

Stabilization Constraints from different-average Public Debt Levels in a Monetary Union with Country-size Asymmetry

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Abstract

In the sequence of the recent financial and economic crisis, the recent public debt accumulation is expected to hamper considerably business cycle stabilization, by enlarging the budgetary consequences of the shocks. This paper analyses how the average level of public debt in a monetary union shapes optimal discretionary fiscal and monetary stabilization policies and affects stabilization welfare.

We use a two-country micro-founded New-Keynesian model, where a benevolent central bank and the fiscal authorities play discretionary policy games under different union-average debt-constrained scenarios.

We find that high debt levels shift monetary policy assignment from inflation to debt stabilization, making cooperation welfare superior to non-cooperation. Moreover, when average debt is too high, welfare moves directly (inversely) with debt-to-output ratios for the union and the large country (small country) under cooperation. However, under non-cooperation, higher average debt levels benefit only the large country.

Keywords: Monetary union; optimal fiscal and monetary policies; asymmetric countries; public debt. *JEL codes:* E52; E61; E62; E63

1 Introduction

In the sequence of the recent financial and economic crisis, the level of government indebtedness has increased considerably in many European and Monetary

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Union (EMU) countries. Besides i) undermine the sustainability of public finances and ii) amplify steady-state distortions relative to the efficient outcome, high public debt levels iii) directly hamper business cycle stabilization through creating incentives to bias monetary policy towards debt-stabilization concerns. Naturally, the latter risk is expected to be more effective under sufficiently large debt-to-output ratios. However, debt consequences on stabilization costs are not clearly unambiguous. Rising high public debt levels, by assigning a growing role for a central bank towards debt stabilization, may enlarge the scope of fiscal policy to stabilize the business cycle. In turn, the rise of the public debt levels, when they are small enough and monetary policy is still assigned to its traditional price stabilization task, may cause higher stabilization costs as it may force fiscal policy to accrued debt stabilization efforts. Moreover, the study of the stabilization consequences of higher government indebtedness is particularly relevant in a monetary union where national fiscal policymakers of different-size countries interact strategically with a single monetary authority.

The stabilization impact of different government debt levels were examined by Leith and Wren-Lewis (2007a), Stehn and Vines (2008a) and Blake and Kirsanova (2010a) but in a closed economy context. This paper analyses how the average level of public debt in a monetary union shapes optimal discretionary fiscal and monetary stabilization policies and affects the welfare of each country-member.

We use a two-country micro-founded New-Keynesian macroeconomic model with monopolistic competition and sticky prices, in line with that developed by Beetsma and Jensen (2004, 2005). As in Leith and Wren-Lewis (2007a, 2007b), the model allows for fiscal policy to have demand and supply-side effects, by considering as fiscal policy instruments the home-biased public consumption and the tax rate, under different union-average debt-constrained scenarios. We assume that the monetary authority - maximizing the union-wide welfare - and the fiscal authorities - maximizing their national counterparts - engage in discretionary policy games. Optimal solutions are computed numerically using appropriate algorithms to mimic cooperative outcomes and also to reflect the different timing structures of the (non-cooperative) policy games: Nash, monetary leadership and fiscal leadership. We follow the methodology developed in the recent work of Kirsanova and co-authors (Blake and Kirsanova, 2010b, for a closed-economy setup, and Kirsanova et al., 2005, for an open-economy setup).

Preliminary numerical results indicate that, monetary policy shifts from an inflation-stabilization assignment to a debt-stabilization assignment, when debt becomes high enough and that non-cooperation dominates cooperation in a low-debt monetary union but the reverse occurs in a high-debt monetary union.

Furthermore, under policy cooperation, when large (small) steady-state debt-to-output ratios increase symmetrically in both countries, welfare improves (deteriorates) for the whole union and for the large country while deteriorating (improving) for the small country.

In turn, under non-cooperation (Nash, monetary leadership or fiscal leadership) and for realistic debt levels, only the large country is able to benefit from (symmetrically) higher levels of government indebtedness. The small country and the union as a whole face higher welfare stabilization costs, the higher debt-to-output levels are.

The paper is organized as follows. In Section 2 we develop the setup for policy analysis. In Section 3 we perform policy analysis related with dynamic

responses and welfare evaluation under different debt levels. Section 4 concludes.

2 Setup for Policy Analysis

The model developed by Beetsma and Jensen (2004, 2005) is extended to capture country-size asymmetry, to allow for a more generic case of cross-country consumption elasticity and to include *different fiscal policy scenarios*.

The monetary union is modelled as a closed area with two countries, H (Home) and F (Foreign), populated by a continuum of agents $\in [0, 1]$. The relative dimension of country i ($i = H, F$) is $n_i \in (0, 1)$, with $n_H + n_F = 1$. While subject to idiosyncratic shocks, the countries are assumed to have identical economic structures and each one is characterized by two private sectors - households and firms -, one fiscal authority, and is subject to a common monetary policy.

To start, we address the optimization problem of households and firms, living at country H (equivalent to that at F). The next step is to describe the policy environment which includes the presentation of the policy instruments, the equilibrium conditions and the policy objectives. The remainder of this section characterizes the policy games and presents the benchmark calibration.

2.1 Households

The j -household seeks to maximize the following lifetime utility (U_0^j).

$$U_0^j = E_0 \sum_{t=0}^{\infty} \beta^t \left[u \left(C_t^j, \bar{C}_t^H \right) + V \left(G_t^H \right) - v \left(L_t^j \right) \right] \quad (1)$$

where

$$u \left(C_t^j, \bar{C}_t^H \right) = \frac{\sigma}{\sigma-1} \left(C_t^j \right)^{\frac{\sigma-1}{\sigma}} \left(\bar{C}_t^H \right)^{\frac{1}{\sigma}}$$

$$V \left(G_t^H \right) = \delta \frac{\psi}{\psi-1} \left(G_t^H \right)^{\frac{\psi-1}{\psi}}$$

$$v \left(L_t^j \right) = \frac{d}{1+\eta} \left(L_t^j \right)^{1+\eta}$$

with C_t^j , G_t^i and L_t^j denoting, respectively, private consumption, *per capita* public consumption on domestically produced goods and hours of work. \bar{C}_t^i is an exogenous disturbance which affects the demand for consumption goods and C^j is a real consumption Dixit-Stiglitz index defined as

$$C^j \equiv \left[n_H^{\frac{1}{\rho}} \left(C_H^j \right)^{\frac{\rho-1}{\rho}} + n_F^{\frac{1}{\rho}} \left(C_F^j \right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \quad (2)$$

where ρ the elasticity of substitution between H and F consumption baskets, C_H^j and C_F^j are consumption sub-indexes of the continuum of differentiated goods

produced, respectively, in country H and F

$$C_{H,t}^j \equiv \left[\left(\frac{1}{n_H} \right)^{\frac{1}{\theta}} \int_0^{n_H} c_t^j(h)^{\frac{\theta-1}{\theta}} dh \right]^{\frac{\theta}{\theta-1}} ; C_{F,t}^j \equiv \left[\left(\frac{1}{n_F} \right)^{\frac{1}{\theta}} \int_{n_H}^1 c_t^j(f)^{\frac{\theta-1}{\theta}} df \right]^{\frac{\theta}{\theta-1}} \quad (3)$$

and θ is the elasticity of substitution between goods produced in each country.

Maximization of (1) is subject to a sequence of budget constraints of the form

$$P_t C_t^j + E_t \left(Q_{t,t+1} D_{t+1}^j \right) = W_t(j) L_t^j + \int_0^{n_H} \Pi_t^j(k) dk - P_t T_t^H + D_t^j \quad (4)$$

where P is the consumption-based price index defined below, $W(j)$ is the nominal wage rate of labour of type j , $\Pi^j(k)$ is the share of profits of domestic firm k going to household j in country H and T^H is a *per capita* lump sum tax. Household j has access to a complete set of state-contingent securities that span all possible states of nature and are traded across the union. D_{t+1}^j denotes the nominal payoff of a portfolio of state-contingent securities, purchased by the j -household at date t , while $Q_{t,t+1}$ is the stochastic discount factor for one-period ahead nominal payoffs, common across countries.

Assuming no trade barriers and given the structure of preferences, purchasing power parity holds, and the underlying consumption-based price index (P_t) is defined as

$$P_t \equiv \left[n_H P_{H,t}^{1-\rho} + n_F P_{F,t}^{1-\rho} \right]^{\frac{1}{1-\rho}}, \quad (5)$$

while the country-specific price indexes P_H and P_F are given by

$$P_{H,t} \equiv \left[\frac{1}{n_H} \int_0^{n_H} p_t(h)^{1-\theta} dh \right]^{\frac{1}{1-\theta}} ; P_{F,t} \equiv \left[\frac{1}{n_F} \int_{n_H}^1 p_t(f)^{1-\theta} df \right]^{\frac{1}{1-\theta}} \quad (6)$$

where $p(h)$ and $p(f)$ are the prices of typical goods h and f produced in H and F, respectively.

The problem of the representative household can be split into an intertemporal and an intratemporal problem. In regards to the household's intratemporal problem, it requires choosing the allocation of a given level of expenditure across the differentiated goods to maximize the consumption index, C^j . Plugging into the appropriate output aggregators the resulting individual demands and the optimal government spending allocation across domestically produced goods, we obtain the national aggregate demands, Y^H and Y^F ,

$$Y_t^H = \left(\frac{P_{H,t}}{P_t} \right)^{-\rho} C_t^W + G_t^H \quad (7H)$$

$$Y_t^F = \left(\frac{P_{F,t}}{P_t} \right)^{-\rho} C_t^W + G_t^F \quad (7F)$$

where the union-wide consumption, C^W , is defined as $C^W \equiv \int_0^1 C^j dj$, and

$$\left(\frac{P_H}{P}\right)^{\rho-1} = n_H + n_F T^{1-\rho}; \quad \left(\frac{P_F}{P}\right)^{\rho-1} = n_H T^{\rho-1} + n_F \quad (8)$$

The variable T stands for the terms-of-trade, defined as the relative price of the F-bundle of goods in terms of the H-bundle of goods ($T \equiv P_F/P_H$). According to (8), changes in the terms-of-trade imply a larger response in a country's aggregate demand the smaller the size of the country, *i.e.*, the larger the degree of openness.

As for the household's intertemporal problem, the household chooses the set of processes $\{C_t^j, L_t^j; D_{t+1}^j\}_{t=0}^\infty$, taking as given all the other processes and the initial wealth, as to maximize the intertemporal utility function (1) subject to (4). Solution for this problem yields the familiar Euler equation

$$u_c(C_t^j, \bar{C}_t^H) = \beta(1+i_t) E_t \left\{ \left(\frac{P_t}{P_{t+1}}\right) u_c(C_{t+1}^j, \bar{C}_{t+1}^H) \right\}, \quad (9)$$

where $1+i_t = \frac{1}{E_t Q_{t,t+1}}$ is the gross risk-free nominal interest rate. Moreover, assuming that the initial state-contingent distribution of nominal bonds is such that the life-time budget constraints of all households are identical, the risk-sharing condition implies that

$$u_c(C_t^H, \bar{C}_t^H) = u_c(C_t^F, \bar{C}_t^F) \quad (10)$$

Finally, the labour supply decision determines that the real wage for labour type j is given by

$$\frac{W_t(j)}{P_t} = \mu_{w,t}^H * \frac{v_L(L_t^j)}{u_c(C_t^j, \bar{C}_t^H)} \quad (11)$$

where $\mu_{w,t}^H \geq 1$ is an exogenous H-specific wage markup that is used as a device to introduce the possibility of "pure cost-push shocks" that affects the equilibrium price behaviour but does not change the efficient output, as in Benigno and Woodford (2004, 2005).

2.2 Firms

There are a continuum of firms in country H and in country F . The production function for the differentiated consumption good y , indexed by $h \in [0, n_H]$ in country H and by $f \in [n_H, 1]$ in country F, is described, for $y(h)$, by

$$y_t(h) = a_t^H L_t(h) \quad (12)$$

where a_t^H is an exogenous H-specific technology shock, common to all H-firms, and $L_t(h)$ is the firm-specific labour input offered by a continuum of H-households, indexed in the unit interval. In a symmetric equilibrium, the work effort chosen by the household (L_t^h) equals the aggregate labour input ($L_t(h)$).

Firms are assumed to set prices on a staggered basis, as in Calvo (1983).

Each period, a randomly selected fraction of firms at H $(1 - \alpha^H)$ have the opportunity to change their prices, independently of the time that has elapsed since the last price-resetting, while the remaining firms keep the prices of the previous period. If it has the chance to reset prices in period t , an optimizing h -firm will set $p_t^o(h)$ in order to maximize the expected future profits, subject to the demand for its product and the production technology. The first order condition for this optimizing wage-taker firm can be expressed as

$$\left(\frac{p_t^o(h)}{P_{H,t}}\right)^{1+\theta\eta} = \frac{\frac{\theta}{\theta-1} E_t \sum_{s=t}^{\infty} (\alpha^H \beta)^{s-t} \mu_{w,s}^H (1 - \zeta^H) v_y(Y_s^H; a_s^H) \left(\frac{P_{H,s}}{P_{H,t}}\right)^{\theta(1+\eta)} Y_s^H}{E_t \sum_{s=t}^{\infty} (\alpha^H \beta)^{s-t} (1 - \tau_s^H) u_c(C_s^H, \bar{C}_s^H) \left(\frac{P_{H,s}}{P_{H,t}}\right)^{\theta-1} \left(\frac{P_{H,s}}{P_s}\right) Y_s^H} \quad (13)$$

where $p_t^o(h)$ still applies at s , τ_s^H is a proportional tax rate on sales with the non-zero steady-state level $\bar{\tau}^H$, and ζ^H is an employment subsidy fully financed by lump sum taxes that, removing average monopolistic and tax rate distortions, ensures the efficiency of the steady-state output level.¹ The price index P_H evolves according to the law of motion

$$P_{H,t}^{1-\theta} = \alpha^H P_{H,t-1}^{1-\theta} + (1 - \alpha^H) p_t^o(h)^{1-\theta} \quad (14)$$

2.3 Policy Environment

In this section, we describe the instruments and constraints for the monetary and fiscal policies and present a set of meaningful objective functions facing the policy authorities. These policy functions have a twofold purpose: (i) to enable the derivation of optimal discretionary policy rules across several regimes of monetary and fiscal policies interactions and (ii) to assess the welfare impacts of the different policy regimes.

2.3.1 Policy instruments and constraints

The monetary authority sets a common nominal interest rate, i_t , for the union. As for fiscal policy, we assume that the home-biased government spending (G^H) and the sales tax rate (τ^H) are the stabilization fiscal policy instruments and, thus, fiscal policy encompasses demand and supply-side effects. In turn, lump-sum taxes (T^H) only adjust to fully accommodate an employment subsidy (ζ^H) and the government inter-temporal solvency condition appears as an additional binding constraint to the set of possible equilibrium paths of the endogenous variables. The budget constraints for the fiscal authorities can be written as

$$B_t^H = (1+i_{t-1}) B_{t-1}^H + P_{H,t} G_t^H - \tau_t^H P_{H,t} Y_t^H \quad (15H)$$

$$B_t^F = (1+i_{t-1}) B_{t-1}^F + P_{F,t} G_t^F - \tau_t^F P_{F,t} Y_t^F \quad (15F)$$

where B_t^H and B_t^F represent the *per capita* nominal government debt of country H and F, respectively.²

¹Following Leith and Wren-Lewis (2007a, 2007b), we use this employment subsidy as a device to eliminate linear terms in the social welfare function without losing the possibility of using the sales tax rates as fiscal policy instruments.

²With asset markets clearing only at the monetary union level, the sole public sector inter-temporal budget constraint is the union-wide consolidated debt. However, in the context of

Equivalently,

$$b_t^i = (1 + i_t) \left(b_{t-1}^i \frac{P_{t-1}}{P_t} + \frac{P_{i,t}}{P_t} G_t^i - \tau_t^i \frac{P_{i,t}}{P_t} Y_t^i \right), \quad i = H, F \quad (16)$$

where the variable $b_t^i \equiv \frac{(1+i_t)B_t^i}{P_t}$ denotes the real value of debt at maturity in *per capita* terms.

2.3.2 Equilibrium Conditions

To solve for the optimal policy, authorities have to take into account both the private sector behaviour as well as the budget constraints, described above. These conditions can be log-linearized and written in gap form as

$$E_t c_{t+1}^w = c_t^w + \sigma (i_t - E_t \pi_{t+1}^w) \quad (17)$$

$$y_t^H = s_c \rho n_F q_t + (1 - s_c) g_t^H + s_c c_t^w \quad (18H)$$

$$y_t^F = -s_c \rho n_H q_t + (1 - s_c) g_t^F + s_c c_t^w \quad (18F)$$

$$\pi_t^H = k^H \left[(1 + s_c \rho \eta) n_F q_t + \frac{1 + s_c \sigma \eta}{\sigma} c_t^w + (1 - s_c) \eta g_t^H + \frac{\bar{\tau}^H}{(1 - \bar{\tau}^H)} \tau_t^H \right] + \beta E_t \pi_{t+1}^H \quad (19H)$$

$$\pi_t^F = k^F \left[-(1 + s_c \rho \eta) n_H q_t + \frac{1 + s_c \sigma \eta}{\sigma} c_t^w + (1 - s_c) \eta g_t^F + \frac{\bar{\tau}^F}{(1 - \bar{\tau}^F)} \tau_t^F \right] + \beta E_t \pi_{t+1}^F \quad (19F)$$

$$q_t = q_{t-1} + \pi_t^F - \pi_t^H - (\tilde{T}_t - \tilde{T}_{t-1}) \quad (20)$$

$$\hat{b}_t^H = \frac{1}{\beta} \left\{ \hat{b}_{t-1}^H - \pi_t + n_F (1 - \beta) q_t + \frac{\bar{Y}}{b} [(1 - s_c) g_t^H - \bar{\tau}^H y_t^H - \bar{\tau}^H \tau_t^H] \right\} + i_t + \hat{\varepsilon}_{b^H,t} \quad (21H)$$

$$\hat{b}_t^F = \frac{1}{\beta} \left\{ \hat{b}_{t-1}^F - \pi_t - n_H (1 - \beta) q_t + \frac{\bar{Y}}{b} [(1 - s_c) g_t^F - \bar{\tau}^F y_t^F - \bar{\tau}^F \tau_t^F] \right\} + i_t + \hat{\varepsilon}_{b^F,t} \quad (21F)$$

where

$$k^{H,F} \equiv \frac{(1 - \alpha^H)(1 - \alpha^H \beta)}{\alpha^H (1 + \theta \eta)}; \quad k^{F,H} \equiv \frac{(1 - \alpha^F)(1 - \alpha^F \beta)}{\alpha^F (1 + \theta \eta)},$$

$\hat{\varepsilon}_{b^H,t}$ and $\hat{\varepsilon}_{b^F,t}$ are composite shocks defined as

$$\begin{aligned} \hat{\varepsilon}_{b^H,t} &= \tilde{i}_t + \frac{1}{\beta} \left\{ n_F (1 - \beta) \tilde{T}_t + \frac{\bar{Y}}{b} [(1 - s_c) \tilde{G}_t^H - \bar{\tau}^H \tilde{Y}_t^H + (1 - \bar{\tau}^H) \tilde{\mu}_{w,t}^H] \right\} \\ \hat{\varepsilon}_{b^F,t} &= \tilde{i}_t + \frac{1}{\beta} \left\{ -n_H (1 - \beta) \tilde{T}_t + \frac{\bar{Y}}{b} [(1 - s_c) \tilde{G}_t^F - \bar{\tau}^F \tilde{Y}_t^F + (1 - \bar{\tau}^F) \tilde{\mu}_{w,t}^F] \right\} \end{aligned}$$

a monetary union with an institutional arrangement like the EMU, there are arguments to impose the verification of this inter-temporal budget constraint at the national levels.

and where lower case variables refer to variables in gaps. For a generic variable, X_t , its gap is defined as $x_t = \widehat{X}_t - \widetilde{X}_t$, where \widehat{X}_t and \widetilde{X}_t denote, respectively, their effective and efficient values, in log-deviations from the zero-inflation efficient steady state (see, section 2.3.3, below).³ A "union-wide" variable, X^w , is defined as $X^w \equiv nX^H + (1-n)X^F$.

Equation (17) refers to the IS equation, written in terms of the union consumption⁴ and nominal interest-rate gaps. Equations (18H) and (18F) are country-specific aggregate demand equations, with s_c being the steady-state consumption share of output and q_t being the terms-of-trade gap ($\equiv \widehat{T}_t - \widetilde{T}_t$). These three equations constitute the aggregate demand-side block of the model and were derived from log-linearization of equations (7H), (7F), (8), (9) and (10).

The aggregate supply-side block of the model was obtained from the log-linear approximation of equations (13) and (14), as well as from their Foreign counterparts, around the efficient steady state equilibrium. Equations (19H) and (19F) are open-economy pure New-Keynesian aggregate supply (AS) curves. Positive gaps on the terms-of-trade, consumption and public spending have inflationary consequences at H: an increase in the demand for H-produced goods leads to more work effort, and, thus, raises marginal costs. Moreover, the positive gaps on the terms-of-trade and on the consumption exert an additional inflationary pressure as they reduce the marginal utility of nominal income for households. The efficient tax rate $\widetilde{\tau}_t^i$, used to compute the tax rate gap ($\tau_t^i = \widehat{\tau}_t^i - \widetilde{\tau}_t^i$) in country i , is defined as the tax rate required to fully offset the impact of an idiosyncratic "cost-push" (wage markup) shock.⁵ Equation (20) is the terms-of-trade gap's identity, reflecting the inflation differential and the one-period change in the efficient level of the terms-of-trade ($\widetilde{T}_t - \widetilde{T}_{t-1}$).

The final equations, (21H) and (21F), are the government budget constraints. Shocks impinge on debt accumulation and create "fiscal stress" through their effects on the efficient equilibrium.⁶

Given the path for policy instruments and the initial value of \widehat{T}_{t-1} , the system including equations (17)-(21F) provides solutions for the endogenous variables c_t^w , y_t^H , y_t^F , π_t^H , π_t^F , q_t , b_t^H and b_t^F .

2.3.3 Policy Objectives - The Social Planner's Problem

The optimal allocation for the monetary union as a whole, in any given period t , can be described as the solution to the following social planner's problem, where the single policy authority is willing to maximize the discounted sum of the utility flows of the households belonging to the whole union (W):

³This definition does not apply for the inflation rates, as stable prices are optimal under sticky prices.

⁴The risk-sharing condition implies that $c_t^w = c_t^H = c_t^F$.

⁵The steady-state tax rates are given by $\overline{\tau}^i = (1-\beta)\frac{\overline{b}^i}{\overline{Y}} + (1-s_c)$ and the efficient tax rates by $\widetilde{\tau}_t^i = -\frac{1-\overline{\tau}^i}{\overline{\tau}^i}\widehat{\mu}_{w,t}^i$, for $i = H, F$.

⁶The derivations of all these equations are available upon request.

$$\begin{aligned}
\max_{C_{H,t}^H, C_{H,t}^F, \overline{C}_{F,t}^H, \overline{C}_{F,t}^F, G_t^H, G_t^F} W &= E_0 \left\{ \sum_{t=0}^{\infty} \beta^t [n_H w_t^H + n_F w_t^F] \right\}, & (22) \\
\text{with } w_t^H &= u(C_t^H, \overline{C}_t^H) + V(G_t^H) - \frac{1}{n_H} \int_0^{n_H} v(L_t^j) dj \\
\text{and } w_t^F &= u(C_t^F, \overline{C}_t^F) + V(G_t^F) - \frac{1}{n_F} \int_0^1 v(L_t^j) dj \\
&\text{s.t.} \\
\text{(production functions)} & Y_t^H = a_t^H L_t^H \\
& Y_t^F = a_t^F L_t^F \\
\text{(resource constraints)} & n_H Y_t^H = n_H C_{H,t}^H + n_F C_{H,t}^F + n_H G_t^H \\
& n_F Y_t^F = n_H C_{F,t}^H + n_F C_{F,t}^F + n_H G_t^F \\
\text{(consumption indexes)} & C_t^H \equiv \left[n_H^{\frac{1}{\rho}} (C_{H,t}^H)^{\frac{\rho-1}{\rho}} + n_F^{\frac{1}{\rho}} (C_{F,t}^H)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \\
& C_t^F \equiv \left[n_H^{\frac{1}{\rho}} (C_{H,t}^F)^{\frac{\rho-1}{\rho}} + n_F^{\frac{1}{\rho}} (C_{F,t}^F)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}
\end{aligned}$$

The social planner will choose to produce equal quantities of the different goods in each country. Moreover, the aggregation over all agents (households, governments and central bank) cancels out the budget constraints and, thus, the social planner's solution is not constrained by them.

Maximization program in (22) yields the following optimality conditions

$$u_c(C_t^H, \overline{C}_t^H) n_H^{\frac{1}{\rho}} \left(\frac{C_{H,t}^H}{C_t^H} \right)^{-\frac{1}{\rho}} = v_y(Y_t^H; a_t^H) \quad (23)$$

$$u_c(C_t^H, \overline{C}_t^H) n_F^{\frac{1}{\rho}} \left(\frac{C_{F,t}^H}{C_t^H} \right)^{-\frac{1}{\rho}} = v_y(Y_t^F; a_t^F) \quad (24)$$

$$u_c(C_t^F, \overline{C}_t^F) n_H^{\frac{1}{\rho}} \left(\frac{C_{H,t}^F}{C_t^F} \right)^{-\frac{1}{\rho}} = v_y(Y_t^H; a_t^H) \quad (25)$$

$$u_c(C_t^F, \overline{C}_t^F) n_F^{\frac{1}{\rho}} \left(\frac{C_{F,t}^F}{C_t^F} \right)^{-\frac{1}{\rho}} = v_y(Y_t^F; a_t^F) \quad (26)$$

$$V_G(G_t^H) = v_y(Y_t^H, a_t^H) \quad (27)$$

$$V_G(G_t^F) = v_y(Y_t^F, a_t^F) \quad (28)$$

Efficient equilibrium In a symmetric efficient steady state equilibrium, it follows that $\overline{Y}^H = \overline{Y}^F = \overline{Y}$; $\overline{C}^H = \overline{C}^F = \overline{C}$; $\overline{C}_H^H = \overline{C}_H^F = n_H \overline{C}$; $\overline{C}_F^H = \overline{C}_F^F = n_F \overline{C}$ and $\overline{G}^H = \overline{G}^F = \overline{G}$.

The complete solution for the efficient equilibrium is given by the following expressions (29-32)

$$\tilde{C}_t^w = \frac{1}{1 + \eta [s_c \sigma + (1 - s_c) \psi]} \left\{ [1 + (1 - s_c) \psi \eta] \widehat{C}_t^w + (1 + \eta) \sigma \widehat{a}_t^w \right\} \quad (29)$$

$$\tilde{C}_{H,t}^H - \tilde{C}_{F,t}^H = \tilde{C}_{H,t}^F - \tilde{C}_{F,t}^F = -\frac{\rho(1 + \eta)}{1 + \eta [s_c \rho + (1 - s_c) \psi]} (\widehat{a}_t^F - \widehat{a}_t^H) \quad (30)$$

$$\tilde{G}_t^w = \frac{\psi}{1 + \eta [s_c \sigma + (1 - s_c) \psi]} \left[-\eta s_c \widehat{C}_t^w + (1 + \eta) \widehat{a}_t^w \right] \quad (31)$$

$$\tilde{G}_t^F - \tilde{G}_t^H = \frac{(1 + \eta) \psi}{1 + \eta [s_c \rho + (1 - s_c) \psi]} (\widehat{a}_t^F - \widehat{a}_t^H) \quad (32)$$

To fully define the gap variables described in section above, we need to determine the efficient interest rate and terms-of-trade levels. The former follows directly from the Euler equation, while the latter results from the combination of equation (30) with the optimal intratemporal household's allocations

$$\tilde{i}_t = \frac{1}{\sigma} E_t \left[\left(\tilde{C}_{t+1}^w - \tilde{C}_t^w \right) - \left(\widehat{C}_{t+1}^w - \widehat{C}_t^w \right) \right] \quad (33)$$

$$\tilde{T}_t = -\frac{1 + \eta}{1 + \eta [s_c \rho + (1 - s_c) \psi]} (\widehat{a}_t^F - \widehat{a}_t^H). \quad (34)$$

In a debt-unconstrained scenario this efficient allocation would correspond to the decentralized flexible-price equilibrium when monopolistic and tax distortions are removed through an employment subsidy and the implemented government spending rules agree with those derived under the social planner's optimization. However, in this debt-constrained policy scenario, that union-wide optimal allocation may not be supported as a flexible-price equilibrium, since fiscal policy instruments may have to deviate from those rules to ensure fiscal solvency. Anyway, the policy problem will be formulated with variables in gaps defined in terms of the efficient outcomes and the two steady state equilibriums coincide.

Steady state equilibrium In order to avoid the traditional inflationary bias problem arising from an inefficiently low steady-state output level, we will assume the existence of an employment subsidy that removes average monopolistic and tax rate distortions. To compute this employment subsidy, observe that the profit-maximizing H-firms, in a flexible-price setup, choose the same price $p_t(h) = P_{H,t}$ such that

$$u_c \left(C_t^H, \overline{C}_t^H \right) = \frac{\theta}{(\theta - 1) (1 - \tau_t^H)} \mu_{w,t}^H \left(1 - \zeta^H \right) \left[n_H + n_F T_t^{1-\rho} \right]^{\frac{1}{1-\rho}} v_y \left(Y_t^H, a_t^H \right)$$

and, the F counterpart of this price-setting behaviour is given by

$$u_c \left(C_t^F, \overline{C}_t^F \right) = \frac{\theta}{(\theta - 1) (1 - \tau_t^F)} \mu_{w,t}^F \left(1 - \zeta^F \right) \left[n_H T_t^{\rho-1} + n_F \right]^{\frac{1}{1-\rho}} v_y \left(Y_t^F, a_t^F \right)$$

To get symmetry in the steady-state levels of the output, consumption, government spending and prices in both countries, we need to impose that $\frac{\theta}{(\theta-1)(1-\bar{\tau}^H)}\bar{\mu}_w(1-\zeta^H) = \frac{\theta}{(\theta-1)(1-\bar{\tau}^F)}\bar{\mu}_w(1-\zeta^F) = \bar{\mu}$ where, as we have already remarked, the employment subsidy ζ^i is fully financed by lump sum taxes.

In steady state, we verify that

$$u_c(\bar{C}, \bar{C}) = \bar{\mu}v_y(\bar{Y}, \bar{a})$$

and, if the employment subsidy ζ^i is set to match $\bar{\mu} = 1$, the efficient steady-state output level holds. Hence, the employment subsidy in country $i = H, F$ is assumed to take the value

$$\zeta^i = 1 - \frac{(\theta-1)(1-\bar{\tau}^i)}{\theta\bar{\mu}_w} \quad (35)$$

The steady-state nominal (and real) interest rate is $\bar{i} = \frac{1-\beta}{\beta}$.

2.3.4 Policy Objectives - The Social Loss Function

Benevolent authorities, under full cooperation, seek to maximize welfare for the monetary union as a whole, W , given, now, the set of equations describing the effective economic structure dynamics (17)-(21F). This environment enables the derivation of union-wide optimal stabilization policies, but serves also as a benchmark to assess alternative policy regimes.

Following Woodford (2003), we compute the second-order approximation of W around a deterministic steady state. Ignoring the terms independent of policy and terms of three or higher order, the welfare objective takes the form:

$$W \simeq -\Omega E_0 \left\{ \sum_{t=0}^{\infty} \beta^t L_t \right\}, \quad (36)$$

where the per-period social loss function (L_t), similar to the one derived by Beetsma and Jensen (2004, 2005), is defined as⁷

$$\begin{aligned} L_t = & \Lambda_c (c_t^w)^2 + \Lambda_g \left[n_H (g_t^H)^2 + n_F (g_t^F)^2 \right] + \Lambda_{gc} c_t^w (n_H g_t^H + n_F g_t^F) \\ & + \Lambda_T q_t^2 - \Lambda_{gT} (g_t^F - g_t^H) q_t + n_H \Lambda_\pi^H (\pi_t^H)^2 + n_F \Lambda_\pi^F (\pi_t^F)^2 \end{aligned} \quad (37)$$

and

$$\begin{aligned} \Lambda_c & \equiv s_c \left(\frac{1}{\sigma} + s_c \eta \right), \quad \Lambda_g \equiv (1-s_c) \left(\frac{1}{\psi} + (1-s_c)\eta \right), \quad \Lambda_{gc} \equiv 2s_c(1-s_c)\eta, \\ \Lambda_T & \equiv n_H n_F s_c \rho (1+s_c \rho \eta), \quad \Lambda_{gT} \equiv 2n_H n_F s_c (1-s_c) \rho \eta, \\ \Lambda_\pi^H & \equiv \frac{\theta(1+\theta\eta)\alpha^H}{(1-\alpha^H\beta)(1-\alpha^H)}, \quad \Lambda_\pi^F \equiv \frac{\theta(1+\theta\eta)\alpha^F}{(1-\alpha^F\beta)(1-\alpha^F)} \end{aligned}$$

Fluctuations in the consumption and the public spending gaps imply welfare

⁷The derivation of the social loss function is available upon request.

losses in line with the respective households' risk aversions ($1/\sigma$ and $1/\psi$) and with the elasticity of disutility with respect to work effort (η). Inflation at H is more costly the higher the degree of nominal rigidity (α^H), the higher the elasticity of substitution between H-produced goods (θ) and the higher η . The welfare cost of inflation (Λ_π^H) vanishes when prices are fully flexible ($\alpha^H = 0$).

At the monetary union level, misallocation of goods also applies for deviations of the terms-of-trade from the respective efficient level. The costs of this distortion (Λ_T) increase with the elasticity of substitution between Home and Foreign produced goods (ρ), with the steady-state consumption share on output (s_c), with η and decrease with country-size asymmetry. Following an asymmetric technology shock, efficiency requires prices to change as to shift the adjustment burden "equally" across the two countries (Benigno and López-Salido, 2006). This creates a trade-off between the stabilization of relative prices to the correspondent efficient levels and the stabilization of inflation in both countries and it provides a rationale for the stabilization role of fiscal policy.

The cross-term between the consumption gap and the weighted average government spending gap occurs because positive co-movements between these two variables cause undesirable fluctuations in the work effort for the monetary union as a whole, in addition to the effort fluctuations caused by each of these variables *per se*. There is also a negative cross-term between the terms of trade gap and the relative spending gap that is increasing (in absolute value) with η and ρ , while decreasing with country-size asymmetry. This negative co-movement arises because a positive terms-of-trade gap rises H-competitiveness which, combined with a negative relative public spending gap (higher public spending at H than at F), shifts demand towards H-produced goods. As a consequence, work effort shifts from F- towards H-households (cf. Beetsma and Jensen 2004 and 2005, for these arguments).

2.3.5 Other policy objectives

We also consider that policymakers may have divergent policy objectives. This is a valid assumption since it is reasonable to conjecture that national (fiscal) authorities are mainly concerned with their own citizens and so, their objective functions should only comprise the utility of the respective constituencies. Pragmatically, we approximate the national welfare criteria through welfare losses obtained from splitting the union-wide loss function.⁸

We will also consider the case of the delegation of monetary policy to a weight-conservative central bank by distorting the weights on the inflation and the output terms of the social loss function. This is usually seen as a potential solution to reduce the time-inconsistency problems of policy stabilization, which can be aggravated by specific incentives of the fiscal authorities.

⁸Forlati (2009) provides fully micro-founded welfare criteria for the case of non-coordinated fiscal and monetary policies in a monetary union.

The table below summarizes the policy environments we will analyze.

Benevolent Cooperative Policymakers	
$L_t^{H,F} = L_t^M = L_t$	
Benevolent non-Cooperative Policymakers	
$L_t^H = \Lambda_c (c_t^H)^2 + \Lambda_g (g_t^H)^2 + \Lambda_{gc} c_t^w g_t^H + \Lambda_T q_t^2 + \frac{1}{n_H} \Lambda_{gT} g_t^H q_t + \Lambda_\pi^H (\pi_t^H)^2$	
$L_t^F = \Lambda_c (c_t^F)^2 + \Lambda_g (g_t^F)^2 + \Lambda_{gc} c_t^w g_t^F + \Lambda_T q_t^2 - \frac{1}{n_F} \Lambda_{gT} g_t^F q_t + \Lambda_\pi^F (\pi_t^F)^2$	
$L_t^M = L_t$	
Conservative Central Bank	
L_t^H, \bar{L}_t^F	
$L_t^M = (1 - \rho^c) \left\{ \Lambda_c (c_t^w)^2 + \Lambda_g \left[n_H (g_t^H)^2 + n_F (g_t^F)^2 \right] + \Lambda_{gc} c_t^w (n_H g_t^H + n_F g_t^F) \right.$	
$\left. + \Lambda_T q_t^2 - \Lambda_{gT} (g_t^F - g_t^H) q_t \right\} + \rho^c \left\{ n_H \Lambda_\pi^H (\pi_t^H)^2 + n_F \Lambda_\pi^F (\pi_t^F)^2 \right\}$	

2.4 Policy Games

We assume that fiscal and monetary authorities set their policy instruments in order to minimize the respective loss functions, given the dynamic structure of the economies, and that they can engage in various policy games. We will consider, as a benchmark case for policy analysis, that policymakers are benevolent and cooperate under discretion. To assess the importance of time-consistency, we also compute the optimal policy solution under commitment. These two optimizing problems will be solved by using the algorithms in Söderlind (1999).

We also consider discretionary non-cooperative policy games and, depending on the time of events, we obtain Nash or leadership equilibria. In these different setups, the timing of the events is as following: 1) the private sector forms expectations; 2) the shocks are realized; 3a) the central bank sets the interest rate; 3b) the fiscal authorities choose simultaneously the right amount of fiscal policy instruments. There is a Nash equilibrium, if 3a) and 3b) occur simultaneously; there is monetary leadership if 3a) occurs before 3b); and, if the order of these occurrences is reversed, there is a fiscal leadership. To solve for these dynamic policy games we use the methodology developed by Blake and Kirsanova (2010b) and Kirsanova *et al.* (2005). The derivation of a numerical algorithm for the solution of the non-cooperative monetary leadership discretionary game is deferred to a separate appendix, available upon request.

2.5 Calibration

Our baseline calibration was chosen taking as reference Beetsma and Jensen (2004, 2005), Benigno (2004), Benigno and López-Salido (2006) and Ferrero (2009).

The discount factor β is 0.99, which implies a 4% annual basis steady-state interest rate. The parameter θ , the elasticity of substitution between goods produced in the same country, is equal to 11, implying a price mark-up of 10%. In turn, the elasticity of substitution between H and the F produced goods, ρ , is set at 4.5. We assume $\sigma = \psi = 0.4$, which implies a coefficient of risk aversion for private and public consumption equal to 2.5. The steady-state share of public consumption in output $(1 - s_c)$ is set at 0.25. We parameterize $\eta = 0.47$,

implying a labour supply elasticity of $1/0.47$.

Our benchmark calibration aims to reflect a perfectly symmetric setup from which we can diverge and assess how country-size asymmetry affects the results. Hence, we begin by assuming that the two economies in the monetary union are of equal size ($n_i = 0.5$) and have identical degrees of nominal rigidities ($\alpha^H = \alpha^F$). We select a value for α equal to 0.75, in order to get an average length of price contracts equal to one year.

The country-size asymmetry case is illustrated for $n_H = 0.8$.

We set yearly steady-state debt-to-output ratio ($\bar{b}/4\bar{Y}$) within the range [5%; 19%], step 2.5 pp., to characterize a low-debt monetary union. For the high-debt monetary union, the debt ratios are set on the interval [40%; 110%], step 10 pp.. The above mentioned ranges were set as to allow for a single equilibrium for all debt-to-output levels and to ensure that welfare dynamics evolves monotonically with debt. In particular, the low-debt monetary union is illustrated for a debt-to-output ratio of 10%, while the high-debt case takes as reference a debt level of 60%.

Finally, we assume that the consumption and the technology shocks follow an uncorrelated AR(1) process with common persistence of 0.85, while the wage mark-up shocks are i.i.d., and the standard deviation of the innovations are equal to 0.01.

3 Optimal discretionary stabilization policies

The increasing levels of government indebtedness experienced by the generality of the EMU countries are expected to hamper considerably business cycle stabilization, by enlarging the budgetary consequences of the shocks. Actually, these negative consequences for macroeconomic stabilization are expected to be more serious under discretion than under commitment. This follows from the fact that debt-constrained optimal stabilization policies face a policy trade-off between short-run stabilization and the reduction of permanent effects on debt and real welfare-related variables. Given welfare's convexity and discounting, the optimal policy solution under commitment delivers permanent effects on debt (and on real welfare-related variables) and, thus, the pre-shock public debt level affects only marginally the policy response to shocks and welfare.⁹ Conversely, time-consistency (discretion) requires that permanent effects are fully eliminated and all variables return to their pre-shock levels and, thus, the initial level of government indebtedness meaningfully affects the policy response to shocks and welfare.

However, as we will see next, such welfare consequences are far from being clearly unambiguous. As Leith and Wren-Lewis (2007a) or Stehn and Vines (2008a) remarked, the elimination of permanent effects is achieved diversely when public debts are small or large, because the level of government indebtedness affects the relative effectiveness of the fiscal and monetary policy instruments attached to debt-stabilization. The effectiveness of monetary policy on

⁹This result is reminiscent of the tax smoothing result of the optimal taxation literature (Barro, 1979 and Lucas and Stokey, 1983).

Benigno and Woodford (2004), Schmitt-Grohé and Uribe (2004b) or Leith and Wren-Lewis (2007a), on closed economy models, and Ferrero (2009) or Leith and Wren-Lewis (2007b), on open economy models, show that the optimal policy response to shocks requires permanent variations in the level of public debt.

promoting debt-stabilization increases with the initial level of public debt, because its leverage over debt-interest payments increases, while that of the fiscal policy diminishes. Furthermore, fiscal policy instruments – particularly, the tax rate – become progressively more apt to offset inflationary consequences, the larger the steady-state debt-to-output ratios are (as higher debt steady-state levels lead to higher steady-state tax rate levels and, so, a negative tax rate gap has a larger negative impact on inflation). Hence, the level of government indebtedness crucially shapes the optimal monetary and fiscal policy responses to shocks under discretion.

For sufficiently small debt levels ($b < 20\%$, under our calibration), in face of a symmetric shock simultaneously boosting debt and inflation, the conventional monetary and fiscal policy assignments apply: in the first period, the interest rate gap increases to control for inflation (“active” monetary policy) and government spending gaps diminish while the tax rate gaps increase to provide debt stabilization (“passive” fiscal policy).¹⁰

However, if the level of government indebtedness becomes too high, unconventional policy assignments may emerge: monetary policy moves towards debt stabilization (“passive” monetary policy) and aggregate fiscal policy may move towards the inflation stabilization assignment (“active” fiscal policy) for $b > 60\%$ (Cf. Figure 1, responses to a symmetric negative technology shock for $b = 10\%$ and $b = 80\%$, under policy cooperation). Thus, the stabilization consequences of higher government indebtedness are critically determined by the level of public debt itself, given its key influence on monetary and fiscal policy interactions.

¹⁰Taking as a starting point Leeper’s (1991) categorization of “passive”/“active” policies, we refer to a “passive” policy when it promotes debt-stabilization. Otherwise, when policy instruments promote short-run stabilization, policy is said to be “active”.

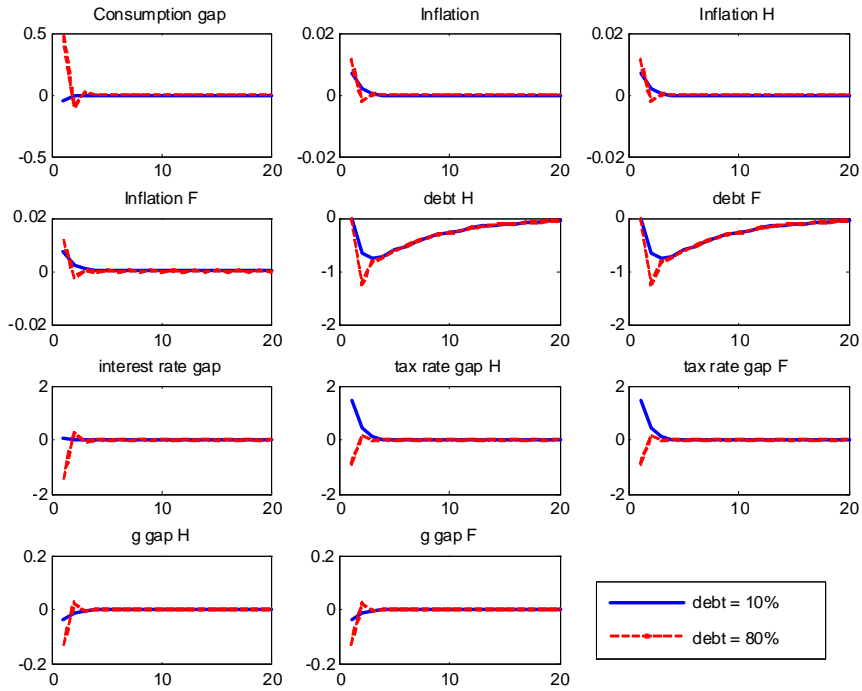


Figure 1: Responses to a symmetric negative 1% technology shock, Cooperation

Therefore, to assess the stabilization constraints from different public debt levels we will consider two policy scenarios: a low-debt and a high-debt monetary union. The former requires for an “active” monetary policy while the latter requires for a “passive” monetary policy.

3.1 Low-debt Monetary Union

In our analysis the economies are hit by the full menu of shocks; however, we focus on technology shocks because their impacts on welfare dominate.¹¹

3.1.1 Cooperation

Country-specific technology shocks cause asymmetric budgetary consequences: higher in the home than in the foreign country. As a consequence, domestic effects dominate union-wide effects and monetary policy’s response. Furthermore, time-consistency and the consequent debt stabilization bias make domestic shocks to cause higher stabilization costs than external ones.¹² Figure 2 details the impulse responses of key endogenous variables to a 1% negative technology shock hitting country H, in a country-size symmetric monetary union,

¹¹Technology shocks account for more than 88% of the total of the stabilization costs of the union. Considering the available policy stabilization instruments, consumption and cost-push shocks produce stabilization trade-offs only because of their effects on debt: trade-offs would be fully eliminated, if lump-sum taxes were available to ensure balanced-budget.

¹²In a debt-unconstrained policy scenario, domestic and foreign technology shocks have symmetric impacts and that requires symmetric fiscal policy responses; equally-distributed stabilization costs apply (see Machado and Ribeiro, 2010).

considering two alternative debt-to-output ratios. It confirms that the union-wide inflation follows the same path of domestic (H) inflation and that the latter fluctuates more than foreign (F) inflation.

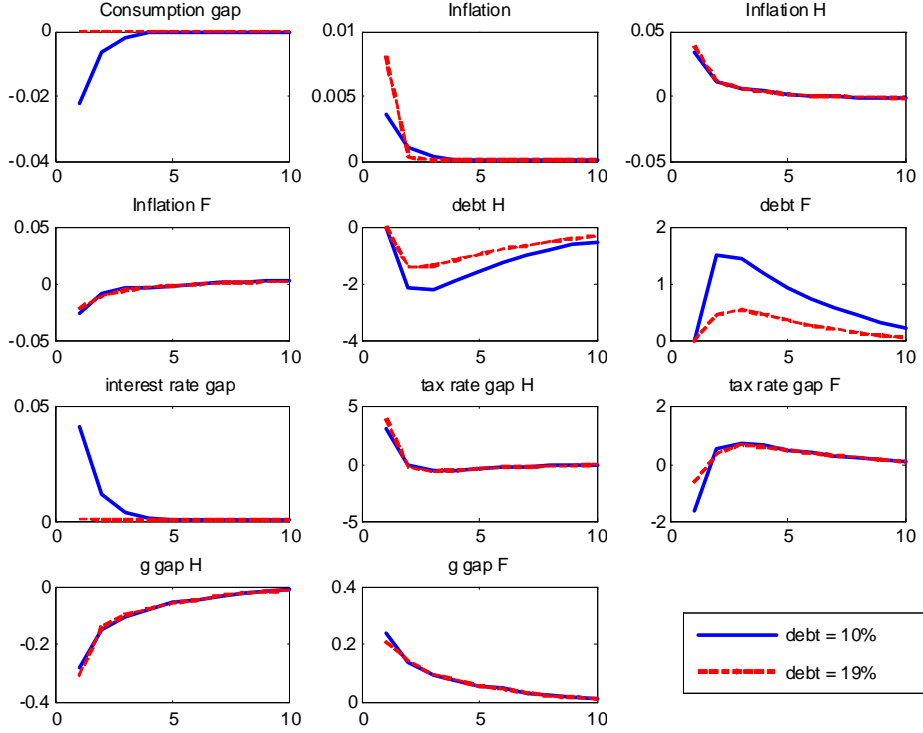


Figure 2: Responses to a 1% negative technology shock at H, Cooperation

Also, the higher steady-state debt-to-output ratios are, the larger are budgetary consequences of the shock as well as the incentives towards debt-stabilization; thus, as we have already referred the stabilization costs are expected to be larger.

In fact, larger steady-state debt-to-output ratios amplify the budgetary consequences of a domestic country-specific technology shock while they attenuate those of an external shock, even when monetary policy becomes progressively less biased towards the control of the union-wide (and H) inflation (a less “active” MP occurs only for $b \geq 10\%$), given the higher basis of incidence of debt-service costs. Fiscal policy also becomes more biased towards debt-stabilization (more “passive” FP) in face of a domestic shock while the reverse occurs in face of an external one. Therefore, the stabilization performance of domestic shocks deteriorates while that of external shocks improves, for higher levels of government indebtedness (Cf., in Figure 2, the different stabilization performances regarding inflation at H and F for different debt levels). Under equal-size countries, the first effect dominates and, as expected, welfare deteriorates for higher debt-to-output ratios (Table 5, for $n_H = 0.5$).

Under country-size asymmetry, changes in the relative prices affect more the marginal costs and inflation rates of smaller (and more open) economies; thus,

country-specific shocks inflict higher stabilization costs to a small country than to a large one. In turn, country-specific shocks at the large country naturally dominate welfare evaluation for the large (domestic shocks) as well as for the small (external shocks) country. Hence, welfare improves for the small country and reduces for the large country as well as for the union, when the indebtedness level increases across all the monetary union governments (Table 5, for $n_H = 0.8$).

3.1.2 Non-Cooperation

Given the assumptions we made on the policy objective functions under non-cooperation, differences in policy outcomes relative to cooperation only arise because national fiscal authorities do not internalize the cross-border effects of their policies. Relative to cooperation, nationally-oriented fiscal policies react less (more) when they cause positive (negative) externalities.

Compared with cooperation, in a country-size symmetric monetary union, a negative technology shock at H requires a smaller variation of the tax rate gap and a larger response of the government spending gap in both countries, because these instruments have opposite cross-border effects.¹³ Furthermore, since the domestic (foreign) fiscal policy reaction causes a positive (negative) externality on the union-wide debt, non-cooperation leads to a relatively less (more) “passive” policy at H (F). Under Nash and relative to cooperation, aggregate fiscal policy ends up by being less “passive” and monetary policy becomes less “active”.¹⁴ The benefit on better macroeconomic stabilization from fiscal policy moderation dominates the cost of reducing monetary policy activeness, resulting in a superior welfare relative to cooperation. This finding confirms a more general result that policy cooperation can be counterproductive in the presence of a pre-existing distortion.¹⁵ The already existing bias towards insufficient (fiscal) stabilization (debt-stabilization bias) worsens when the fiscal authorities shift from non-cooperation towards cooperation.

Relative to Nash, monetary leadership alleviates even more time-consistency problems while fiscal leadership magnifies them. Under fiscal leadership, being aware of monetary policy’s “activeness”, aggregate fiscal policy becomes more “passive”, with negative consequences for macroeconomic stabilization. Under monetary leadership, being aware of fiscal authorities’ incentives towards less debt-adjustment, monetary policy’s response becomes more aggressive towards inflation-adjustment and allows for a better stabilization outcome, relative to Nash. Monetary leadership dominates fiscal leadership, except for very low debt levels ($b < 6.5\%$), and all non-cooperative outcomes grant lower stabilization costs than cooperation (see Table 5, for $n_H = 0.5$).

As in cooperation, when steady-state debt-to-output ratios increase, the

¹³The tax rate responses alleviate the effects of the shock on the terms-of-trade gap (positive externality) while those of the government spending magnify them (negative externality).

¹⁴This can be checked by computing, for cooperation and Nash, the aggregate government spending and tax rate responses to an idiosyncratic negative technology shock at H, using the feedback coefficients on Table 1.

¹⁵The argument follows from the key contribution of Rogoff (1985), according to which the cooperation among a subset of players (all policymakers) could lead to such an adverse reaction of the outsiders (the private sectors of the two countries) that all players would be better off by not cooperating. Non-cooperation may alleviate time-consistency problems. See Beetsma et al. (2001) for a review on the literature on the desirability of policy coordination.

stabilization costs of domestic shocks increase and dominate the reduction of those attached to external shocks, consequently welfare deteriorates with debt.

In a country-size asymmetric monetary union, it matters the type but also the size of the externality non-internalized by the fiscal authorities of both countries. The small countries, causing small externalities, have incentives to engage in more debt-adjusting fiscal policies than under cooperation while large countries face the reverse incentives. Under Nash, the (union-wide benevolent) central bank corrects the effects of such asymmetry reacting relatively more to the inflationary consequences suffered by a small country than it would do under cooperation, while taking the converse attitude relative to the large country (cf. the monetary feedback coefficients on technology shocks at Table 2, cooperation vs. Nash). Compared with cooperation, the resulting policy-mix is welfare-improving for the small country and for the union as a whole while welfare-decreasing for the large country (see Table 5, for $n_H = 0.8$).

Fiscal leadership intensifies the fiscal policy response of the large country to debt consequences, once monetary policy is expected to control for domestic inflationary consequences. In turn, under monetary leadership, the central bank, anticipating the incentives, further enhances fiscal discipline for the large country while moderates that of the small country.

The welfare losses reported in Table 5 show that non-cooperation dominates cooperation, for the small country and the monetary union as a whole while the reverse occurs for the large country. However, a small country is always better-off under monetary leadership while a large country clearly prefers fiscal leadership to monetary leadership. At the union level, monetary leadership allows for a better stabilization performance than fiscal leadership for sufficiently high debt levels ($b \geq 10\%$).

Furthermore, larger debt levels worsen the stabilization performance at the union level. However, a large country can benefit with larger debt levels if they are high enough ($b > 10\%$), under its most preferred regime (fiscal leadership); and a small country can take advantage from higher government indebtedness, but only for sufficiently low debt levels ($b < 12.5\%$) and under monetary leadership (see Table 5).

3.2 High-debt Monetary Union

3.2.1 Cooperation

As before, domestic shocks cause higher stabilization costs than external shocks. However, as monetary policy is now “passive” and assists, with increasing effectiveness, the control of the union-wide and domestic debts, domestic fiscal policy becomes progressively less biased towards debt-management (less “passive”) and the stabilization performance of domestic shocks improves, with the level of government indebtedness. On the contrary, the foreign country experiences a worse stabilization performance, because monetary policy, enlarging its budgetary consequences, forces fiscal policy to deviate towards debt stabilization. Thus, differently from the low-debt scenario, the stabilization performance of domestic shocks improves while that of external shocks deteriorates, for larger debt-to-output ratios, as it is apparent from Figure 3.

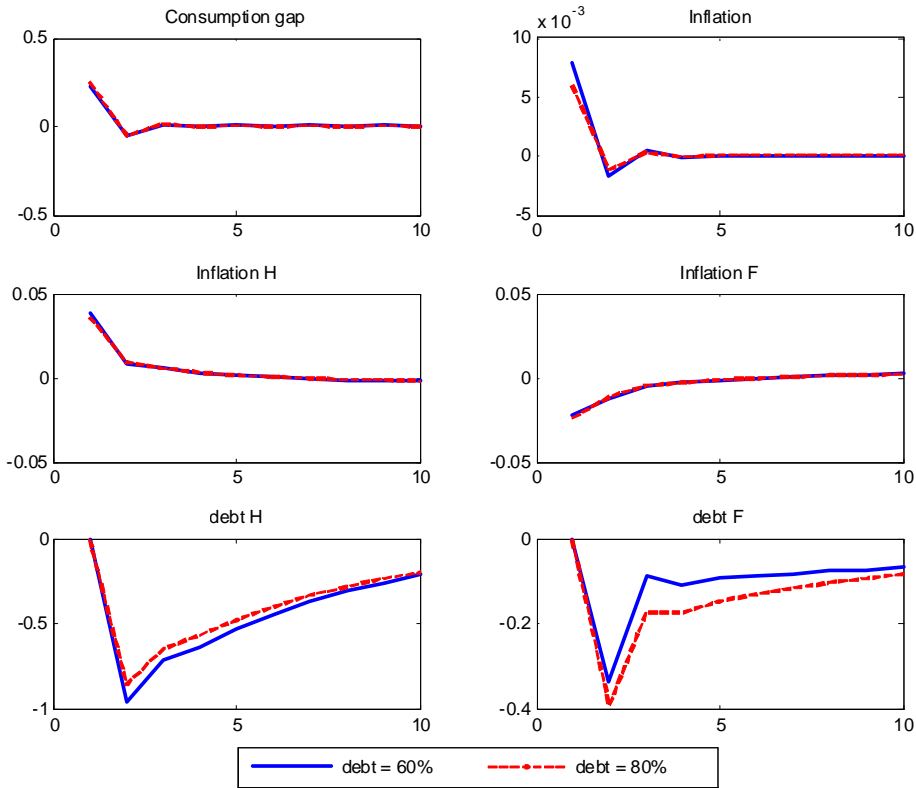


Figure 3: Responses to a 1% negative technology shock at H, Cooperation

At odd with expected, under equal-size countries, the first effect dominates and welfare improves, except when debt becomes too high ($b > 140\%$, cf. Table 6). This result also applies for the whole monetary union under country-size asymmetry as well as for the large country. However, for the small and more open economy, the worse stabilization of external (H) shocks dominates over the improvement in the stabilization of domestic (F) shocks and welfare deteriorates, for larger debt-to-output ratios across the union (Table 6).

3.2.2 Non-Cooperation

In a country-size symmetric monetary union, the incentives for the fiscal authorities under non-cooperation are common to those observed in a low-debt monetary union. However, in a high-debt scenario the response of monetary policy is completely different. Under Nash, while aggregate fiscal policy remains, as in the low-debt scenario, less biased towards debt-adjustment, the central bank is compelled to a more “passive” monetary policy in order to soften aggregate debt adjustment.¹⁶ The inflationary stance of monetary policy aggravates and dominates over the benefit from enhanced macroeconomic stabilization delivered by fiscal policy moderation. Therefore, Nash is welfare-inferior to cooperation. Relative to Nash, fiscal leadership magnifies the monetary policy time-consistency

¹⁶This can be checked by computing, for cooperation and Nash, the aggregate government spending and tax rate responses to an idiosyncratic negative technology shock at H, using the feedback coefficients reported in Table 3.

problems while fiscal leadership alleviates them. Under fiscal leadership, being aware of the monetary policy reaction against debt misalignments, fiscal authorities care even less about debt control. On balance, Nash solution effects are reinforced and, thus, fiscal leadership delivers an even worse stabilization outcome. In turn, a leading central bank, being aware of fiscal authorities' incentives towards less debt-adjustment, moderates its "passive" monetary policy and compels national governments to act closer to the cooperative outcome, yielding lower welfare costs. (See Table 6, $n_H = 0.5$)

Now, the increase of government indebtedness augments the stabilization costs of domestic and external shocks and, thus, the union's welfare gets worse, in contrast with the cooperative outcome.

In a country-size asymmetric monetary union, the differentiated incentives of small and large countries determine, now, that the central bank accommodates the budgetary consequences of the small country relatively more than it would do under cooperation, while taking the converse attitude relative to the large country (cf. the monetary feedback coefficients on technology shocks in Table 4, cooperation vs. Nash). The resulting policy-mix under Nash is welfare-decreasing for the small country and the union as a whole while welfare-improving for the large country (see Table 6). Fiscal leadership further moderates the fiscal policy response of the large country to debt consequences, once monetary policy is expected to adjust further to its domestic debt. In turn, monetary leadership enhances fiscal discipline for the large country, as the central bank, anticipating the incentives, accommodates to a lower extent its budgetary consequences.

The welfare losses reported in Table 6 show that, cooperation dominates non-cooperation, for the small country and the monetary union as a whole while the reverse occurs for the large country. As in the low-debt case, a small country is always better-off under monetary leadership while a large country clearly prefers fiscal leadership. At the union level, monetary leadership allows for a better stabilization performance than fiscal leadership.

Furthermore, in contrast with the cooperative outcome, larger debt levels worsen the stabilization performance at the union level. However, this welfare reduction impacts exclusively in the small country, as the large country achieves an increasing stabilization performance, when debt increases.

4 Concluding Remarks

Average union debt levels appear to be non-neutral to union-wide and country-specific stabilization performance.

A first set of implications are related to debt levels impacts on monetary policy assignment. The union-wide benevolent central bank makes interest rate optimally react to promote inflation stabilization for sufficiently low debt-to-output levels, but the reaction function shifts towards debt-stabilization when union average debt becomes large enough. This monetary policy shift impinges strong inflexions regarding welfare stabilization.

First, while in a high-debt scenario cooperation dominates non-cooperation at the union level, in a low-debt scenario non-cooperative outcomes are welfare superior. Non-cooperation induces fiscal policy to be less debt-adjusting at the union-wide level, as fiscal authorities do not fully internalize the positive externality on the union-wide debt.

In a high-debt environment, the mitigation of fiscal policy time-consistency problems aggravates those of monetary policy in such a way that non-cooperation delivers worse stabilization outcomes than cooperation. Conversely, in a low-debt environment, monetary policy only becomes less “active”, allowing for non-cooperation to deliver better stabilization outcomes than cooperation.

Second, unequal-size countries, causing asymmetric externalities, have distinct incentives under non-cooperation that induce monetary policy to be relatively more “active”/”passive” towards the small country under low/high-debt scenarios. As a consequence, the small country achieves a better/worse stabilization performance under non-cooperation under low/high-debt scenarios, while the reverse occurs for the large country.

Finally, the leadership structure has key stabilization consequences. Clearly, a large country benefits with fiscal leadership while a small country is better-off under monetary leadership. At the union level, monetary leadership dominates fiscal leadership for reasonable debt levels.

A second set of implications is how the previous mentioned outcomes move along different debt levels.

As regards cooperation, the increase of government debt produces opposite welfare results in low and high-debt scenarios. It enlarges (reduces) welfare stabilization costs for the union as whole and for a large country while the reverse occurs for a small country, in a low (high) debt monetary union.

As for non-cooperation, the increase in government indebtedness reduces the union’s welfare in the two debt scenarios. Debt mostly worsens the stabilization performance of the small country while it mostly improves that of the large country.

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Tables

Table 1: Policy reaction functions, Debt = 10%, $n_H = 0.5$

		a_t^H (1)	a_t^F (2)	μ_t^H (3)	μ_t^F (4)	\bar{c}_t^w (5)	a_{t-1}^H (6)	a_{t-1}^F (7)	q_{t-1} (8)	b_{t-1}^H (9)	b_{t-1}^F (10)
	\dot{i}_t	-0.0410	-0.0410	0.0642	0.0642	-0.1871	0.0000	-0.0000	0	0.0344	0.0344
	g_t^H	0.2789	-0.2412	-0.0590	-0.0001	0.0862	-0.2178	0.2178	-0.3902	-0.0316	-0.0001
C	τ_t^H	-3.0823	1.6134	2.2703	0.0307	-3.3549	1.1632	-1.1632	2.0836	1.2173	0.0165
	g_t^F	-0.2412	0.2789	-0.0001	-0.0590	0.0862	0.2178	-0.2178	0.3902	-0.0001	-0.0316
	τ_t^F	1.6134	-3.0823	0.0307	2.2703	-3.3549	-1.1632	1.1632	-2.0836	0.0165	1.2173
	\dot{i}_t	-0.0405	-0.0405	0.0635	0.0635	-0.1851	-0.0000	0.0000	-0.0000	0.0340	0.0340
	g_t^H	0.2967	-0.2635	-0.0515	-0.0005	0.0758	-0.3599	0.3599	-0.6448	-0.0276	-0.0002
N	τ_t^H	-2.3261	0.8668	1.9221	0.3638	-3.3330	3.8982	-3.8982	6.9830	1.0306	0.1951
	g_t^F	-0.2635	0.2967	-0.0005	-0.0515	0.0758	0.3599	-0.3599	0.6448	-0.0002	-0.0276
	τ_t^F	0.8668	-2.3261	0.3638	1.9221	-3.3330	-3.8982	3.8982	-6.9830	0.1951	1.0306
	\dot{i}_t	-0.0422	-0.0422	0.0661	0.0661	-0.1927	0	0	0	0.0354	0.0354
	g_t^H	0.2840	-0.2509	-0.0486	-0.0032	0.0755	-0.3446	0.3446	-0.6173	-0.0261	-0.0017
FL	τ_t^H	-3.0649	1.5718	2.1074	0.2316	-3.4103	5.3897	-5.3897	9.6547	1.1300	0.1242
	g_t^F	-0.2509	0.2840	-0.0032	-0.0486	0.0755	0.3446	-0.3446	0.6173	-0.0017	-0.0261
	τ_t^F	1.5718	-3.0649	0.2316	2.1074	-3.4103	-5.3897	5.3897	-9.6547	0.1242	1.1300
	\dot{i}_t	-0.0408	-0.0408	0.0639	0.0639	-0.1862	-0.0000	0.0000	-0.0000	0.0342	0.0342
	g_t^H	0.2966	-0.2635	-0.0514	-0.0004	0.0755	-0.3595	0.3595	-0.6439	-0.0276	-0.0002
ML	τ_t^H	-2.3160	0.8569	1.9203	0.3654	-3.3326	3.8662	-3.8662	6.9255	1.0297	0.1959
	g_t^F	-0.2635	0.2966	-0.0004	-0.0514	0.0755	0.3595	-0.3595	0.6439	-0.0002	-0.0276
	τ_t^F	0.8569	-2.3160	0.3654	1.9203	-3.3326	-3.8662	3.8662	-6.9255	0.1959	1.0297

Table 2: Policy reaction functions, Debt = 10%, $n_H = 0.8$

		a_t^H (1)	a_t^F (2)	μ_t^H (3)	μ_t^F (4)	\bar{c}_t^w (5)	a_{t-1}^H (6)	a_{t-1}^F (7)	q_{t-1} (8)	b_{t-1}^H (9)	b_{t-1}^F (10)
	\dot{i}_t	-0.0655	-0.0164	0.1027	0.0257	-0.1871	0.0000	-0.0000	0.0000	0.0551	0.0138
	g_t^H	0.1342	-0.0965	-0.0590	-0.0000	0.0862	-0.0871	0.0871	-0.1561	-0.0317	-0.0000
C	τ_t^H	-2.1142	0.6454	2.2887	0.0123	-3.3549	0.4653	-0.4653	0.8334	1.2272	0.0066
	g_t^F	-0.3859	0.4236	-0.0002	-0.0589	0.0862	0.3486	-0.3486	0.6244	-0.0001	-0.0316
	τ_t^F	2.5815	-4.0504	0.0491	2.2519	-3.3549	-1.8611	1.8611	-3.3338	0.0263	1.2075
	\dot{i}_t	-0.0385	-0.0391	0.0977	0.0239	-0.1773	-0.0673	0.0673	-0.1205	0.0524	0.0128
	g_t^H	0.1377	-0.1020	-0.0552	-0.0008	0.0815	-0.1607	0.1607	-0.2879	-0.0296	-0.0004
N	τ_t^H	-1.4740	0.0355	2.1014	0.1521	-3.2857	1.0770	-1.0770	1.9293	1.1268	0.0815
	g_t^F	-0.4157	0.4445	-0.0037	-0.0414	0.0658	0.6388	-0.6388	1.1442	-0.0020	-0.0222
	τ_t^F	1.6273	-2.9945	0.6312	1.5105	-3.1228	-9.9399	9.9399	-17.8057	0.3385	0.8099
	\dot{i}_t	-0.0647	-0.0149	0.1054	0.0194	-0.1820	-0.0201	0.0201	-0.0360	0.0565	0.0104
	g_t^H	0.1293	-0.0937	-0.0533	-0.0024	0.0813	-0.1406	0.1406	-0.2519	-0.0286	-0.0013
FL	τ_t^H	-1.9396	0.4848	2.2137	0.0653	-3.3228	2.0106	-2.0106	3.6016	1.1870	0.0350
	g_t^F	-0.4107	0.4396	-0.0047	-0.0405	0.0659	0.6359	-0.6359	1.1392	-0.0025	-0.0217
	τ_t^F	2.1558	-3.5595	0.5664	1.6326	-3.2062	-11.4902	11.4902	-20.5827	0.3037	0.8754
	\dot{i}_t	-0.1021	0.0208	0.1117	0.0156	-0.1855	-0.1620	0.1620	-0.2902	0.0599	0.0083
	g_t^H	0.1555	-0.1187	-0.0600	0.0023	0.0841	-0.0928	0.0928	-0.1663	-0.0322	0.0012
ML	τ_t^H	-2.3656	0.8521	2.3190	0.0519	-3.4569	-0.9814	0.9814	-1.7580	1.2435	0.0278
	g_t^F	-0.3929	0.4183	-0.0044	-0.0354	0.0581	0.6543	-0.6543	1.1720	-0.0024	-0.0190
	τ_t^F	0.3327	-1.5473	0.6755	1.2274	-2.7744	-9.9329	9.9329	-17.7930	0.3622	0.6581

Table 3: Policy reaction functions, Debt = 60%, $n_H = 0.5$

		a_t^H (1)	a_t^F (2)	μ_t^H (3)	μ_t^F (4)	\bar{c}_t^v (5)	a_{t-1}^H (6)	a_{t-1}^F (7)	q_{t-1} (8)	b_{t-1}^H (9)	b_{t-1}^F (10)
	\dot{i}_t	0.6826	0.6826	-0.1734	-0.1734	0.2921	-0.0000	0.0000	-0.0000	-0.5733	-0.5733
	g_t^H	0.3391	-0.1862	-0.0497	0.0109	0.0327	-0.2053	0.2053	-0.3678	-0.1644	0.0359
C	τ_t^H	-2.4114	2.0082	1.0910	-0.9886	-0.0863	0.6206	-0.6206	1.1117	3.6068	-3.2681
	g_t^F	-0.1862	0.3391	0.0109	-0.0497	0.0327	0.2053	-0.2053	0.3678	0.0359	-0.1644
	τ_t^F	2.0082	-2.4114	-0.9886	1.0910	-0.0863	-0.6206	0.6206	-1.1117	-3.2681	3.6068
	\dot{i}_t	0.7520	0.7520	-0.1911	-0.1911	0.3218	-0.0000	0.0000	-0.0000	-0.6316	-0.6316
	g_t^H	0.3594	-0.2256	-0.0471	0.0131	0.0286	-0.2269	0.2269	-0.4065	-0.1557	0.0433
N	τ_t^H	-0.0943	1.1465	0.5464	-0.8137	0.2251	-1.8627	1.8627	-3.3366	1.8061	-2.6899
	g_t^F	-0.2256	0.3594	0.0131	-0.0471	0.0286	0.2269	-0.2269	0.4065	0.0433	-0.1557
	τ_t^F	1.1465	-0.0943	-0.8137	0.5464	0.2251	1.8627	-1.8627	3.3366	-2.6899	1.8061
	\dot{i}_t	0.7524	0.7524	-0.1912	-0.1912	0.3220	0.0000	-0.0000	0.0000	-0.6320	-0.6320
	g_t^H	0.3396	-0.2056	-0.0437	0.0097	0.0287	-0.1830	0.1830	-0.3278	-0.1445	0.0320
FL	τ_t^H	0.3780	0.6837	0.4446	-0.7143	0.2272	-2.6778	2.6778	-4.7968	1.4696	-2.3613
	g_t^F	-0.2056	0.3396	0.0097	-0.0437	0.0287	0.1830	-0.1830	0.3278	0.0320	-0.1445
	τ_t^F	0.6837	0.3780	-0.7143	0.4446	0.2272	2.6778	-2.6778	4.7968	-2.3613	1.4696
	\dot{i}_t	0.6932	0.6932	-0.1761	-0.1761	0.2966	-0.0000	0.0000	-0.0000	-0.5823	-0.5823
	g_t^H	0.3627	-0.2208	-0.0479	0.0119	0.0304	-0.2350	0.2350	-0.4210	-0.1584	0.0392
ML	τ_t^H	-0.3669	1.0894	0.6066	-0.7901	0.1546	-1.5500	1.5500	-2.7766	2.0052	-2.6120
	g_t^F	-0.2208	0.3627	0.0119	-0.0479	0.0304	0.2350	-0.2350	0.4210	0.0392	-0.1584
	τ_t^F	1.0894	-0.3669	-0.7901	0.6066	0.1546	1.5500	-1.5500	2.7766	-2.6120	2.0052

Table 4: Policy reaction functions, Debt = 60%, $n_H = 0.8$

		a_t^H (1)	a_t^F (2)	μ_t^H (3)	μ_t^F (4)	\bar{c}_t^w (5)	a_{t-1}^H (6)	a_{t-1}^F (7)	q_{t-1} (8)	b_{t-1}^H (9)	b_{t-1}^F (10)
	i_t	1.0921	0.2730	-0.2775	-0.0694	0.2921	-0.0000	0.0000	-0.0000	-0.9173	-0.2293
	g_t^H	0.2274	-0.0745	-0.0432	0.0043	0.0327	-0.0821	0.0821	-0.1471	-0.1428	0.0144
Coop	τ_t^H	-1.2065	0.8033	0.4979	-0.3954	-0.0863	0.2482	-0.2482	0.4447	1.6459	-1.3072
	g_t^F	-0.2978	0.4508	0.0174	-0.0562	0.0327	0.3285	-0.3285	0.5885	0.0574	-0.1859
	τ_t^F	3.2131	-3.6163	-1.5817	1.6842	-0.0863	-0.9929	0.9929	-1.7786	-5.2289	5.5676
	i_t	0.9293	0.5793	-0.2338	-0.1495	0.3228	-3.1787	3.1787	-5.6940	-0.7730	-0.4942
	g_t^H	0.1456	-0.0272	-0.0242	-0.0059	0.0253	-0.3065	0.3065	-0.5490	-0.0800	-0.0194
Nash	τ_t^H	1.4286	-0.5334	-0.0721	-0.1553	0.1915	-3.5439	3.5439	-6.3482	-0.2384	-0.5135
	g_t^F	-0.4296	0.5744	0.0210	-0.0578	0.0310	0.4076	-0.4076	0.7302	0.0694	-0.1910
	τ_t^F	6.8594	-5.5344	-1.6558	1.3191	0.2835	-16.9330	16.9330	-30.3325	-5.4738	4.3608
	i_t	0.9368	0.5749	-0.2294	-0.1547	0.3234	-2.9852	2.9852	-5.3476	-0.7584	-0.5113
	g_t^H	0.1364	-0.0178	-0.0226	-0.0075	0.0254	-0.2692	0.2692	-0.4823	-0.0747	-0.0249
FL	τ_t^H	1.7470	-0.8120	-0.1151	-0.1225	0.2001	-4.0777	4.0777	-7.3045	-0.3805	-0.4048
	g_t^F	-0.4037	0.5484	0.0172	-0.0539	0.0310	0.3051	-0.3051	0.5466	0.0568	-0.1783
	τ_t^F	6.1141	-4.7821	-1.5078	1.1694	0.2850	-13.0557	13.0557	-23.3871	-4.9846	3.8657
	i_t	0.6527	0.7404	-0.1957	-0.1582	0.2981	-3.0052	3.0052	-5.3833	-0.6471	-0.5231
	g_t^H	0.1457	-0.0265	-0.0239	-0.0064	0.0255	-0.3578	0.3578	-0.6408	-0.0789	-0.0212
ML	τ_t^H	1.2850	-0.4787	-0.0305	-0.1744	0.1725	-3.7175	3.7175	-6.6592	-0.1008	-0.5765
	g_t^F	-0.4309	0.5880	0.0230	-0.0629	0.0336	0.3051	-0.3051	0.5465	0.0761	-0.2080
	τ_t^F	6.3608	-5.4950	-1.6520	1.4320	0.1853	-14.6393	14.6393	-26.2237	-5.4611	4.7339

Table 5: Losses – H and F households (L^H, L^F) and union-wide (L) – Low-Debt

	$b = 5\%$	$b = 7.5\%$	$b = 10\%$	$b = 12.5\%$	$b = 15\%$	$b = 19\%$
$n_H = 0.5$ - Union-wide loss*100						
LCoop	4.7806	4.8124	4.8459	4.8786	4.9082	4.9444
LN	4.6836	4.6825	4.7052	4.7512	4.8134	4.9132
LML	4.6781	4.6821	4.7047	4.7439	4.7941	4.8767
LFL	4.6604	4.6952	4.7382	4.7879	4.8393	4.9036
$n_H = 0.8$ - Union-wide loss*100						
LCoop	3.1790	3.2154	3.2550	3.2954	3.3339	3.3857
LN	3.1214	3.1323	3.1578	3.2015	3.2617	3.3681
LML	3.1298	3.1486	3.1760	3.2116	3.2523	3.3146
LFL	3.1153	3.1429	3.1775	3.2222	3.2771	3.3624
$n_H = 0.8$ - Loss of a representative household country H and F						
L^H_{Coop}	2.4060	2.4694	2.5388	2.6099	2.6778	2.7692
L^H_N	2.6775	2.6741	2.6698	2.6669	2.6668	2.6715
L^H_{ML}	2.7204	2.7583	2.7997	2.8443	2.8883	2.9425
L^H_{FL}	2.6708	2.6825	2.6847	2.6785	2.6682	2.6551
L^F_{Coop}	6.2712	6.1994	6.1200	6.0376	5.9584	5.8518
L^F_N	4.8973	4.9653	5.1101	5.3399	5.6416	6.1548
L^F_{ML}	4.7675	4.7097	4.6808	4.6808	4.7085	4.8027
L^F_{FL}	4.8932	4.9844	5.1486	5.3967	5.7125	6.1916

Table 6: Losses – H and F households (L^H, L^F) and union-wide (L) – High-Debt

	$b = 40\%$	$b = 50\%$	$b = 60\%$	$b = 70\%$	$b = 80\%$	$b = 90\%$	$b = 100\%$	$b = 110\%$
$n_H = 0.5$ - Union-wide loss*100								
LCoop	4.9456	4.9173	4.8950	4.8790	4.8679	4.8602	4.8550	4.8517
LN	4.9083	4.9870	5.1264	5.2616	5.3746	5.4657	5.5391	5.5991
LML	4.8840	4.9274	5.0697	5.2227	5.3816	5.4507	5.5297	5.5930
LFL	5.1412	5.2830	5.3826	5.4596	5.5226	5.5756	5.6211	5.6606
$n_H = 0.8$ - Union-wide loss*100								
LCoop	3.4394	3.4152	3.3917	3.3726	3.3577	3.3462	3.3373	3.3305
LN	3.4686	3.4900	3.5174	3.5413	3.5608	3.5767	3.5902	3.6018
LML	3.3425	3.3916	3.4625	3.5078	3.5360	3.5563	3.5728	3.5868
LFL	3.4998	3.5420	3.5623	3.5753	3.5855	3.5946	3.6031	3.6111
$n_H = 0.8$ - Loss of a representative household country H and F								
L^H_{Coop}	2.8423	2.7833	2.7272	2.6810	2.6440	2.6146	2.5910	2.5717
L^H_N	2.6277	2.5687	2.5232	2.4906	2.4671	2.4496	2.4360	2.4251
L^H_{ML}	2.7470	2.6293	2.5531	2.5040	2.4721	2.4506	2.4352	2.4236
L^H_{FL}	2.5536	2.5029	2.4701	2.4484	2.4332	2.4217	2.4127	2.4054
L^F_{Coop}	5.8276	5.9426	6.0497	6.1391	6.2122	6.2724	6.3228	6.3656
L^F_N	6.8319	7.1753	7.4944	7.7439	7.9352	8.0853	8.2070	8.3088
L^F_{ML}	5.7244	6.4406	6.5449	7.5228	7.7913	7.9794	8.1231	8.2398
L^F_{FL}	7.2844	7.6980	7.1275	8.0828	8.1951	8.2862	8.3643	8.4339