

# Financial disruption as a cost of sovereign default: a quantitative assessment\*

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## Abstract

The recent European debt crisis has sparked a heated debate on the merits of fiscal austerity. Since the main objective of the proposed fiscal tightenings is to reduce sovereign default risk, the solution to this debate depends on the costs of a sovereign debt restructuring. One important cost is its negative effect on the banking system. This paper extends an off-the-shelf macroeconomic model with financial frictions in order to quantitatively assess the costs of financial disruption ensuing from a sovereign debt restructuring. Results show that the losses from financial disruption are offset by the benefits of a less contractionary fiscal policy. Government size is crucial for the relative effects of financial disruption as austerity becomes substantially more costly when tax rates are large.

KEYWORDS: Financial disruption; sovereign debt; sovereign default; Deleveraging.

JEL CLASSIFICATION: E32, F34, G01, H63.

## 1 Introduction

A large part of policy discussion in the last couple of years has focused on the possibility of sovereign default by the so called GIPS. One important topic in discussion has been the deleterious effect of sovereign debt restructuring on the banking system and, consequently, on the economy as a whole. The mechanism runs as follows: sovereign debt restructuring leads to lower price for sovereign debt, and thus implies a reduction in the value of banks' assets. This in turn forces banks to deleverage, reducing credit in the economy and leading to a sharp fall in economic activity. Avoiding the need for sovereign debt restructuring has thus been a top priority of European policy makers. In response to

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this issue, large primary surpluses have been proposed, and often implemented, in those European countries facing the risk of default.<sup>1</sup>

Despite the importance of this topic, there is a shortage of model-based quantitative assessments of the effects of the financial disruption caused by sovereign default on economic activity. The contribution of this paper is a quantitative assessment of the effects of an exogenous debt restructuring episode. An off-the-shelf macroeconomic model with financial frictions along the lines of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) is extended to allow for sovereign debt.<sup>2</sup> Leverage-constrained banks hold government bonds. We simulate a debt restructuring episode in which banks suffer portfolio losses and study the effects this has on the economy.

The model portrays a closed economy, calibrated to capture some key features of the Euroarea. Debt restructuring is modelled as a sharp fall in current debt payments that phases out over time. By negatively affecting banks' balance sheets, a debt restructuring episode forces them to deleverage. However, a reduction in the government's debt servicing needs allows for a reduction in taxes – which is captured in the model by an exogenous fiscal rule. Since the objective of the paper is to understand financial disruption as a cost of sovereign default, debt restructuring leads to no other cost to the economy.

In a version of the model with lump-sum taxes, the financial disruption ensuing from a debt restructuring episode leads to a reduction in economic activity. Investment drops leading to a persistent reduction in output. However, the deleterious effects of financial disruption are more than offset by the stimulus in the economy provided by a reduction in distortionary taxes. In a version of the model with labour taxes, sovereign debt restructuring leads to a decrease in investment that affects capital formation in the short and medium run. However, it also allows for a reduction in distortionary taxation that leads to an increase in labour supply. Overall, output and welfare increase.

Sovereign default is a transfer, not a destruction of wealth. A default episode tightens the constraints on banks and forces them to deleverage, which leads to lower investment and lower output. However, it also loosens the government's budget constraint, allowing for a less contractionary fiscal policy. The theoretical net effect on output and welfare is thus ambiguous, so the policy question calls for a quantitative analysis. This paper models financial frictions and distortionary taxation in a standard way and the effect of

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<sup>1</sup>For recent contributions to this policy debate, see VoxEU columns from Páris and Wyplosz (2014), Mody (2014) and Buitier (2014).

<sup>2</sup>This framework has been used and extended in several directions. Examples include Villa and Yang (2011), Gertler, Kiyotaki and Queralto (2012), Arosa and Coelho (2013), Dedola, Karadi and Lombardo (2013), Gertler and Karadi (2013), Meeks, Nelson and Alessandri (2013), Rannenberg (2013), Takamura (2013), Villa (2013) and Correia et al (2014). Bocola (2014) also extends Gertler-Kiyotaki framework to study the connection between sovereign risk and financial frictions.

financial frictions is not important enough to overcome the benefits from lower taxes.

The net impact of debt restructuring on the economy is importantly affected by the government size. In countries where government spending and tax rates are large, as in many European countries, the negative effects of financial disruption are dwarfed by the relief from lower taxes. The marginal losses from taxation are increasing in the level of taxes, and our results shows this effect is quantitatively important.

Interestingly, a sovereign debt restructuring shock leads to negative effects on output and consumption if the government sharply reduces taxes in response to its lower borrowing needs. Following the default episode, banks need to deleverage and reduce credit to the economy. In this scenario, government borrowing crowds out credit to the private sector, reducing investment and capital accumulation even further. Hence a conservative fiscal stance in the aftermath of default helps to mitigate the negative effects from the ensuing financial disruption.

Since we study only one channel through which sovereign default impacts the real economy, we cannot make positive statements about the effects of sovereign default. Nevertheless, the results in this paper raise questions about the magnitude of the damage from financial disruption caused by sovereign default in comparison to the costs of tight fiscal policy that has been needed to avoid debt restructuring.

Our model builds on the literature about the role of financial frictions in business cycles and the so called “financial accelerator” channel. Many of the main contributions to this literature introduce financial frictions as an agency problem.<sup>3</sup> Gertler and Karadi (2011) and Gertler, Kiyotaki and Queralto (2012) study the recent financial crisis and the effects of unconventional monetary policy using a financial accelerator model where banks face a no-moral-hazard constraint that limits their ability to raise funds. Like in other models in this literature, these frictions amplify the effects of exogenous shocks to business cycles.<sup>4</sup>

The paper most closely related to ours is Bocola’s (2014) work on the macroeconomic implications of sovereign risk. Bocola (2014) also builds on the Gertler-Karadi-Kiyotaki framework, but there are important differences between his approach and ours. While his paper focuses on the effects of shocks to the risk of sovereign default, our paper considers a policy shock that triggers immediate debt restructuring.<sup>5</sup> Moreover,

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<sup>3</sup>See, e.g., Bernanke and Gertler (1989), Carlstrom and Fuerst (1997), Kiyotaki and Moore (1997) and Bernanke, Gertler and Gilchrist (1999).

<sup>4</sup>Boissay, Collard and Smets (2013) expand the financial accelerator framework and are able to generate credit freezes and banking crises as a result of endogenous pro-cyclical movements in banks’ balance sheets.

<sup>5</sup>An important finding of Bocola (2014) is that news about sovereign risk generates a precautionary motive for banks to deleverage (the “risk channel”) in addition to the liquidity channel that is also present in this paper. Owing to the nature of our policy experiment, the risk channel is not relevant here.

distortionary taxation is absent from his analysis but key to our results, since the benefits from relaxing the government's budget constraint crucially depend on distortions from taxation. Our model can thus be used to compare the benefits from debt restructuring and the cost from the ensuing financial disruption.

The results of the paper speak to the literature on the costs of sovereign default. A central question of this literature, dating back from Eaton and Gersovitz (1981) and Bulow and Rogoff (1989), is about the nature of the losses from sovereign default episodes, which is behind the question about why sovereign debt markets exist. In a recent survey of this literature, Panizza, Zettelmeyer and Sturzenegger (2009) argue there is not much evidence that external penalties are the main reason why governments repay their debts and highlight the importance of internal costs following defaults. A recent literature on debt crises has thus aimed at exploring the channels through which default can trigger domestic output costs. Brutti (2011), building on Broner and Ventura (2011), presents a theoretical model where sovereign default leads to liquidity crisis and output losses. This is the channel we explore in the paper, and the results raise question marks about the magnitude of those costs.

Empirical work has explored the link between sovereign risk and banks' financing conditions. Borensztein and Panizza (2008) show empirical evidence that default episodes tend to magnify the probability of banking crises and domestic credit crunches, associated to balance sheet effects and confidence collapse. Andritzky (2012) points out that one important consequence of the subprime crisis was a reversal in investor base for government securities for some advanced G20 economies. Bank of International Settlements (2011) reports changes in bank's balance sheets and funding conditions as a consequence of the European debt crisis and highlight that an increase in sovereign risk may affect the market value of banks' balance sheets through their holdings of sovereign debt. Gennaioli, Martin and Rossi (2013) provide evidence that sovereign bonds generate a liquidity benefit for banks in normal times, but become costly during debt crises.<sup>6</sup>

Our paper is also related to recent research investigating the links between sovereign risk and macroeconomic stability. Corsetti et al (2013) and Corsetti et al (2014) develop macroeconomic models with financial frictions using Curdia and Woodford's (2008) framework, but they assume an exogenous connection between sovereign risk and banks' spreads (loan over deposit rates), while here this connection is endogenous and crucial for our analysis. Bolton and Jeanne (2011) analyse theoretically the consequences of debt crises in a financially integrated world, where a sovereign country's debt can be used as

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<sup>6</sup>See also De Bruyckere et al (2012) and Popov and Van Horen (2013).

collateral by banks in other countries. Guerrieri, Iacoviello and Minetti (2012) analyse the international transmission of sovereign risk and default in the Eurozone through the banks' balance sheet channel and show that default in the so called "periphery countries" spreads to banks in the core.

This paper is organized as follows. Next section presents the model, Section 3 shows the results and Section 4 concludes.

## 2 Model

The stochastic general equilibrium model abstracts from nominal rigidities and monetary policy. The modeling of financial frictions follows Gertler and Karadi (2011) and Gertler, Kiyotaki and Queralto (2012). The key difference in this model is the inclusion of a government that issues non-state contingent debt, held by banks only, that can be defaulted on. Differently from the literature on sovereign default that builds on Eaton and Gersovitz (1981), our model considers a closed economy. In our calibration, banks' positions on government debt amount to a large fraction of GDP, so one could think of our economy as representing the whole Euroarea, where much of each country's sovereign debt is held either by domestic creditors or by financial institutions within the block.

The economy is populated by five types of agents: households, good producers, capital producers, bankers and government.

### 2.1 Households

There is a representative household with a continuum of members of measure unity, with a fraction  $1 - f$  that are *workers* and a fraction  $f$  that are *bankers*. Workers supply labour and return wages to the family, while bankers own a financial intermediary and return dividends to their household. Households can save in form of deposits held by intermediaries. They supply funds to banks in form of non-contingent short term debt (deposits, denoted  $D_t$ ), that pay a risk-free gross real return rate  $R_t$ . We additionally assume households can not buy government bonds directly.

Households choose consumption, labour supply and riskless debt to maximize expected discounted utility. We assume preferences in logarithmic form that follow a GHH specification, in order to avoid the wealth effects on labour supply (Greenwood, Hercowitz and Huffman, 1988).

$$E_t \sum_{i=0}^{\infty} \beta^i \log \left[ C_{t+i} - \frac{\psi}{1 + \varphi} L_{t+i}^{1+\varphi} \right] \quad (1)$$

Households are subject to the following budget constraint:

$$C_t + D_{t+1} = W_t L_t + R_t D_t + \Pi_t - T_t \quad (2)$$

where  $W_t$  is the wage rate,  $T_t$  are taxes paid to the government and  $\Pi_t$  are the dividends obtained from the ownership of nonfinancial firms and banks. We will analyse the case of both lump sum taxes and distortionary taxes on labour.

From the first order conditions for consumption/saving, we get:

$$E_t \beta \Lambda_{t,t+1} R_{t+1} = 1 \quad (3)$$

where  $\Lambda_{t,t+1}$  is the households' stochastic discount factor:

$$\Lambda_{t,t+1} \equiv \frac{\varrho_{t+1}}{\varrho_t}$$

and  $\varrho_t$  is marginal utility of consumption,

$$\varrho_t \equiv \left( C_t - \frac{\psi}{1+\varphi} L_t^{1+\varphi} \right)^{-1}$$

The first order condition for labour supply depends on the form of taxation.

In every period, there is a probability  $(1-\theta)$  that a banker becomes a worker. In order to maintain the fraction in each occupation constant over time, in each period there is a random fraction  $(1-\theta)f$  of workers that become bankers. Workers that become bankers receive a “start up” capital from the household to start business. Expected survival time of a bank is thus  $1/(1-\theta)$ . This prevents bankers from accumulating enough wealth so as to overcome their financial constraints.

Households also own nonfinancial firms (capital and good producers). However, they are not able to acquire capital directly or to provide funds to these firms. All financial intermediation for production must be made by a bank.

## 2.2 Good producers

The representative firm in this sector produces output in a competitive market, using labour and capital in a Cobb-Douglas technology:

$$Y_t = K_t^\alpha L_t^{1-\alpha} \quad (4)$$

with  $0 < \alpha < 1$ .

As usual, labour demand implies that the real wage rate equals the marginal product of labour:

$$W_t = (1-\alpha) \frac{Y_t}{L_t} \quad (5)$$

In order to produce in period  $t + 1$ , firms need to buy the amount of capital  $K_{t+1}$  at the end of period  $t$  from capital producers. In order to finance the acquisition of capital, firms issue securities  $S_t$  and an arbitrage condition ensures the value of these securities equals the value of the capital to be bought. The intermediaries buy these securities. Denoting by  $Q_t$  the price of one unity of capital, we have:

$$Q_t K_{t+1} = Q_t S_t$$

There are no frictions in this process. Intermediaries have perfect information about the firm and about future payoffs, so securities are state-contingent. Frictions exist within the process of banks obtaining resources from households.

In order to satisfy the zero profit condition in the competitive market, goods producers buy capital goods up to the point that gross profits per unit of capital  $Z_t$  equal the marginal product of this input:

$$Z_t = \frac{Y_t - W_t L_t}{K_t} = \alpha \frac{Y_t}{K_t}$$

A firm that sells  $S_t$  securities to acquire capital must return all its profits in the next period to the bank. Call  $R_{kt}$  the gross return to capital in time  $t$ , the amount a bank obtains as a return over each unity of credit supplied in the form of acquired securities. The representative goods producer owes a bank an amount  $Q_t S_t R_{kt+1}$  at the end of the period. This value equals the sum of profits  $\Pi_{ft}$  obtained through capital utilization in production (gross of capital remuneration) and the market value of the effective non-depreciated capital, that could be sold back in the market after production has taken place.

$$Q_t S_t R_{kt+1} = \Pi_{ft+1} + (1 - \delta) Q_{t+1} K_{t+1}$$

Substituting for  $\Pi_{ft}$  and  $S_t$  and dividing both sides by  $K_{t+1}$ :

$$Q_t R_{kt+1} = \alpha \frac{Y_{t+1}}{K_{t+1}} + (1 - \delta) Q_{t+1}$$

Hence, the gross return to capital in period  $t + 1$  is given by the ratio between the value generated by one unity of capital acquired by the firm in period  $t$  over the price at which it was bought.

$$R_{kt+1} = \frac{Z_{t+1} + (1 - \delta) Q_{t+1}}{Q_t} \quad (6)$$

### 2.3 Capital producers

The market for capital is competitive. At the end of each period, capital producers build new capital for the following period using the final output as an input in the production.

Capital goods are then sold back to good producers at price  $Q_t$ . They are subject to convex adjustment costs in this process.<sup>7</sup> A capital producer chooses investment  $I_t$  in order to maximize discounted profits, taking the price of capital  $Q_t$  as given.

Adjustment costs are a convex function of investment. The capital producers' problem is given by:

$$\max E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \Lambda_{t,\tau} \left[ Q_{\tau} I_{\tau} - \left[ 1 + f \left( \frac{I_{\tau}}{I_{\tau-1}} \right) \right] I_{\tau} \right]$$

with  $f(1) = f'(1) = 0$  and  $f''(1) > 0$ . Non-zero profits are possible when the economy is not in steady state, and profits are transferred to the household.

The first order condition for investment is given by:

$$Q_t = 1 + f \left( \frac{I_t}{I_{t-1}} \right) + \frac{I_t}{I_{t-1}} f' \left( \frac{I_t}{I_{t-1}} \right) - E_t \beta \Lambda_{t,t+1} \left( \frac{I_{t+1}}{I_t} \right)^2 f' \left( \frac{I_{t+1}}{I_t} \right) \quad (7)$$

This condition states that capital price will equal the marginal cost of investment.

The adjustment cost function assumes the form:

$$f(\cdot) = \frac{\eta_i}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2$$

where  $\eta_i$  refers to the inverse elasticity of investment with respect to the price of capital.

## 2.4 Government

Government spending is fixed and equal to  $\bar{G}$ . To finance itself, government taxes households and issues debt, which is bought by banks. Lump sum taxes are set in order to prevent large deviations of debt from its steady state level:

$$T_t = \bar{T} + \gamma(B_t - \bar{B}) \quad (8)$$

where  $B_t$  is the level of debt in the market at time  $t$ . In steady state,  $B_t = \bar{B}$ . The parameter  $\gamma$  determines how much taxes fall when government debt is reduced.<sup>8</sup>

The government issues debt with the following maturity structure: every period a fraction  $\mu$  of the outstanding debt stock comes due and  $1 - \mu$  goes on to add to the next period's debt pile. This is equivalent to assuming the government always issues debt with varying maturities, being  $1 - \mu$  the ratio between the amount of debt coming due in  $t + 1$  and the amount coming due in  $t$ .

<sup>7</sup>As pointed out by Gertler and Kiyotaki (2010), adjustment costs enhance the quantitative performance of the model without adding much complication.

<sup>8</sup>Section 3.5.2 considers a fiscal policy rule that depends on the real value of debt.



The objective of the paper is to study the effect of a debt restructuring caused by an exogenous policy shock. We introduce this possibility in the model by assuming that repayment is given by a random variable  $m_t \in [0, 1]$ . The variable  $m_t$  represents the actual fraction of debt coming due at  $t$  that is repaid, and it is given by:

$$m_t = \min\{\iota_t, 1\} \quad (9)$$

where

$$\iota_t = \rho_\iota \iota_{t-1} + (1 - \rho_\iota) + \epsilon_{\iota t} \quad (10)$$

where  $\rho_\iota$  is a positive constant and  $\epsilon_{\iota t}$  is a normally distributed error term with mean 0 and standard deviation  $\sigma_\iota$ . In steady state,  $\iota_t = 1$ , meaning that the government fully repays the amount of debt that comes due in  $t$ . However, the fraction to be repaid is subject to shocks.

A debt restructuring episode triggered by a policy decision is captured by a one-off negative shock on  $\iota$ . The auto-regressive specification captures the fact that in case of debt restructuring, sovereigns tend to repudiate short term debt in order to lengthen the debt repayment profile. So repayment drops in the first periods following a default episode but grow in time, tending again to a hundred percent of the maturing fraction as the shock vanishes completely.<sup>9</sup>

In each period, the government repays  $\mu m_t$  of the debt. The price of government debt  $\chi_t$  is the expected discounted sum of the amount to be received in the next period and the value of the remaining debt held in the balance sheet.

$$\chi_t = E_t \beta \Lambda_{t,t+1} [\mu m_{t+1} + (1 - \mu) \chi_{t+1}] \quad (11)$$

A shock to  $m_t$  affects not only the haircut in  $t$ , but also the expected repayment in the following periods, which induces changes in bonds' prices, directly influencing banks' balance sheets and investment decisions.

The gross return on bonds is the ratio between the value to be payed back by the government in the next period plus the expected value of the remaining outstanding debt divided by the current price of debt:

$$R_{bt+1} = \frac{\mu m_{t+1} + (1 - \mu) E_t \chi_{t+1}}{\chi_t} \quad (12)$$

The government's financing requirement for period  $t + 1$ ,  $\chi_t A_{t+1}$ , is the difference between the fraction of debt repaid ( $\mu B_t$  times the fraction effectively honoured  $m_t$ ) and

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<sup>9</sup>Besides allowing for the simulation of a debt restructuring episode, this specification can also capture the fact that sovereign debt is risky. The standard deviation of  $\epsilon_{\iota t}$  can be calibrated to capture this risk.

the amount of government spending that is not covered by taxes (primary deficit):

$$\chi_t A_{t+1} = \mu m_t B_t + G_t - T_t \quad (13)$$

The total outstanding debt in  $t + 1$  is given by:

$$B_{t+1} = (1 - \mu)B_t + A_{t+1} \quad (14)$$

## 2.5 Banks

Following Gertler and Karadi (2011), banks can raise funds from households in form of deposits or from retained earnings, accumulating net worth. They use the available funds to buy state-contingent securities from good producers, but also to buy government bonds  $B_{t+1}$  at price  $\chi_t$ . Banks are the only agents that buy sovereign debt. A bank's balance sheet is composed by the assets it holds (government bonds and private securities), liabilities (deposits) and net worth:

$$\chi_t B_{t+1} + Q_t K_{t+1} = N_t + D_t \quad (15)$$

where  $N_t$  is a banker's net worth and  $D_t$  are deposits raised from households, and we used  $S_t = K_{t+1}$ . Net worth in  $t + 1$  is the gross payoff from assets funded at  $t$  net of returns to depositors. Let  $R_{kt+1}$  denote the gross rate of return on a unit of a bank's private securities from  $t$  to  $t + 1$ . The net worth then is given by:

$$N_{t+1} = R_{kt+1} Q_t K_{t+1} + R_{bt+1} \chi_t B_{t+1} - R_{t+1} D_{t+1} \quad (16)$$

with

$$R_{kt+1} = \frac{Z_{t+1} + (1 - \delta)Q_{t+1}}{Q_t}$$

The objective of a banker is to maximize its future terminal value, given by the discounted value of net worth, accounting for the probabilities that she exits at each period:

$$V_t = E_t \left[ \sum_{i=1}^{\infty} (1 - \theta) \theta^{i-1} \beta^i \Lambda_{t,t+i} N_{t+i} \right] \quad (17)$$

The bank's ability to obtain funds is limited by a moral hazard constraint as in Gertler and Karadi (2011). At each period, a banker may choose to divert a fraction  $\lambda$  of her assets in the form of dividends to her family and hence defaults on part of her debt. In this case, the remaining fraction  $1 - \lambda$  of her assets will be recovered by other depositors, leading the bank to bankruptcy. This fraction  $\lambda$  is exogenous and constant. This constraint could also be interpreted as a leverage constraint imposed by official regulation, along the lines of the Basel Agreements. In equilibrium, leverage is pinned down by this constraint.

Anticipating the possibility of funds diversion, depositors will limit their lendings to ensure banks won't divert funds. The bank's value must be at least as large as its gain from deviating funds, so as to discourage diversion.

$$V_t \geq \lambda(\chi_t B_{t+1} + Q_t K_{t+1}) \quad (18)$$

The expressions in (15) and (16) yield the evolution of the bank's net worth as a function of the state variables  $K_t$ ,  $B_t$  and  $N_{t-1}$ :

$$N_t = (R_{kt} - R_t)Q_{t-1}K_t + (R_{bt} - R_t)\chi_{t-1}B_t + R_t N_{t-1} \quad (19)$$

Let  $V_t(K_{t+1}, B_{t+1}, N_t)$  be the maximized value of the bank's objective. It will satisfy the following Bellman equation.

$$V_t(K_{t+1}, B_{t+1}, N_t) = E_t \beta \Lambda_{t,t+1} \{ (1 - \theta) N_{t+1} + \theta \text{Max} [V_{t+1}(K_{t+2}, B_{t+2}, N_{t+1})] \} \quad (20)$$

In each period, the banker chooses a portfolio composition of capital and bonds,  $K_{t+1}$  and  $B_{t+1}$ , in order to maximize her value function subject to the incentive constraint and the law of motion for net worth, taking into account that she exits with probability  $(1 - \theta)$ .

We conjecture the value function is a linear function of the balance sheets' components:

$$V_t(K_{t+1}, B_{t+1}, N_t) = \nu_t Q_t K_{t+1} + \zeta_t \chi_t B_{t+1} + \eta_t N_t \quad (21)$$

In the Appendix we show that this conjecture is true, as long as:

$$\eta_t = E_t \beta \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \quad (22)$$

$$\nu_t = E_t \beta \Lambda_{t,t+1} \Omega_{t+1} (R_{kt+1} - R_{t+1}) \quad (23)$$

$$\zeta_t = E_t \beta \Lambda_{t,t+1} \Omega_{t+1} (R_{bt+1} - R_{t+1}) \quad (24)$$

with

$$\Omega_{t+1} = 1 - \theta + \theta [\phi_{t+1} \zeta_{t+1} + \varpi_{t+1} (\nu_{t+1} - \zeta_{t+1}) + \eta_{t+1}] \quad (25)$$

and

$$\varpi_t \equiv \frac{Q_t K_{t+1}}{N_t} \quad (26)$$

Each component of the banks' value function can be interpreted as follows:  $\eta_t$  is saving in deposits' costs from an additional unity of net worth. The variables  $\nu_t$  and  $\zeta_t$  are the marginal discounted gains of expanding, respectively, private securities' holdings and government bonds' holdings. Finally,  $\Omega_t$  is the shadow marginal value of net worth and affects the banks' intertemporal discount factor.

Define  $\phi_t$  as the leverage ratio, the maximum ratio of bank assets over equity:

$$\phi_t \equiv \frac{Q_t K_{t+1} + \chi_t B_{t+1}}{N_t}$$

The constraint in (18) can be rewritten as:

$$\nu_t Q_t K_{t+1} + \zeta_t \chi_t B_{t+1} + \eta_t N_t \geq \lambda(\chi_t B_{t+1} + Q_t K_{t+1})$$

If this constraint binds, we get:

$$\phi_t = \frac{\eta_t + \varpi_t(\nu_t - \zeta_t)}{\lambda - \zeta_t} \quad (27)$$

## 2.6 Evolution of bank's net worth

The total net worth in the banking sector equals the sum of existing banks' net worth  $N_{et}$  and entering banks' start-up capital  $N_{nt}$  provided by their families. The net worth of existing banks equals the net earnings from assets over liabilities from one period to another, i.e., earnings from holding securities plus earnings from holding government bonds, minus costs from deposits. This expression must be multiplied by the fraction  $\theta$  of banks that survive between periods:

$$N_{et} = \theta [(R_{kt} - R_{bt})\varpi_{t-1} + (R_{bt} - R_t)\phi_{t-1} + R_t] N_{t-1} \quad (28)$$

Families transfer to each new banker a constant fraction  $\omega/(1-\theta)$  of total assets from exiting bankers, given by  $(1-\theta)[Q_t K_t + \chi_t B_t]$ . Hence entering bankers' net worth will be:

$$N_{nt} = \omega(Q_t K_t + \chi_t B_t) \quad (29)$$

Total net worth from banks in the economy is thus:

$$N_t = N_{et} + N_{nt}$$

## 2.7 Market clearing

Output can be used for consumption, government spending or investment (including adjustment costs). Aggregate demand is given by:

$$Y_t = C_t + I_t \left[ 1 + f \left( \frac{I_t}{I_{t-1}} \right) \right] + G_t \quad (30)$$

Market clearing in the goods market requires the expression for demand in (30) to equal supply, given by (4).

The banks' balance sheet can be written as:

$$Q_t K_{t+1} + \chi_t B_{t+1} = \phi_t N_t$$

Demand for securities and bonds is given by the balance sheet constraint, given by (27). The supply of securities by firms is given by the expression for capital accumulation:

$$K_{t+1} = (1 - \delta)K_t + I_t$$

Finally, market clearing for deposits is obtained from balance sheet identity. Total deposits supplied by families must equal the difference between banks' assets and net worth.

$$D_t = Q_t K_{t+1} + \chi_t B_{t+1} - N_t$$

### 3 Results

The paper aims at understanding the effect of a sovereign debt restructuring episode on the economy under the assumption that there are no costs from default beyond the damage to the financial sector. Hence we simulate a shock to our model economy that represents a debt restructuring episode triggered by an exogenous policy decision. This is captured by a negative shock to the variable  $\iota_t$ . That yields a haircut on debt maturing in each period that decreases in time, thus implying a reduction in the level of debt and a lengthening of the debt repayment profile.

The model assumes that all asset intermediation in the economy is made through the banking system and that sovereign debt is entirely held by banks. Since the costs of default come from its negative effects on financial intermediation, our results can be seen as an upper bound to this particular cost of sovereign default.

The response to shocks can be linearly approximated in the neighbourhood of a non-stochastic steady-state. We study impulse response functions of the model variables following a negative shock to debt payments.<sup>10</sup>

#### 3.1 Calibration

The persistence of the shock is set to match some empirical evidence from default episodes. The shock has a persistence of 0.9, vanishing only after ten years. Debt price falls instantly by 13% following the shock. The initial haircut is set to 40% of the maturing debt,

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<sup>10</sup>Simulations were conducted using Dynare. The results presented in the paper consider a first order approximation around the steady state of the model. Second order effects were also considered and are discussed later in the paper.

and decreases exponentially according to the persistence parameter, so that subsequent realizations of the variable  $m_t$  represent consecutive but decreasing in size haircuts, that are significant up to around 8 years after the initial shock.<sup>11</sup>

Values assigned to utility parameters follow conventional calibration in the literature. For the household sector, the discount factor  $\beta$  is set to 0.99. The parameters of the GHH preferences are also chosen as usual. Labour disutility equals 1 and the Frisch inverse elasticity of labour supply,  $\varphi$ , is set to 3, implying a labour supply elasticity equal to 1/3. In case of labour income taxes, these values imply that the Laffer curve peaks when the labour tax rate is around 75%.<sup>12</sup>

The parameters for the banking sector were set to match three moments also tracked by Bocola (2014): (i) a steady state spread of capital return over risk-free rate of 1%, (ii) a leverage ratio of 4.3 and, (iii) an average horizon of a decade for bankers. The fraction  $\lambda$  that a banker can divert to her household equals 0.375, the proportional transfer to new banks  $\omega$  is set to 0.002, and the probability a banker survives in the following period,  $\theta$ , equals 0.97.

Parameters of the production sector were calibrated to match steady state values of the main macroeconomic aggregates of the European Union in 2012 (as well as the moments of the financial sector used in Bocola (2014)). The share of capital in the production function,  $\alpha$ , was set to 0.3 and depreciation rate  $\delta$  is 2,5% per quarter. The ratios Investment/GDP, Consumption/GDP and Government Spending/GDP have been set, respectively, to 20, 58 and 22%. Weighted debt-to-GDP average ratio across EU countries in 2012 was 85% and hence represents total debt in our model economy. Using these relations, we have a debt-to-capital ratio in the economy of around 10% and a debt-to-total assets of around 8,5%.<sup>13</sup> Table 3.1 shows the main targeted relations in equilibrium.<sup>14</sup>

Table 1: Main targeted steady state relations

Investment-to-GDP	Debt-to-GDP	Leverage	Debt maturity	Labour elasticity
0.2	0.85	4.3	6.6 years	0.33

<sup>11</sup>Empirical evidence suggests default episodes and debt renegotiation have an average length of 4-8 years and debt-to-GDP ratios tend to return to initial levels. For further empirical evidence of default episodes, see Panizza, Sturzenegger and Zettelmeyer (2009).

<sup>12</sup>Trabant and Uhlig (2011) characterize Laffer curves for EU countries in a neoclassical growth model featuring constant Frisch elasticity preferences. They find an average peak that goes from 62 to 68%, which would imply a larger elasticity of labour supply and thus strengthen our results.

<sup>13</sup>European data on national accounts, government debt and banking sector statistics can be found on Eurostat. Gennaioli, Martin and Rossi (2013) find an average debt-to-total assets ratio of 9% for a sample of 18000 banks in 18 default episodes from 1998 to 2012. This ratio has increased on average 3-4 percentage points for European countries in the last two years (see the Financial Times article from Thompson (2013, 23 Dec)).

<sup>14</sup>The complete set of parameters and values used in the model can be found in the appendix.

Average residual maturity of government debt in the Euroarea is 6.6 years. Since the maturity of debt held by banks tends to be a bit shorter than the average (for liquidity management purposes), we chose an average debt maturity of five years. Hence we set the fraction of debt that matures each period,  $\mu$ , to 0.056.<sup>15</sup>

The elasticity of taxes to debt deviation from steady state,  $\gamma$ , is set to 0.2 in the baseline calibration. In Section 3.5, we analyse the effects of different fiscal policy rules.

In the next subsection we consider the case of lump-sum taxes. We then analyse the case of distortionary taxation over labour income in the following subsection.

### 3.2 Lump-sum taxes

In case of lump-sum taxes, the first order condition for labour supply is simply:

$$W_t = \psi L_t^\varphi \tag{31}$$

Labour market equilibrium requires labour supply to equal labour demand. That happens when the wage implied by both expressions (31) and (5) is the same:

$$\psi L_t^\varphi = (1 - \alpha) \frac{Y_t}{L_t}$$

Figure 1 shows the system dynamics following the debt restructuring shock. The negative shock to  $\iota$  implies an initial reduction in debt repayments of 40%. Since around 5% of the total debt stock matures at each period, this implies an initial fall in the nominal level of debt of only 2%, but the price of government debt falls by 13%.

The debt restructuring process generates a decline in investment owing to the decline of banks' net worth together with the leverage restriction they face. Banks' assets lose value, so they are forced to deleverage. Tighter credit reduces private investment, and the capital stock starts to decline, which leads to a fall in output. A lower capital stock also implies a lower marginal product of labour and wages, so households supply less hours and output depresses further.<sup>16</sup> However, quantitatively, this effect is not very important. As a consequence of the drop in asset demand by banks, the spread of capital returns over the risk free rate rises, raising the costs for new capital acquisition.

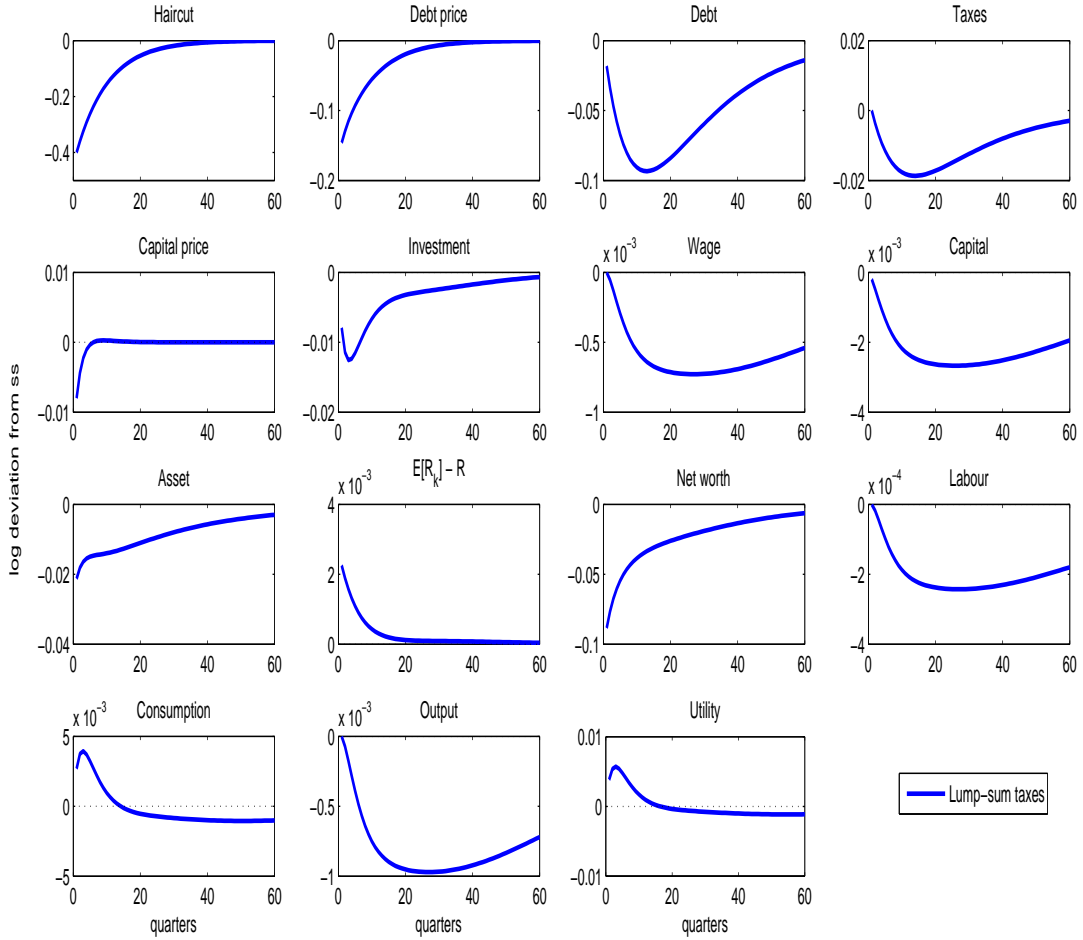
Sovereign default implies a transfer from the banks to the government. That allows the government to charge lower taxes – which can be interpreted as removing the need

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<sup>15</sup>This is also in line with Bocola (2014). For an analysis of size and composition of Euroarea government debt, see Lojsch, Rodriguez-Vives and Slavik (2011).

<sup>16</sup>Owing to the GHH preferences, there is no wealth effect on labour supply.

Figure 1: Lump-sum taxes



for increasing taxes in order to service debt. That leads to an increase in households' disposable income, and the initial fall in investment is partially compensated by an increase in consumption. In the banking sector, this is a reflection of the deleveraging process: banks take fewer deposits, households face a lower demand for their savings and consume more in the present period.

The initial increase in consumption is short lived. Capital stock keeps falling and after around 2 years, consumption is below its steady state level. It will take long for output and consumption to recover to pre-default levels: 15 years after the shock, output is about half way through the recovery and consumption is still far from its steady state level. The costs of default imposed by financial frictions are very persistent. Since the effects on



labour supply are an order of magnitude lower than the effects on consumption, the path of agents' utility mimics the path of consumption.

In sum, the debt restructuring shock weakens banks' balance sheets and force them to deleverage. Output drops and takes a long time to recover.<sup>17</sup>

### 3.3 Distortionary taxes

Avoiding a sovereign debt restructuring process often requires a tight fiscal policy. That is also true in the context of the recent policy debate about the indebted Southern European countries. As a concrete example, the Italian government under Mario Monti dramatically raised taxes in 2011-2012 in what was called a "plan to save Italy". Had Italy defaulted, the whole European Union would have been badly affected, as banks holding Italian bonds would suffer losses and be forced to cut credit to firms, but the austerity measures sparked a heated policy debate.

The results in Section 3.2 capture the costs of avoiding a credit tightening but not much of the costs of fiscal austerity because taxes are lump sum. This section considers a debt restructuring episode in a situation with distortionary taxation and analyses the effect of the default shock on the economy.

We consider that government revenues are obtained through taxation over labour income. The Government charges a rate  $\tau_t$  over labour income, adjusted according to debt deviation from steady state with the same elasticity  $\gamma$  of the lump-sum case.

$$T_t = \tau_t W_t L_t$$

with

$$\tau_t = \tau_w [1 + \gamma(B_t - \bar{B})]$$

where  $\tau_w$  is a parameter calibrated to generate the same steady state tax revenue as in the lump-sum case.<sup>18</sup> The first order condition for labour supply is now given by:

$$\psi L_t^\varphi = (1 - \tau_t) W_t$$

Labour market equilibrium then requires:

$$\psi L_t^\varphi = (1 - \tau_t)(1 - \alpha) \frac{Y_t}{L_t}$$

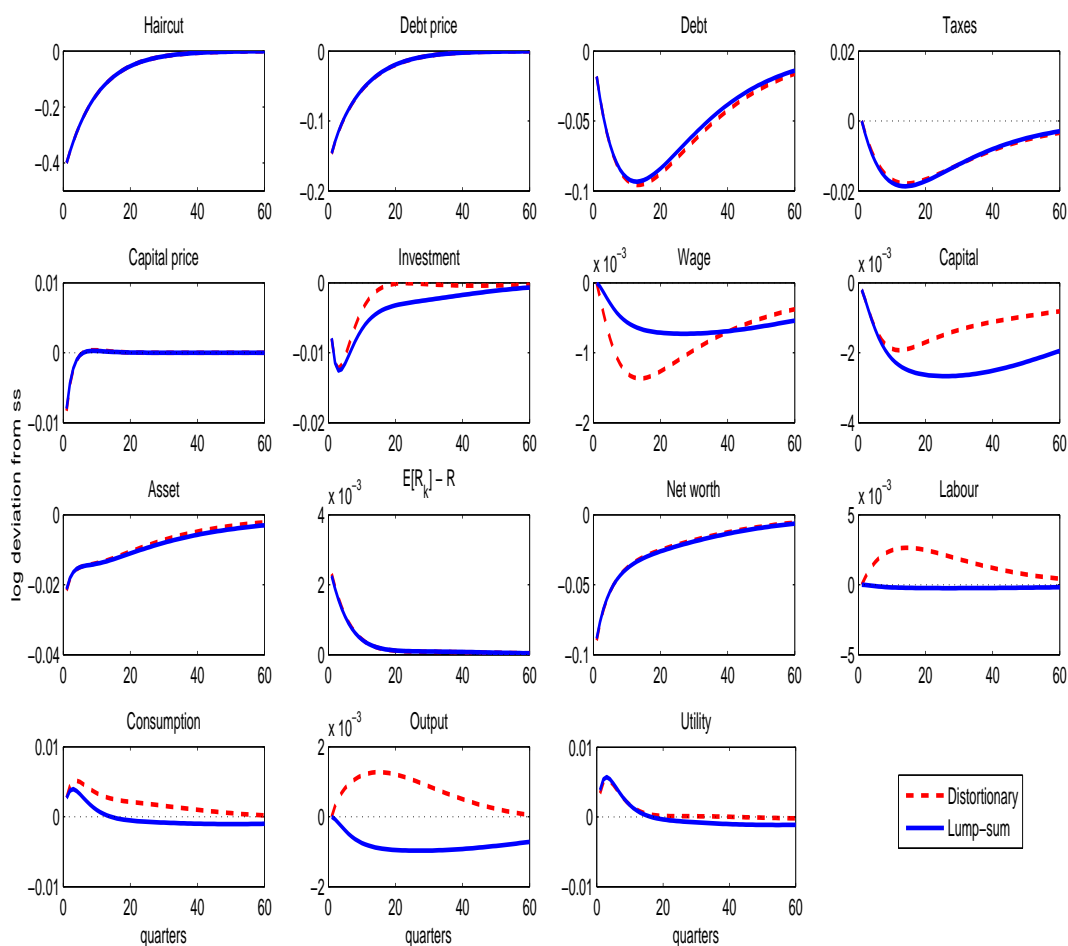
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<sup>17</sup>Bocola (2014) considers an increase in the probability of sovereign default that also causes the price of government debt to fall by 13%. The effects on the net worth of banks and on the cost of credit in his simulations and in our paper are the same. However, the effects on the economy are different. One reason behind the difference is that a sovereign debt restructuring entails an immediate transfer from banks to the government, which is absent in the case of news shocks.

<sup>18</sup>The elasticity of taxes with respect to debt deviation, as well as debt-to-GDP and debt-to-total assets, are the same as before.

Figure 2 plots the response of the economy to the debt restructuring shock for the case of both lump-sum and distortionary taxes. The immediate impact on the financial sector after the shock is essentially the same for both cases. Banks lose some of their net worth and need to deleverage, which affects the supply of credit for producers and hence the capital stock. The key difference between the two cases is the reaction of labour markets to tax adjustments after the shock. In both cases, lower demand for labour from firms presses down the wage rate. However, in case of distortionary taxation, there is an opposing effect: with lower taxes, workers are now willing to supply more labour because their net earnings have increased. This effect turns out to be important.

Figure 2: Lump-sum vs. Distortionary taxes



Although the capital stock is depressed by the investment slump and the wage rate gets even lower than in the previous exercise, output goes up and is always above its steady state level. Likewise, the effect on consumption is also positive. Owing to the increase in output, it takes less time for investment to return to its pre-default levels. The increase in labour supply is substantially higher than the decrease in labour observed in Section 3.2.

Owing to the large effect on labour, agents' utility in this case does not mimic the path of consumption. Nevertheless, the net effect is clear: the debt restructuring shock leads to an increase in utility in the short run and no effects in the medium and long run (consumption is then larger, but so is labour supply, and both effects cancel out). The credit tightening has persistent effects on the economy, but these effects are not large enough to offset the positive impact of lower taxes.

The message from this section is that in an economy calibrated to match some key aggregate variables of the European Union, where financial frictions are modelled in a standard Gertler-Karadi-Kiyotaki way, the cost of austerity from distortionary taxes beats the cost of a financial disruption.

### 3.4 Government size

This extension studies the role of government size for the costs of fiscal austerity. We compare the baseline scenario, where government spending represents 22% of the total output and distortionary taxes are 32% of labour income to three other cases where we vary the size of government in terms of spending to GDP and labour taxes. The three cases are called, respectively, small, large and huge government and are displayed in the table below. The labour tax rate ( $\tau$ ) in the large government case is in line with many European economies.

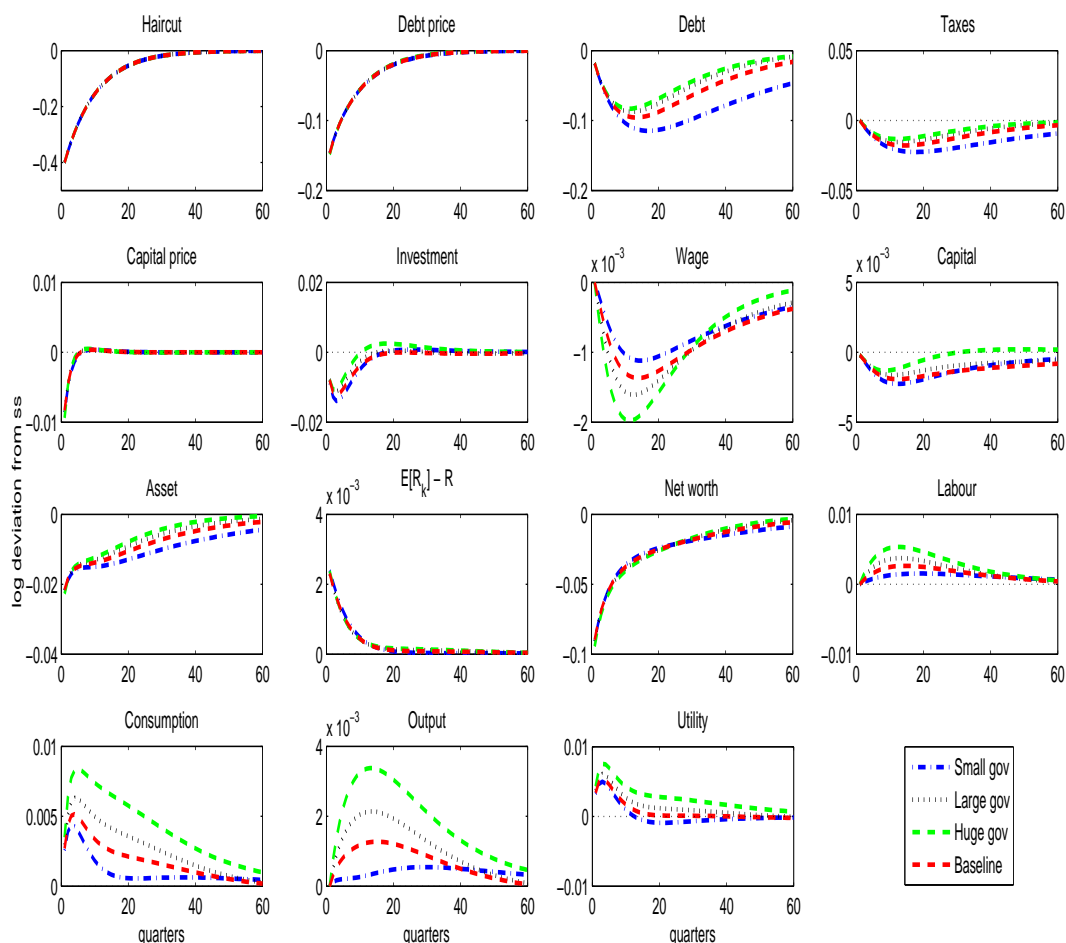
Table 2: Parameters for comparison between different government sizes

Model	$\tau$	G/Y
Baseline	32%	22%
Small government	20%	13%
Large government	42%	29%
Huge government	51%	35%

The results are in Figure 3. The behavior of debt price, banks' net worth and interest rates is very similar in all cases. The key difference is the reaction of labour supply. When the tax rate is large, a reduction in the tax rate generates a small decline in tax revenues.

Hence, a decrease in the tax burden allows for a larger fall in the tax rate, which leads to a large positive effect on labour supply. The behaviour of output depends crucially on the increase in labour supply.

Figure 3: Government size



As it turns out, financial disruption is a relevant cost for small governments, but as government size gets larger, the losses from financial disruption are dwarfed by reduction in the costs of austerity. In case of large government, the cumulated increase in output is substantially larger than the observed decrease in case of lump-sum taxes.

The message from this section is that the government size is crucial in the comparison

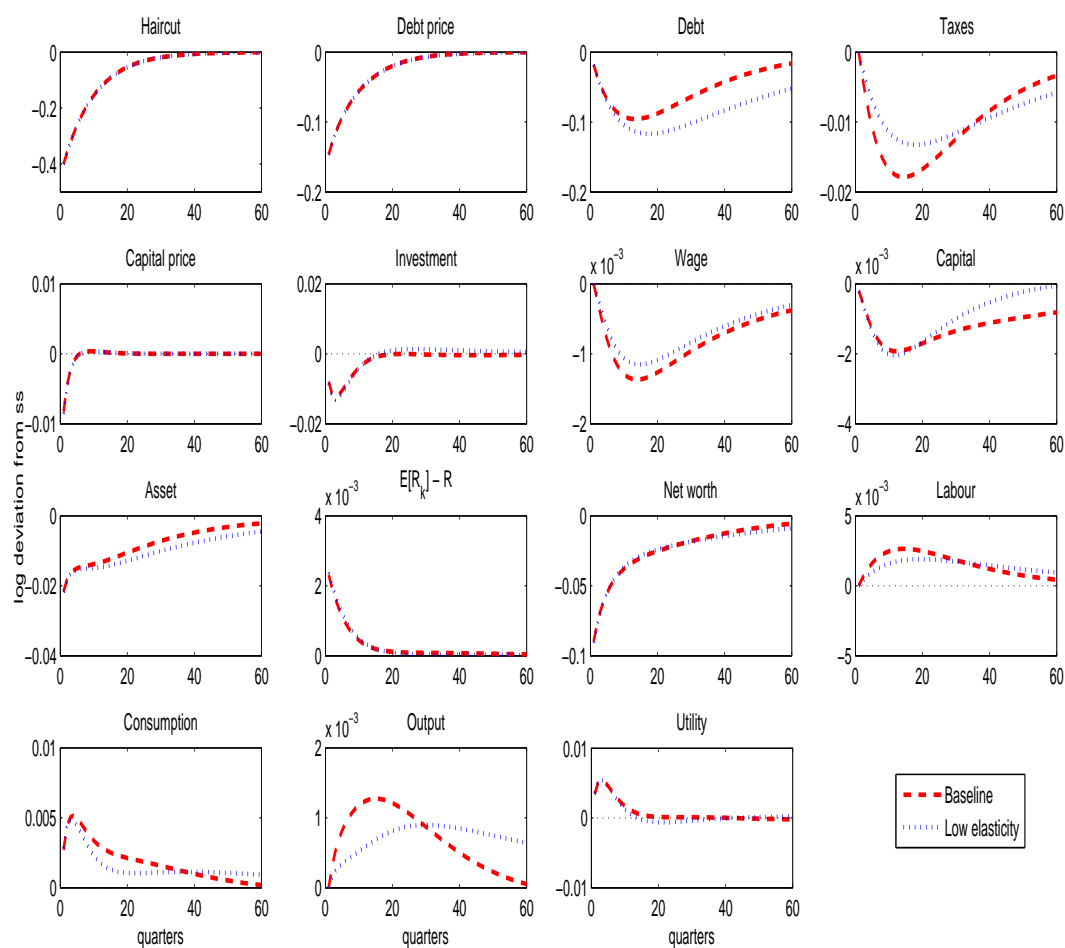
between the costs of fiscal austerity and the losses from financial disruption. The positive effects of debt restructuring found in Section 3.3 are stronger in case of large governments.

### 3.5 Extensions

#### 3.5.1 The effect of the tax elasticity

We first study the case of a lower elasticity of taxes with respect to debt deviation. In the baseline calibration, elasticity ( $\gamma$ ) equals 0.2. Here, it is set to 0.12. Figure 4 displays the results.

Figure 4: Distortionary taxes with lower tax elasticity



When taxes react less to a reduction in debt, labour supply does not increase so much in the short run. However, the low reaction of taxes in the short run implies that it takes much longer for the level of debt to converge back to its steady state, leading to larger tax cuts in the long run.

The capital stock recovers faster than in case of an initial higher tax cut. That is because the government needs to borrow less, so banks' balance sheets have more room for private securities. In contrast, the labour tax rate remains below its steady state level for a long time. As a result, output initially goes down, but more than makes up for the initial drop in the medium and long run.

In sum, a lower tax elasticity implies a lower tax cut following the debt restructuring shock and leads to less output and consumption in the short run but more output and consumption in the long run.

### 3.5.2 The effect of expansionary fiscal policy

So far we have considered a fiscal rule based on the nominal level of debt given by ((8)). We now assume instead that the government targets the deviation from steady state in terms of present real value of debt:

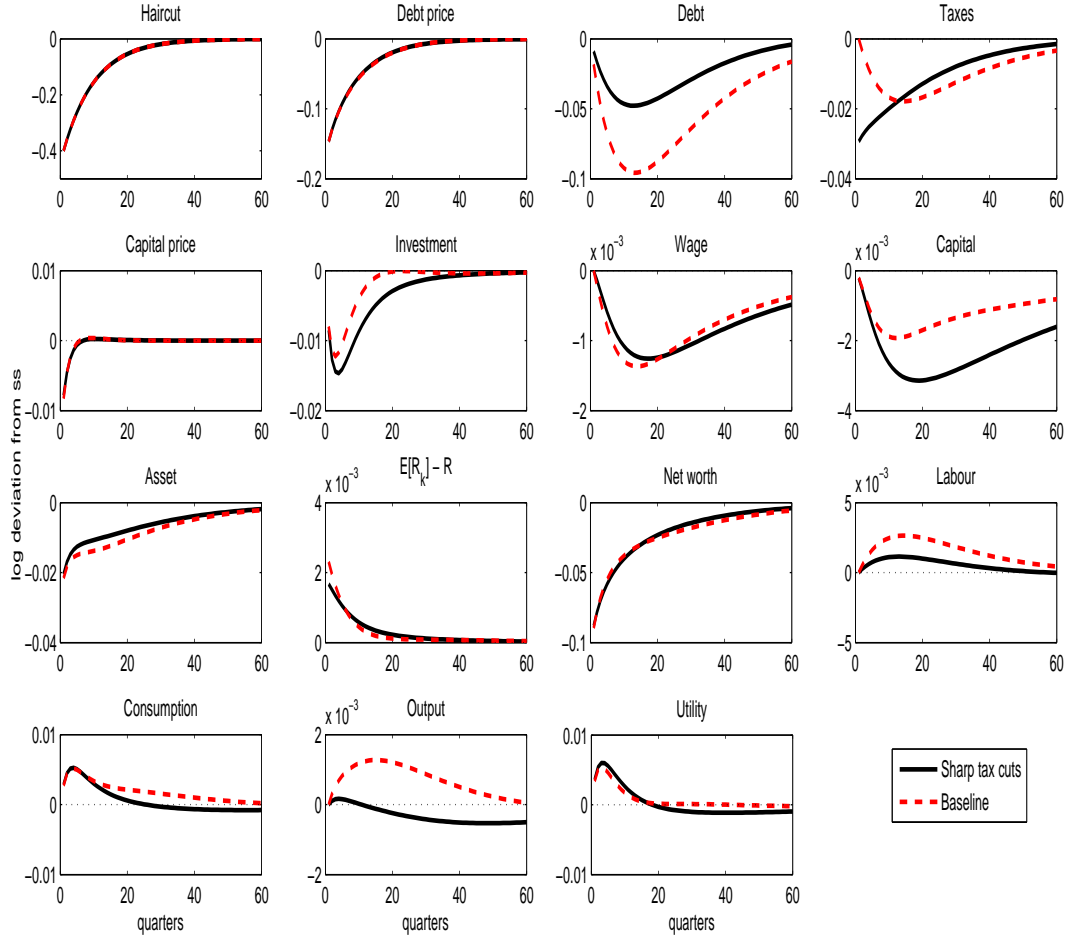
$$\tau_t = \tau_w [1 + \gamma(\chi_t B_t - \bar{\chi} \bar{B})]$$

Figure 5 displays the results, using  $\gamma = 0.2$  as well. The key difference is that the government now adjusts taxes instantly after the shock, reflecting the immediate fall in debt prices that follows the haircut. This fast cut in taxes prevents the debt stock from falling much.

Interestingly, that deepens the disruption in credit to the private sector and leads to a negative effect on the economy. Lower taxes imply a lower reduction in borrowing needs, which crowds out investment owing to the leverage constraint on banks. Perhaps surprisingly, labour supply does not react as much as before despite the larger tax cuts, because the lower levels of investment and capital imply a lower labour productivity. Output response turns out to be negative through the whole period.

Our previous results indicated that the financial disruption caused by a sovereign debt restructuring was compensated by the positive effect of tax cuts. This section adds an important qualification to those results. Expansionary fiscal policy following the default episode crowds out private investment and precludes economic recovery. The persistence

Figure 5: Alternative fiscal rule



of the effects on the financial sector implies the disruption in credit markets lasts for long, which more than offsets any positive effect from lower distortionary taxation.

The message of this section is that a debt restructuring episode ought to be followed by a conservative fiscal policy in order to maintain government borrowing needs at a low level, minimizing the disruption in credit to the private sector.

### 3.5.3 The model with a foreign creditor

In another extension, we now suppose that a constant fraction  $\kappa$  of total debt is in the hands of external creditors. Debt in the domestic economy  $B_t^d$  is thus:

$$B_t^d = (1 - \kappa)B_t$$

This is the amount of debt in bank's balance sheets, implying that:

$$Q_t K_{t+1} + \chi_t B_{t+1}^d = D_t + N_t$$

The remainder of the model is the same as before. The government does not distinguish between domestic and foreign bonds, as in Broner and Ventura (2011). We set kappa to 0.3.

Figure 6 shows that the introduction of foreign creditors reduces the costs of a debt restructuring. In this case, there is a transfer of foreign resources to the domestic economy, and nothing else changes. Hence the effects on output and welfare are even more positive than in the previous section. As before, we are once more abstracting from other costs of default, such as external penalties and sanctions, and possible second order effects due to foreign creditor's portfolio allocation following the shock.

#### 3.5.4 Second order effects

We also solved the model and simulated a debt restructuring episode using a second order approximation in order to capture non-linear effects that could be present in the analysis. The results change very little. In short, returns exhibit a more volatile path towards steady state, but the financial disruption from default is actually smaller than in our model. The investment drop reduces from around 1.25% in the baseline case to about 1%. On average, the disruption is around 80% to 90% of what it was using only a first order approximation. Results and figures are available upon request.

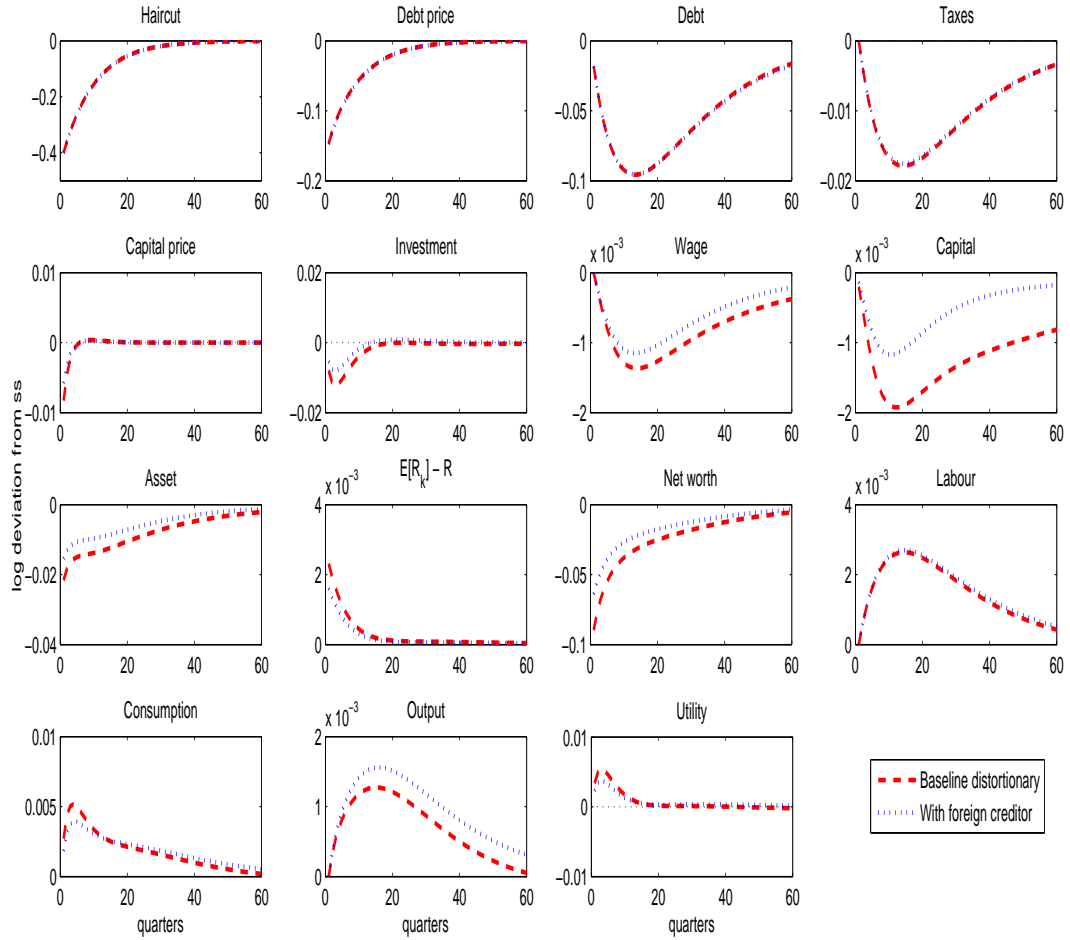
## 4 Final Remarks

Following the recent crisis in the highly indebted Euroarea economies, a large debate on the merits of fiscal austerity has erupted. On the one hand, fiscal tightenings would improve a government's finances and reduce the risk of sovereign default. On the other hand, such a contractionary fiscal policy would have negative effects in the economy, the dead weight losses from taxation being an important example of such costs. One key issue in this debate is thus the costs of sovereign default.

At the current stage, we do not know enough about those costs to formulate a clear policy prescription. This paper studies the impact of a sovereign debt restructuring episode on the economy through the credit intermediation channel. In our quantitative exercise,



Figure 6: Foreign creditor



the costs of debt restructuring turn out to be smaller than the costs of distortionary taxation that would be required to serve the whole debt. The latter exerted even larger effects in the case of sizeable governments.

There are (at least) two ways to interpret the results in this paper. One possible explanation is that the Gertler-Karadi-Kiyotaki framework is not capturing well the damage to the economy inflicted by financial disruption. However, models employing this type of financial friction have been successful in explaining several features of the data.<sup>19</sup> This

<sup>19</sup>Villa and Yang (2013) show the model fits the data well and the banking friction plays an important role in explaining cycles in the UK (see also Villa (2011)); Gertler and Karadi (2013) show that long scale asset purchases work in the model in a way that is broadly consistently with empirical evidence; Rannenberg (2013) builds on this framework and presents a model that explains much of the behavior of investment and cost of external finance in the great recession; Meeks, Nelson e Alessandri (2013) show that an extension of this framework captures some of the key features of an economy in which traditional and shadow banks interact; Bocola (2014) shows his model fits well the cyclical behavior of the leverage

interpretation would thus cast doubts on the foundations of a fast-growing literature.

The alternative conclusion is that the negative effects of sovereign debt restructuring on the economy through the banking sector are not large enough to offset the costs of fiscal austerity – although a tight fiscal policy in the wake of a debt restructuring episode is required for this result. Sovereign default is a transfer that tightens the banks leverage constraint but loosens a government constraint and the latter effect appears to be more important.

## References

- [1] Aersosa, W. and Coelho, C., (2013). *Using a DSGE Model to Assess the Macroeconomic Effects of Reserve Requirements in Brazil*. Banco Central do Brasil Working Paper Series 303.
- [2] Andritzky, J., (2012). *Government Bonds and their Investors: What are the facts and do they matter?*. IMF Working Paper 158.
- [3] Bank for International Settlements, (2011). *The impact of sovereign credit risk on bank funding conditions*. CFGS Papers 43.
- [4] Bernanke, B. and Gertler, M., (1989). *Agency Costs, Net Worth, and Business Fluctuations*. American Economic Review 79, 14-31.
- [5] Bernanke, B., Gertler, M. and Gilchrist, S., (1999). *The Financial Accelerator in a quantitative Business Cycle Framework*. In: J. B. Taylor and M. Woodford (ed.), Handbook of Macroeconomics, edition 1, volume 1, chapter 21, 1341-1393 Elsevier.
- [6] Bocola, L., (2014). *The Pass-Through of Sovereign Risk*. Manuscript, University of Pennsylvania.
- [7] Boissay, F., Collard, F. and Smets, F., (2013). *Booms and systemic banking crises*. European Central Bank Working Paper Series 1514.
- [8] Bolton, P. and Jeanne, O., (2011). *Sovereign default risk and bank fragility in financially integrated economies*. NBER Working Paper Series 16899.
- [9] Borensztein, E. and Panizza, U., (2008). *The Costs of Sovereign Default*. IMF Working Papers 238.

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constraint and fluctuations in sovereign default risk.

- [10] Broner, F. and Ventura, J., (2011). *Globalization and Risk Sharing*. Review of Economic Studies 78, 49-82.
- [11] Brutti, F., (2011). *Sovereign defaults and liquidity crises*. Journal of International Economics 84, 65-72.
- [12] Buiter, W., (2014). *Why fiscal sustainability matters*. VoxEU. Retrieved from <http://www.voxeu.org/article/why-fiscal-sustainability-matters>
- [13] Bulow, J. and Rogoff, K., (1989). *Sovereign Debt: Is to forgive to forget?*. The American Economic Review 79, 43-50.
- [14] Carlstrom, C. and Fuerst, T., (1997). *Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis*. The American Economic Review 87, 893-910.
- [15] Correia, I., De Fiore, F., Teles, P. and Tristani, O., (2014). *Credit Spreads and Credit Policies*. Working Paper.
- [16] Corsetti, G., Kuester, K., Meier, A. and Mueller, G., (2013). *Sovereign risk, fiscal policy and macroeconomic stability*. The Economic Journal 123, 99-132.
- [17] Corsetti, G., Kuester, K., Meier, A. and Mueller, G., (2014). *Sovereign risk and belief-driven fluctuations in the Euro Area*. Journal of Monetary Economics 61, 53-73.
- [18] Curdia, V. and Woodford, M., (2008). *Credit Frictions and Optimal Monetary Policy*. BIS Working Papers 278.
- [19] De Bruyckere, V., Gerhardt, M., Schepens, G. and Vennet, R., (2012). *Bank/Sovereign Risk Spillovers in the European Debt Crisis*. European Banking Center Discussion Paper 2012-021.
- [20] Dedola, L., Karadi, P. and Lombardo, G., (2013). *Global implications of national unconventional policies*. Journal of Monetary Economics 60, 66-85.
- [21] Eaton, J. and Gersovitz, M., (1981). *Debt with Potential Repudiation: Theoretical and Empirical Analysis*. The Review of Economic Studies 48, 289-309.
- [22] Gennaioli, N., Martin, A. and Rossi, S., (2013). *Banks, Government Bonds, and Default: What do the data say?*. Economics Working Papers 1378, Department of Economics and Business, Universitat Pompeu Fabra.

- [23] Gertler, M. and Karadi, P., (2011). *A model of unconventional monetary policy*. Journal of Monetary Economics 58, 17-34.
- [24] Gertler, M. and Karadi, P., (2013). *QE 1 vs. 2 vs. 3...: A Framework for Analysing Large-Scale Asset Purchases as a Monetary Policy Tool*. International Journal of Central Banking 9, S1.
- [25] Gertler, M. and Kiyotaki, N., (2010). *Financial Intermediation and Credit Policy in Business Cycle Analysis*. in B. Friedman and M. Woodford (ed.), Handbook of Monetary Economics, edition 1, volume 3.
- [26] Gertler, M., Kiyotaki, N. and Queralto, A., (2012). *Financial Crises, Bank Risk Exposure and Government Financial Policy*. Journal of Monetary Economics 59, 14-34.
- [27] Greenwood, J., Hercowitz, Z. and Huffman, G., (1988). *Investment, Capacity Utilization and the Business Cycle*. The American Economic Review 78, 402-417.
- [28] Guerrieri, L., Iacoviello, M. and Minetti, R., (2012). *Banks, sovereign debt and the international transmission of business cycles*. NBER Working Paper 18303.
- [29] Kiyotaki, N., and Moore, J., (1997). *Credit Cycles*. Journal of Political Economy 105, 211-248.
- [30] Lojsch, D., Rodriguez-Vives, M., and Slavik, M., (2011). *The size and composition of government debt in the euro area*. European Central Bank Occasional Paper Series 132.
- [31] Meeks, R., Nelson, B. and Alessandri, P., (2013). *Shadow banks and macroeconomic instability*. Banca d'Italia Temi di discussione (Working papers) 939.
- [32] Mody, A., (2014). *The ghost of Deauville*. VoxEU. Retrieved from <http://www.voxeu.org/article/ghost-deauville>
- [33] Panizza, U., Sturzenegger, F., and Zettelmeyer, J., (2009). *The Economics and Law of Sovereign Debt and Default*. Journal of Economic Literature 47, 651-698.
- [34] Pâris, P., and Wyplosz, C., (2014). *The PADRE plan: Politically Acceptable Debt Restructuring in the Eurozone*. VoxEU. Retrieved from <http://www.voxeu.org/article/padre-plan-politically-acceptable-debt-restructuring-eurozone>

- [35] Popov, A., and Van Horen, N., (2013). *The impact of sovereign debt exposure on bank lending: evidence from the European debt crisis*. DNB Working Paper 382.
- [36] Rannenberg, A., (2013). *Bank leverage cycles and the external finance premium*. Deutsche Bundesbank Discussion Paper 55.
- [37] Takamura, T., (2013). *A general equilibrium model with banks and default on loans*. Bank of Canada Working Paper 2013-3.
- [38] Thompson, C., (2013, 23 December). *Europe banks overexposed to domestic debt*. Financial Times.
- [39] Trabant, M., and Uhlig, H., (2011). *The Laffer curve revisited*. Journal of Monetary Economics 58, 305-327.
- [40] Villa, S., (2013). *Financial Frictions in the Euro Area: A Bayesian Assessment*. European Central Bank Working Paper Series 1521.
- [41] Villa, S. and Yang, J., (2011). *Financial intermediaries in an estimated DSGE model for the UK*. In: J. Chadha and S. Holly (ed.), Interest Rates, Prices and Liquidity: Lessons from the Financial Crisis, Cambridge University Press.

## A Banks allocation problem

Using the conjecture for the value function form suggested in (21), we can write the Lagrangian for the banks' maximization problem. Banks will maximize its terminal value (17) subject to the constraint (18).

$$\mathcal{L} = \nu_t Q_t K_{t+1} + \zeta_t \chi_t B_{t+1} + \eta_t N_t - \mu_t [\lambda(Q_t K_{t+1} + \zeta_t \chi_t B_{t+1}) - \nu_t Q_t K_{t+1} + \zeta_t \chi_t B_{t+1} + \eta_t N_t]$$

That can be simplified to

$$\mathcal{L} = [\nu_t Q_t K_{t+1} + \zeta_t \chi_t B_{t+1} + \eta_t N_t] (1 + \mu_t) - \mu_t \lambda (Q_t K_{t+1} + \zeta_t \chi_t B_{t+1})$$

where  $\mu_t$  is the Lagrangian multiplier with respect to the incentive constraint. The first order conditions for  $K_{t+1}$ ,  $B_{t+1}$  and  $\mu_t$  are:

$$\nu_t (1 + \mu_t) = \mu_t \lambda$$

$$\zeta_t (1 + \mu_t) = \mu_t \lambda$$

$$\lambda(Q_t K_{t+1} + \zeta_t \chi_t B_{t+1}) = \nu_t Q_t K_{t+1} + \zeta_t \chi_t B_{t+1} + \eta_t N_t$$

The first and second FOCs are symmetric. On the left hand side is the marginal benefit for the bank from expanding each of the assets components and on the right hand side the marginal cost of tightening the incentive constraint by  $\lambda$ . The last FOC is the incentive constraint itself.

The constraint binds ( $\mu_t > 0$ ) only if the marginal discounted value of both the banks assets is positive. In case the constraint binds, the FOCs for securities and bonds show that the discounted marginal value for each of those components should be equal. It means that in the margin, the bank is indifferent from investing resources in government bonds or private securities.

Now we show that the conjectured form of the value function holds. From (19), (20) and (21) we have:

$$\nu_t Q_t K_{t+1} + \zeta_t \chi_t B_{t+1} + \eta_t N_t = E_t \beta \Lambda_{t,t+1} \{ (1-\theta) N_{t+1} + \theta [\nu_{t+1} Q_{t+1} K_{t+2} + \zeta_{t+1} \chi_{t+1} B_{t+2} + \eta_{t+1} N_{t+1}] \}$$

Using the definitions of  $\varpi_t$  and  $\phi_t$ , we simplify the above equation to:

$$LHS = E_t \beta \Lambda_{t,t+1} \{ (1-\theta) N_{t+1} + \theta N_{t+1} [\nu_{t+1} \varpi_{t+1} + \zeta_{t+1} (\phi_{t+1} - \varpi_{t+1}) + \eta_{t+1}] \}$$

Inserting the definition of  $\Omega_t$  we get:

$$LHS = E_t \beta \Lambda_{t,t+1} \Omega_{t+1} N_{t+1}$$

Substituting for  $N_{t+1}$ :

$$LHS = E_t \beta \Lambda_{t,t+1} \Omega_{t+1} [(R_{kt+1} - R_{t+1}) Q_t K_{t+1} + (R_{bt+1} - R_{t+1}) \chi_t B_{t+1} + R_{t+1} N_t]$$

Comparing the terms for  $K_{t+1}$ ,  $B_{t+1}$  and  $N_t$ , we see that the conjecture holds if (23), (24) and (22) hold.

## B Parameters and calibrated values

Households		
$\beta$	0.99	Intertemporal discount rate
$\sigma$	1	Intertemporal elasticity of substitution
$\psi$	1	Labour weight in utility
$\varphi$	3	Inverse elasticity of labour supply
Financial Intermediaries		
$\lambda$	0.375	Fraction of assets that can be diverted
$\omega$	0.002	New banks initial capital transfer
$\theta$	0.97	Banks survival rate
Firms		
$\alpha$	0.30	Capital fraction in production function
$\delta$	0.025	Exogenous depreciation rate
$\eta_i$	1.7	Inverse elasticity of net investment with respect to capital price
Government		
$\frac{G}{\bar{Y}}$	0.22	Steady state government expenditure
$\gamma$	0.2	Elasticity of taxes with respect to debt deviations from steady state
$\frac{B}{\bar{Y}}$	0.85	Steady state government debt
$\mu$	0.056	Fraction of debt maturing each period
Shocks		
$\rho_\iota$	0.9	Haircut persistence parameter
$\sigma_\iota$	0.4	Haircut standard deviation