1 B_2^* \geq -\psi Q_1 A_2$$

$$S_2 B_3^* \geq 0.$$

Intratemporal Consumption Choices The intratemporal first order conditions are:

$$C^N = \omega \left(\frac{P^N}{P} \right)^{-\kappa} C, \; C^T = (1 - \omega) \left(\frac{P^T}{P} \right)^{-\kappa} C$$

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 $(1 - v) = (1 - n)\gamma$ and $v^* = n\gamma$. Because of our characterization of a small open economy as an economy in which $n \longrightarrow 0$ 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

$$y^d(f) = \left[\frac{p^*(f)}{P_F^*}\right]^{-\sigma} \left\{\left[\frac{P_F^*}{P^*}\right]^{-\kappa} (1-\omega)C^*\right\}$$

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 λ_t the multipliers on the period budget constraints.

The first order conditions for the asset holdings are:

$$\lambda_0 Q_0 = \mu_0 \psi Q_0 + E\left[\lambda_1 \left(D_1 + Q_1\right)\right]$$

$$\lambda_1 Q_1 = \mu_1 \psi Q_1 + E\left[\lambda_2 D_2\right].$$

where μ_t denotes the Lagrange multiplier on the collateral constraints.

The first order conditions for foreign-currency denominated bond holdings are:

$$S_0 \lambda_0 = S_0 \mu_1 + E_t\left[S_1 \lambda_1 \left(1 + i^*\right)\right]$$

$$S_1 \lambda_1 = S_1 \mu_2 + E_t\left[S_2 \lambda_2 \left(1 + i^*\right)\right].$$

The first order conditions for domestic-curency denominated bond holdings are:

$$\lambda_0 = E_t\left[\lambda_1 \left(1 + i_0\right)\right]$$

$$\lambda_1 = E_t\left[\lambda_2 \left(1 + i_1\right)\right].$$

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

$$E_t\left[\lambda_1\left(1+i_0\right)\right]=\left[\mu_0+E_t\left[\lambda_1\frac{S_1}{S_0}\left(1+i^*\right)\right]\right]$$

and

$$E_t\left[\lambda_2\left(1+i_1\right)\right]=\left[\mu_1+E_t\left[\lambda_2\frac{S_2}{S_1}\left(1+i^*\right)\right]\right]$$

So that we can rewrite the asset price equations as:

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

This equation highlights the fact that, all else being equal, when the constraint binds agents have an incentive to buy the asset and use it as collateral. This can be seen by the fact that the asset price is increasing in μ_t.

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 tradables 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-tradables sector operate under decreasing return to scale in a competitive environment.

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

$$Y_t^N=z_t^N\left(L_t^N\right)^{\delta}$$

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

$$\pi_t^N=P_t^N z_t^N\left(L_t^N\right)^{\delta}-W_tL_t^N.$$

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

$$W_t=P_t^N z_t^N\delta\left(L_t^N\right)^{\delta-1}. \tag{6}$$

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

$$y_t(h) = z_t^T L_t^T(h)$$

in which z_t^T is the sector-specific productivity shock. Moreover 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. Here we assume that when firms can reset prices they have observed the relevant uncertainty.

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:

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

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

$$1 = \frac{\sigma}{\sigma-1}\frac{W_2}{P_2^H z_2^T}$$

We now review the pricing choice 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

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

where

$$\tilde{y}_0(h) = \left(\frac{\tilde{p}_0(h)}{P_{H,0}}\right)^{-\sigma} Y_{H,0},\ \ \tilde{y}_1(h) = \left(\frac{\tilde{p}_0(h)}{P_{H,1}}\right)^{-\sigma} Y_{H,1} \tag{7}$$

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 gives:

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

By using (7), we can rewrite the above condition as:

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

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

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

that can be rewritten as

$$\left(\frac{1-\alpha\left(\Pi_0^H\right)^{\sigma-1}}{1-\alpha}\right)^{\frac{1}{1-\sigma}} = \frac{\tilde{p}_0(h)}{P_0^H},$$

with $\Pi_1^H \equiv \frac{P_0^H}{P_{-1}^H}$.

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:[1]

$$\tilde{p}_1(h) = \frac{\sigma}{\sigma-1} \frac{W_1}{z_1^T}$$

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:

$$\left(\frac{1-\alpha\left(\Pi_1^H\right)^{\sigma-1}}{1-\alpha}\right)^{\frac{1}{1-\sigma}} = \frac{\tilde{p}_1(h)}{P_1^H}$$

Given the set of first order conditions by the firms, it is useful to examine how financial friction affects firms behavior and in particular the interaction between nominal rigidities and the financial constraint that agents face. This interaction is relevant only in period 0 since in period 1 and 2, firms can reset prices at the flexible price level. In period 1 and 2, indeed, there is an indirect effect coming from the financial friction through the endogenous

[1]So nominal rigidities distort the firm pricing decision only at time zero.

state variable B_t^* that determines the household debt position at the beginning of period t: so the higher is the debt (B_t^* more negative), the lower are the resources available for household to spend in the current period, for given other variables.

The pricing equations in period 0, 1, and 2 can therefore be respectively rewritten as follows:

In period 0

$$\frac{\tilde{p}_0(h)}{P_0^H} = \frac{\sigma}{\sigma-1} \frac{E_0\left(\frac{P_0^N z_0^N \delta \left(L_0^N\right)^{\delta-1}}{z_0^T P_0^H} Y_{H,0} + \beta\alpha Q_{0,1} \frac{P_1^N z_1^N \delta \left(L_1^N\right)^{\delta-1}}{z_1^T P_{H,1}} \left(\Pi_1^H\right)^{1+\sigma} Y_{H,1}\right)}{E_0\left[Y_{H,0} + \beta\alpha Q_{0,1} \left(\Pi_1^H\right)^{\sigma} Y_{H,1}\right]}$$

$$\left(\frac{1-\alpha\left(\Pi_0^H\right)^{\sigma-1}}{1-\alpha}\right)^{\frac{1}{1-\sigma}} = \frac{\tilde{p}_0(h)}{P_0^H}$$

In period 1:

$$\frac{\tilde{p}_1(h)}{P_1^H} = \frac{\sigma}{\sigma-1} \frac{P_1^N z_1^N \delta \left(L_1^N\right)^{\delta-1}}{P_1^H z_1^T}$$

$$\left(\frac{1-\alpha\left(\Pi_1^H\right)^{\sigma-1}}{1-\alpha}\right)^{\frac{1}{1-\sigma}} = \frac{\tilde{p}_1(h)}{P_1^H}$$

In period 2:

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

2.3 Monetary Policy

We model monetary policy with a simple pure inflation targeting rule:

$$(1+i_t) = \beta\bar{\Pi} \left(\frac{\Pi_t^H}{\bar{\Pi}}\right)^{\phi_\pi}, \tag{8}$$

in which the target inflation $\bar{\Pi}_t$ is time invariant and set equal to zero.[2] We then consider a second interest rate rule with a macro-prudential component. While the model would allow for several possibilities, we include the level of borrowing to GDP (with a coefficient

[2]There is an issue here in terms of which measure of inflation to target. Here we have included PPI inflation. An alternative is to include 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.

of 0.01), in addition to the inflation term. More formally, the alternative rule is:

$$(1 + i_t) = \beta\bar{\Pi}\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\phi_\pi}\left(1 - \frac{S_t B^*_{t+1}}{P_t C_t}\right)^{\phi_{B^*}} \tag{9}$$

This rule says that, all else equal, the nominal interest rate in period t is higher the higher the level of borrowing in foreign currency as a share of GDP. Raising nominal interest rates when borrowing increases and, all else being equal, acts as a tax on borrowing and hence as a macro prudential intervention, as it applies to both period 0 and 1.

3 Equilibrium conditions

The nontradeable goods market equilibrium condition is:

$$P^N_t z^N_t (L^N_t)^\delta = P^N_t C^N_t \tag{10}$$

Firms' profits are given by

$$\begin{aligned} F_t &= P^N_t z^N_t (L^N_t)^\delta - W_t L^N_t + \frac{1}{n}\int_0^n \left(p_t(z) y_t(z) - W_t \frac{y_t(z)}{z^T_t}\right) dz \\ &= P^N_t C^N_t - W_t L^N_t + P^H_t Y^H_t - W_t \frac{1}{n}\int_0^n l^T_t(z) dz. \end{aligned}$$

As we also have a fixed total labor supply

$$L_t = L^N_t + \frac{1}{n}\int_0^n l^T_t(z) dz = 1. \tag{11}$$

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 is:

$$P^H_t C^H_t + P^F_t C^F_t + S_t B^*_{t+1} = S_t B^*_t (1 + i^*_{t-1}) + D_t + P^H_t Y^H_t, \tag{12}$$

where D_t is the dividend flow from holding the fixed asset and it is assumed to be exogenously given.

The first order conditions for the asset holdings are:

$$\frac{C_0^{-\rho}}{P_0} Q_0 = \mu_0 \psi Q_0 + \beta E_t \left[\frac{C_1^{-\rho}}{P_1} (D_1 + Q_1) \right] \tag{13}$$

$$\frac{C_1^{-\rho}}{P_1} Q_1 = \mu_1 \psi Q_1 + \beta E_t \left[\frac{C_2^{-\rho}}{P_2} D_2 \right]. \tag{14}$$

The first order conditions for foreign bond holdings are:

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

$$\beta S_1 \frac{C_1^{-\rho}}{P_1} = S_1 \mu_1 + \beta^2 E_t \left[S_2 \frac{C_2^{-\rho}}{P_2} (1 + i^*) \right].$$

The first order conditions for domestic bond holdings are:

$$\frac{C_0^{-\rho}}{P_0} = \beta E_t \left[\frac{C_1^{-\rho}}{P_1} (1 + i_0) \right] \tag{15}$$

$$\frac{C_1^{-\rho}}{P_1} = \beta E_t \left[\frac{C_2^{-\rho}}{P_2} (1 + i_1) \right]. \tag{16}$$

No arbitrage implies the following modified version of international parity relationship:

$$E_t \left[\frac{C_1^{-\rho}}{P_1} (1 + i_0) \right] = \left[\mu_0 + E_t \left[\frac{C_1^{-\rho}}{P_1} \frac{S_1}{S_0} (1 + i^*) \right] \right] \tag{17}$$

$$E_t \left[\frac{C_2^{-\rho}}{P_2} (1 + i_1) \right] = \left[\mu_1 + E_t \left[\frac{C_2^{-\rho}}{P_2} \frac{S_2}{S_1} (1 + i^*) \right] \right] \tag{18}$$

We then have the static equilibrium conditions:

$$C^N = \omega \left(\frac{P^N}{P} \right)^{-\kappa} C, \quad C^T = (1 - \omega) \left(\frac{P^T}{P} \right)^{-\kappa} C$$

with

$$\begin{aligned} Y^H &= \left[C^H + C^{H*} \right] = (1 - \gamma) \left(\frac{P^H}{P^T} \right)^{-\theta} (1 - \omega) \left(\frac{P^T}{P} \right)^{-\kappa} C \\ &\quad + \gamma \left(\frac{P^{H*}}{P^{T*}} \right)^{-\theta} (1 - \omega) \left(\frac{P^{T*}}{P^*} \right)^{-\kappa} C^* \end{aligned}$$

and the pricing relationships

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

with

$$1=\left[(1-\gamma)\left(\frac{P^H}{P^T}\right)^{1-\theta}+\gamma\left(\frac{P^F}{P^T}\right)^{1-\theta}\right]^{\frac{1}{1-\theta}},\ \theta>0, \tag{19}$$

On the firms 'side, in the non-tradable sector we have:

$$W_t=P_t^N z_t^N \delta\left(L_t^N\right)^{\delta-1} \tag{20}$$

while from the tradable sector we have:

In period 0:

$$\left(\frac{1-\alpha\left(\Pi_0^H\right)^{\sigma-1}}{1-\alpha}\right)^{\frac{1}{1-\sigma}}=\frac{\sigma}{\sigma-1}\frac{E_0\left(\frac{P_0^N z_0^N\delta\left(L_0^N\right)^{\delta-1}}{z_0^T P_0^H}Y_{H,0}+\beta\alpha Q_{0,1}\frac{P_1^N z_1^N\delta\left(L_1^N\right)^{\delta-1}}{z_1^T P_{H,1}}\left(\Pi_1^H\right)^{1+\sigma}Y_{H,1}\right)}{E_0\left[Y_{H,0}+\beta\alpha Q_{0,1}\left(\Pi_1^H\right)^{\sigma}Y_{H,1}\right]} \tag{21}$$

In period 1:

$$\left(\frac{1-\alpha\left(\Pi_1^H\right)^{\sigma-1}}{1-\alpha}\right)^{\frac{1}{1-\sigma}}=\frac{\sigma}{\sigma-1}\frac{P_1^N z_1^N\delta\left(L_1^N\right)^{\delta-1}}{P_1^H z_1^T} \tag{22}$$

In period 2:

$$1=\frac{\sigma}{\sigma-1}\frac{P_2^N z_2^N\delta\left(L_2^N\right)^{\delta-1}}{P_2^H z_2^T} \tag{23}$$

Note that in the pricing equation (21), $Q_{0,1}=\frac{1}{1+i_0}$and where we have that:

$$\Pi_0^H\equiv\frac{P_0^H}{P_{-1}^H},\ \Pi_1^H\equiv\frac{P_1^H}{P_0^H}$$

We close the system with a Taylor rule for the domestic interest rate as we discussed above.

4 Model Calibration and Solution

Table 1 reports the parameter values of the model, the shocks' process, and the initial conditions. The model is parameterized in the simplest possible manner as we do not attempt to use it quantitatively. The tradeable sector technology shock Z^T is a two-state Markov process that can take two values, either 0.9 or 1.1 with the following transition probabilities $\{0.40.6; 0.40.6\}$. The shock is in period 0 and in period 1. So the economy has two possible states in period 1 and four states in period 2.

The elasticity of substitution between tradable and non-tradable goods and between home and foreign tradable goods is set to one. The relative weight of non-tradable goods is set to 0.5. As a result, tradable and non-tradable consumption are the same in units of consumption. The degree of openness is .25, which, combined with a size parameter of 0.05, yields a value for the relative weight of home tradable goods of .7625. The elasticity of substitution within home tradables goods is set to 6 to yielding a mark up of 20 percent, a conventional value. The labor share parameter δ is set to 0.5. The intertemporal substitution and risk aversion are set $\rho = 1$, as in Jeanne and Korinek (2010).

The nominal rigidity parameter is set to $\alpha = 0.5$, significantly lower than the 0.75 value typically used in the New Keynesian literature. This implies a frequency of adjusting prices of 50 percent and down plays the role of nominal rigidities. The coefficient in the pure inflation targeting rule is set to $\phi_\pi = 1.5$. We then use a more aggressive inflation target with a coefficient of 2.0.

Several observations on the parametrization of the leverage constraint are in order to help understand the results we report in the next section. First, the parameter ψ is set to a value such that the constraint is never binding in period 0, and to 2.5 in period 1, so that the constraint can bind when the economy remains in the bad state in period 1. (The economy is initialized to be in the bad state in period in period 0). Thus, the occasionally binding financial friction is a leverage constraint that limits foreign currency denominated borrowing to 2.5 times the value of collateral in nominal terms; it can constrain borrowing only in period 1, and potentially distorts the allocation (the consumption and borrowing choice) in both period 0 and 1. Note here that, because the Markov shock process has only two states, the probability at time 0 that the constraint binds at time 1 is exogenous and coincides with the probability that the economy remains in the bad state moving from period 0 to period 1. The leverage constraint in period 1, however, will be binding only for certain values of endogenously chosen borrowing at time zero, and the model is calibrated so that the constraint binds when the bad state in period 0 realizes again in period 1.[3]

All allocations are initialized with $B_0^* = -3.8$ in the negative state (state 1). Note that the value of initial debt in either domestic currency or unit of consumption will differ across experiments. The exogenous dividend process in nominal terms is $D_0 = D_1 = D_2 = 0.5$. The foreign interest rate and the discount rate are constant and assumed to be zero

[3]Adopting a stochastic process with continous support will allow us to endogenize the crisis probability.

($\beta = (1+i^*) = 1$), like Jeanne and Korinek (2010). Foreign prices are also constant and normalized to 1: $P^* = P_0^{F*} = P_1^{F*} = P_2^{F*} = 1$. The terminal exchange rate level is $S_2 = 1$.

The model is solved backwards from period 2. For each period, given the current foreign debt level B^*, the state of the tradeable sector technology shock Z^T, and the previous period domestic tradeable price level P^H, we solve a system of equations to obtain the marginal utility of consumption(λ), the nominal exchange rate (S), and the asset price (Q). We then obtain previous period values for these variables from the Euler equations. When solving the system of equations, we first check the solution of the model without the collateral constraint. If the equilibrium allocation satisfies the constraint, then we move to the previous period; if it does not, we solve the system with a binding collateral constraint.

We compute welfare as the ex ante value of the expected utility:

$$\begin{aligned} V &= \log(c_0) + \\ &\quad p_{21}\log(c_{1,1}) + p_{22}\log(c_{1,2}) + \\ &\quad p_{21}p_{11}\log(c_{2,11}) + p_{21}p_{12}\log(c_{2,12}) + p_{22}p_{21}\log(c_{2,21}) + p_{22}p_{22}\log(c_{2,22}); \end{aligned}$$

The variance of period 1 consumption is given by

$$\operatorname{var}(c_1) = p_{21}(c_{1,1} - E(c_1))^2 + p_{22}(c_{1,2} - E(c_1))^2$$

where

$$E(c_1) = p_{21}c_{1,1} + p_{22}c_{1,2}.$$

The variance of period 2 consumption is

$$\operatorname{var}(c_2) = p_{21}p_{11}(c_{2,11} - E(c_2))^2 + p_{21}p_{12}(c_{2,12} - E(c_2))^2 + p_{22}p_{21}(c_{2,21} - E(c_2))^2 + p_{22}p_{22}(c_{2,22} - E(c_2))^2$$

where

$$E(c_2) = p_{21}p_{11}c_{2,11} + p_{21}p_{12}c_{2,12} + p_{22}p_{21}c_{2,21} + p_{22}p_{22}c_{2,22}.$$

5 Alternative frictions and policy rules

In this section we study the impact of alternative combinations of model frictions and policy rules. We first analyze two well known benchmarks: a flexible price allocation without the financial friction and a flexible price economy with the financial friction. The former is the benchmark typically used in the New Keynesian literature, while the latter is comparable to the competitive equilibrium allocation of the models in the new literature on financial stability (Benigno et al (2011), Jeanne and Korinek (2011) and Bianchi and Mendoza (2011)). We then consider an economies with a price rigidity with and without financial frictions.

All four economies have a pure inflation targeting rule with a 1.5 coefficient on inflation, with inflation measured by the PPI index, i.e., (Π_t^H). An alternative would be to use CPI inflation (Π_t).[4] We then consider a second interest rate rule in which a macro-prudential argument is added (the level of borrowing to GDP), in addition to the inflation term. As noted above, the rule with a prudential term is:

$$(1+i_t) = \beta\bar{\Pi}\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\phi_\pi}\left(1-\frac{S_t B^*_{t+1}}{P_t C_t}\right)^{\phi_{B^*}} \tag{24}$$

with a somewhat arbitrary reaction coefficient of 0.01.

This set of experiments is designed to examine the interaction between the two model frictions. In particular, we are interested in the extent to which adherence to conventional monetary policy may exacerbate financial instability, especially in response to negative shocks, as suggested for instance by Taylor (2009) and as conjectured by Woodford (2011). Furthermore, we examine whether adding a macroprudential component to the standard rule might help address the crisis.

Table 2 summarizes the results. The first row reports our welfare measure, computed as explained above. The next three lines report consumption at time 0, and the average and the standard deviation of consumption across states in period 1 (Panel A). As we can see from the table, the differences among allocations in terms of levels of consumption are mirrored in differences in terms of volatility. We can therefore focus on level differences to provide intuition for the main results of the analysis.

Consider first the economy with flexible prices, with and without leverage constraint. As expected, welfare is higher in the flexible price economy without constraint than in the same economy with collateral constraint. The model has finite 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., $B_3^* = 0$). So the economy is on a debt repayment path. In the absence of shocks, consumption smoothing would imply constant tradable consumption over times and current accounts surpluses in both periods of about the same magnitude.

Current accounts over time and across states, in unit of consumption, together with their components are reported in Panel B of Table 2 for all experiments. The path of income

[4] Note that with an inflation coefficient that is aggressive enough to deliver $\Pi_t^H = 0$ the model should approach an allocation equivalent to the flexible price.

is constant over time when the bad state realizes and increases slightly when the good state realizes in period 1. The unconstrained economy with flexible prices displays tradable consumption more or less equalized across periods and states, while tradable consumption in the constrained economy is lower in the bad state in period 1 (as the constraint does not permit enough borrowing to smooth consumption). Both the constrained and the unconstrained economy are in surplus in both period 0 and 1 to repay debt in period 2, but the constrained economy has larger surpluses, matching the lower consumption levels of tradables (and also non-tradables given preference and parameter values).

The current account behavior is driven by the nominal and real exchange rate. In the constrained economy the debt repayment profile is more front loaded with larger current account surpluses and smaller borrowing in period 0. As a result the nominal and the real exchange rate are more depreciated than in the unconstrained economy. Price levels are also more depressed in the constrained economy and as a result the asset price is slightly higher as the dividend is fixed in nominal terms.

Consider now the economy with sticky prices, both with and without leverage constraint. Two results stand out. The first is that the economy with sticky prices without the collateral constraint has lower welfare than the economy with flexible prices and the leverage constraint. The second is that in the economy with sticky prices and the collateral constraint ends up producing higher welfare once interacted with nominal rigidities.

The key to understand both these results is the behavior of the nominal exchange rate, which in the model has both an expansionary expenditure switching effect and a contractionary balance sheet effects via the currency denomination of the initial stock of debt. The initial foreign-currency denominated debt must be repaid in period 2 by increasing exports or reducing imports. In the flexible price model, the former dominates the latter. In the sticky price model, the latter dominates the former, and as a result the exchange rate is much more depreciated in period 0. With sticky prices, the nominal exchange rate overshoots in period 0. This increases the domestic currency value of foreign-currency dominated debt, which in turn exerts even more pressure on domestic price levels at time zero, further increasing the real value of debt. As a result the current account adjustment is much larger and much more front loaded with sticky prices. Tradable consumption (and, given preferences and parameter values adopted, also nontradable consumption) is uniformly lower across states with sticky prices (Panel B.). Associated with this is a higher asset price in both nominal and real terms with sticky prices which provides room for the higher level of equilibium borrowing. Prices are an important part of the adjustment mechanism, including by affecting income and dividends (and hence real equity prices) and in equilibrium are much lower in the sticky price model. The reason why introducing the collateral constraint in the sticky price model is seemingly welfare increasing is that it limits foreign borrowing, and hence contains the negative balance sheet effects stemming from the initial depreciation. Lower borrowing leads to a more appreciated exchange rate which in turns further reduces borrowing.[5]

These results are (preliminary) prima facie evidence that, in this model economy and under the parameter assumptions made, the nominal rigidity friction is more important than the financial friction in welfare terms and that there may be no trade off between monetary and financial stability. Finding that the nominal rigidity is more costly than the financial friction we adopted is consistent with results in the new literature on occasionally binding frictions in which the welfare costs of financial crises is quantitatively small. On the one hand, for instance, in a series of recent studies, Benigno at al (2009, 2010, 2011a) reported relatively small welfare gains from policies that address the underlying source of financial instability, while Mendoza (2002, 2010) finds that the second moments of an economy with and without a collateral constraint similar to that adopted here are very close. And as a result, the financial friction cannot impose high average welfare costs on these economy. However, welfare is state contingent in this class of models, and larger welfare differences can arise in crisis states. On the other hand, it is well known that the transmission of technology shocks with nominal rigidities has first order differences compared to the case in which prices are flexible.

If we increase the inflation coefficient to 2, as one would expect, the allocation moves in the direction of the flexible prices one, without increasing the level of borrowing in period zero in either real terms, domestic currency value, or foreign currency value. We tentatively conclude from this experiment that in this model economy, there is no trade off between financial and macroeconomic stability.

6 Conclusions

In this paper we set up a model with both a nominal rigidity and a financial friction and we study their general equilibrium interaction. 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. While the analysis and the results is preliminary, we find that the welfare cost of nominal rigidities might be larger than the cost of the kind of financial friction analyzed in the new literature on macro-prudential policies and that there might be no trade off between macroeconomic and financial stability. While macro

[5]It is therefore a result that might be sensitive to the assumptions on the initial debt position or the finite-horizon nature of the model.

prudential policies may have their own scope and merit when targeting specific distortions in the financial system they might not be as effective to address these frictions in macro stabilization problem.

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Table 1. Model Parameters and Initial Conditions

Structural parameters	**Values**
Elasticity of substitution between tradable and non-tradable goods	$\kappa = 1$
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	$\upsilon = 0.7625$
Size	$n = 0.05$
Openess	$\gamma = 0.25$
Elasticity of substitution within home tradables	$\sigma = 6$
Labor share in production	$\delta = 0.5$
Credit constraint parameter	$\psi = 2.5$
Share of firms resetting prices	$\alpha = 0.5$
Intertemporal substitution and risk aversion	$\rho = 1$
Dscount factor	$\beta = 1$
Inflation coefficient	$\phi_\pi = 1.5$
Debt coefficient	$\phi_B = 0.01$

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	$B_0^* = -3.8$
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 interest rate rules

Variables	Flexible Prices (Inf. Coeff.=1.5) Constrained (1)	Flexible Prices (Inf. Coeff.=1.5) Unconstrained (2)	Sticky Prices (Inf. Coeff.=1.5) Constrained (3)	Sticky Prices (Inf. Coeff.=1.5) Unconstrained (4)	Sticky Prices (Inf. Coeff.=2) Constrained (5)	Sticky Prices (Inf. Coeff.=2) Unconstrained (6)	Sticky Prices (Inf. Coeff.=1.5 and Prudential component) Constrained (7)
Panel A. Selected variables in Period 0 and 1							
Welfare	-2.362	-2.160	-5.515	-5.897	-4.594	-4.649	-6.060
Consumption							
c0	0.439	0.472	0.149	0.131	0.210	0.207	0.124
c1mean	0.461	0.494	0.178	0.165	0.225	0.222	0.160
c1var	0.00004	0.00002	0.00601	0.00730	0.00395	0.00417	0.00825
Nominal Exchange Rate							
s0	0.443	0.382	0.981	1.006	0.851	0.857	1.015
s1mean	0.650	0.592	1.013	1.021	0.954	0.956	1.021
Average Depreciation Across States in Period 1 (+)	46.79	55.03	3.20	1.42	12.03	11.48	0.58
Real Exchange Rate							
real s0	0.159	0.134	0.606	0.693	0.470	0.480	0.744
real s1mean	0.162	0.137	0.495	0.533	0.403	0.408	0.550
Average Depreciation Across States in Period 1 (+)	1.53	2.51	-18.33	-23.07	-14.34	-14.87	-26.17
Initial Real Foreign Debt	-0.598	-0.503	-2.280	-2.605	-1.777	-1.813	-2.813
Real Foreign Debt Entering Period 1	-0.347	-0.279	-1.504	-1.722	-1.159	-1.184	-1.851
Nominal Foreign Debt Entering Period 1 (In foreign currency)	-2.179	-2.089	-2.480	-2.486	-2.466	-2.468	-2.487
Nominal Foreign Debt Entering Period 1 (In domestic currency)	-0.965	-0.798	-2.434	-2.502	-2.099	-2.116	-2.524
Price Levels							
p0	2.784	2.854	1.618	1.453	1.810	1.787	1.364
pf0	0.443	0.382	0.981	1.006	0.851	0.857	1.015
ph0	1.319	1.359	1.105	1.100	1.115	1.114	1.100
pn0	1.100	1.171	0.352	0.283	0.453	0.441	0.249
Average Inflation Rates Across States in Period 1							
CPI	44.9	51.4	40.3	49.6	40.4	41.0	57.0
PPI	36.8	42.8	1.4	0.5	4.0	3.7	0.1
Nominal Interest Rate							
i_0	1.516	1.584	1.162	1.154	1.244	1.240	1.154
i1mean	1.605	1.710	1.026	1.013	1.090	1.085	1.007
Nominal Asset Price							
q0	0.559	0.507	0.932	0.937	0.831	0.832	0.955
q1mean	0.334	0.296	0.956	0.944	0.480	0.478	0.519
Average Asset Price InflationAcross States in Period 1	-40.21	-41.58	2.59	0.81	-42.30	-42.55	-45.59
Panel B. Current Account and Its Components Across Times and States (In units of consumption)							
Real resource constraint in BAD state in period 0							
Income	0.295	0.287	0.542	0.604	0.457	0.463	0.643
Dividend	0.180	0.175	0.309	0.344	0.276	0.280	0.367
Current account	0.252	0.223	0.776	0.883	0.618	0.629	0.962
CT	0.220	0.236	0.075	0.066	0.103	0.103	0.062
Real resource constraint in BAD state in period 1							
Income	0.288	0.283	0.340	0.344	0.320	0.321	0.344
Dividend	0.122	0.115	0.177	0.180	0.165	0.166	0.181
CURR ACC	0.175	0.154	0.380	0.390	0.334	0.337	0.389
CT	0.234	0.245	0.137	0.135	0.150	0.151	0.136
Real resource constraint in GOOD state in period 1							
Income	0.323	0.312	0.600	0.647	0.507	0.512	0.672
Dividend	0.126	0.117	0.292	0.317	0.242	0.246	0.330
CURR ACC	0.221	0.180	0.835	0.917	0.661	0.673	0.958
CT	0.228	0.249	0.058	0.047	0.085	0.085	0.043

Periods: 0, 1, and 2
States: Bad State (1) and Good State (2)
Variable1mean: weighted average of the values across states.