Journal of Economic Dynamics & Control 000 (2018) 1–21

Contents lists available at ScienceDirect

Journal of Economic Dynamics & Control

journal homepage: www.elsevier.com/locate/jedc

Optimal discretionary monetary and fiscal policies in a country-size heterogeneous monetary union

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ARTICLE INFO

Article history:
Received 26 January 2018
Accepted 30 January 2018
Available online xxx

JEL classification:
E52
E61
E62
E63

Keywords:
Monetary union
Optimal discretionary policies
Country-size asymmetry
Government debt

ABSTRACT

This paper develops a New Keynesian model of a monetary union where atomistic-small economies coexist with a large economy. It explores how the level of public debt shapes non-cooperative discretionary policies. It evaluates welfare losses for small and large member countries.

The paper demonstrates that higher public debt levels hamper business cycle stabilization for the union as a whole and, in particular, penalize the stabilization performance of small country-members. While cooperation and monetary leadership is preferable to fiscal leadership for the union as whole and for the small countries, the big country prefers fiscal leadership, where it explores a larger strategic power vis-a-vis the common monetary policy authority. Political support for cooperation may be hard to achieve. Under low debt levels, cooperative stabilization outcomes are relatively similar to the non-cooperative ones.

1. Introduction

In the course of the latest financial and economic crisis, public debt has increased considerably in many European and Monetary Union (EMU) countries. A higher level of government indebtedness may constrain fiscal policy in business cycle stabilization. Moreover, discretionary policies may further constrain short-run stabilization, creating debt stabilization bias.[1] However, a higher level of government indebtedness may also bring stabilization gains, as it increases the power of monetary policy towards debt-stabilization and lends more effectiveness to fiscal policy on short-run stabilization (Leith and Wren-Lewis, 2013). Therefore, the optimal policy-mix is likely to depend crucially on the level of government indebtedness and welfare stabilization costs may evolve non-monotonically with debt (Blake and Kirsanova, 2011).

Additionally, since in the EMU institution framework a common monetary policy coexists with decentralized fiscal policies, strategic interactions between non-coordinated policies may seriously hamper the business cycle stabilization. Relying on the literature, we conjecture that these strategic interactions and the resulting stabilization costs may be shaped by the

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[1] Benigno and Woodford (2003) and Schmitt-Grohé and Uribe (2004) show that, when policymakers can commit to time-inconsistent policies, government debt follows a random walk behavior, in response to shocks. In turn, Leith and Wren-Lewis (2013) show that, when policymakers are constrained to follow discretionary time-consistent policies, debt no longer follows a random walk and, instead, returns to its steady-state level following shocks. This overzealous behavior towards debt-stabilization (also called "debt stabilization bias") produces significant welfare stabilization costs.

https://doi.org/10.1016/j.jedc.2018.01.043
0165-1889/

leadership structure of monetary and fiscal policy decisions, the extent of government indebtedness and by the country-size asymmetry of the monetary union.

The EMU is a very country-size heterogeneous union. Germany's GDP represents approximately 28.5% of the union's GDP; the three major economies (France, Germany and Italy) represent approximately 66.2% of the Euro area's GDP.[2] It is likely that large and small countries in a monetary union face different stabilization costs. A larger, rather closed, economy is likely to stabilize country-specific shocks better, because the changes in the terms-of-trade have lower effect on its inflation. Such country may also rely more on the common monetary policy for stabilization purposes, due to its larger union-wide effects. Moreover, since its fiscal policy cross-border and union-wide externalities are larger, its fiscal authority realizes that it holds a larger strategic power than a smaller open economy.

In this paper, we assess how the level of public debt shapes discretionary policies in a country-size heterogeneous monetary union and affects macroeconomic stabilization performance in cooperative and non-cooperative regimes (simultaneous-moves, monetary and fiscal leadership). We also evaluate welfare losses for small and big member countries.

To address these issues, we develop a multi-country DSGE model of a monetary union, with monopolistic competition and sticky prices, where national fiscal authorities are allowed to borrow, and where their policy actions have demand and supply-side effects. We assume that monetary and fiscal authorities engage in optimal discretionary policies.[3]

We fill a gap in the literature by developing a multi-country model that allows the analysis of monetary and fiscal policy interactions in a more realistic monetary union environment, where fiscal authorities of large and very small countries coexist. The model includes two blocks, one large country and many atomistic-small countries, where the relative size of the large country can vary. It nests both two-country (e.g., Beetsma and Jensen, 2005, 2004; Ferrero, 2009) and a continuum of small economies (e.g., Galí and Monacelli, 2008; Leith and Wren-Lewis, 2011) monetary union models. Among others, Canzoneri et al. (2005) and Mykhaylova (2011) also consider country-size asymmetry in a monetary union, although only in the two-country setting.[4]

Although many commentators advocate the desirability of policy cooperation in the EMU, this is still a virtual scenario.[5] Indeed, fiscal decentralization in the EMU requires, realistically, to model non-cooperative interactions. Early literature on non-cooperative interactions within a monetary union relies on ad hoc and static models (e.g., Dixit and Lambertini, 2003a, 2003b). More recent, although scarce, literature uses dynamic monetary union models, which are more appropriate to analyze the role of public debt in policy interactions. This literature covers mostly simultaneous-move fiscal and monetary policymaking (e.g., Beetsma and Jensen, 2005; Forlati, 2009; van Aarle et al., 2002). Studies using dynamic models to analyze implications of intra-period leadership are rare, e.g., Blueschke and Neck (2011) and Orjasniemi (2014). The economic framework developed in this paper is general as it encompasses all these cases and further extends to the case of multiple players in a monetary union.

Our results show that government debt levels crucially shape the need for adopting policy cooperation in a monetary union. While, under low debt levels, cooperative outcomes are relatively similar to the non-cooperative ones; in a high debt environment, union-wide welfare costs of non-cooperation are substantially higher than those of cooperation. In this case, mechanisms to enforce cooperation are recommended, because as we show a large country may strongly oppose to cooperation. While intra-period fiscal leadership is likely to be the best among possible leadership arrangements in a single country (e.g., Blake and Kirsanova, 2011), we find that this regime only favors the large country in a monetary union. A highly indebted big country clearly prefers fiscal leadership, where it can exploit a larger strategic power vis-à-vis the common monetary policy authority; this regime, however, imposes substantial welfare costs on the small countries and on the union as a whole.

In turn, our results are in accordance with those of Chari and Kehoe (2007) who argue on the advantage of the intra-period monetary leadership (with precommitment) in a monetary union, albeit using a very different model. In this paper we use a more standard and policy-relevant DSGE model in contrast to the simple two-period model of Chari and Kehoe (2007).

The paper is organized as follows. Section 2 outlines the model. Section 3 describes the policy setup, Section 4 presents the baseline calibration of the model. Section 5 discusses the performance of optimal discretionary policies across different public debt levels and policy regimes, and the implications of country-size asymmetry. It also includes a sensitivity analysis. Section 6 concludes.

2. A currency union model

We model the currency union as a closed system, consisting of two blocks of countries, populated by a continuum of agents $\in$ [0, 1]. The first block is a big country, indexed by **B**, with a relative size of (1-n), $n \in$ [0, 1]. The second block,

[2] Source: Eurostat.

[3] While the literature generally assumes discretionary behavior for fiscal authorities, there is less consensus regarding the modeling of monetary policy behavior. In addition to theoretical and practical feasibility motivations, recent empirical evidence shows that independent central banks, like the ECB, FED or the Bank of England, behave more closely to model simulated outcomes under optimal discretionary policy than under commitment (*e.g.*, Chen *et al.*, 2017a, 2017b, Coroneo *et al.*, 2012, Givens, 2012, and Kirsanova and le Roux, 2013).

[4] Forlati (2015) also develops a two-block model, however we have additional mechanisms in this paper allowing for both monetary and fiscal policy interactions under government debt constraints.

[5] See Beetsma and Giulidori (2010) for a recent survey.

Please cite this article as: P. Vieira et al., Optimal discretionary monetary and fiscal policies in a country-size heterogeneous monetary union, Journal of Economic Dynamics & Control (2018), https://doi.org/10.1016/j.jedc.2018.01.043

indexed by **S**, has dimension n and consists of a continuum of small countries, each of measure zero, indexed by $s \in [0, n]$. The big country (**B**) consists of a continuum of small geographic units, indexed by b, on the interval $[n,1]$. In terms of population (households and firms), each geographic unit is equivalent to a small country, but, differently from the latter, is subject to the same shocks and shares the same fiscal authority.[6]

Households and firms in each geographic unit (s or b) are indexed by h on the interval [0, 1]. In each country, households' preferences reflect home bias in consumption. Each household supplies a differentiated labor input, specializing in the production of a specific final good (indexed by h). Labor is the only input of production and it is immobile across countries. Firms are wage-takers in segmented labor markets and are subject to price stickiness constraint; they are monopolistically competitive and produce a continuum of differentiated final tradable goods. Financial markets are complete and the law of one price holds but, given the home-biased preferences, the purchasing power parity does not hold for aggregate consumption indexes. Each country has an independent fiscal authority, which finances government spending by one-period bonds and distortionary taxes. A common monetary policy is conducted by a single central bank (CB). Countries are subject only to technology shocks.

In this section we only provide a log-linearized summary of the model, while the detailed presentation is provided in Appendix A.[7] All variables are written in gap form ($\tilde{x}_t$).[8] Variables of the form $\overline{\overline{x_t}}$ denote log-deviations of efficient values from the steady-state. Variables for a small and the big countries are indexed, respectively, with s (or i) and **B**, while union-wide variables are superscripted by an asterisk.[9]

2.1. Equilibrium conditions

From the households' optimization problem for countries s and **B** and aggregating over all countries, we get the following union-wide consumption Euler equation with variables in gaps:

$$\tilde{c}_t^* = E_t\left\{\tilde{c}_{t+1}^*\right\} - \sigma\left(\tilde{r}_t^* - E_t\left\{\pi_{t+1}^*\right\}\right), \tag{1}$$

where $\tilde{c}_t^*$, $\tilde{r}_t^*$ and π_{t+1}^* denote union-wide private consumption, short-term nominal interest rate (the monetary policy instrument) and the union-wide inflation rate. Parameter σ denotes the inverse of the intertemporal elasticity of substitution.

A standard New Keynesian open-economy Phillips curve results from the firms' optimization problem with prices set in a staggered fashion *a la* Calvo (1983):

$$\begin{aligned}\pi_t^j &= \beta E_t\left\{\pi_{t+1}^j\right\} + \phi^j\left(\frac{1}{(1-\varphi)[\sigma(1-\alpha)+\Phi]} + \chi\right)\tilde{y}_t^j \\ &\quad - \phi^j\frac{\varphi}{(1-\varphi)[\sigma(1-\alpha)+\Phi]}\tilde{g}_t^j + \phi^j\left(\frac{1}{\sigma(1-\varphi)} - \frac{1}{(1-\varphi)[\sigma(1-\alpha)+\Phi]}\right)\tilde{y}_t^* \\ &\quad - \phi^j\varphi\left(\frac{1}{\sigma(1-\varphi)} - \frac{1}{(1-\varphi)[\sigma(1-\alpha)+\Phi]}\right)\tilde{g}_t^* + \frac{\phi^j}{\left(1-\tau^j\right)}\tilde{\tau}_t^j\end{aligned} \tag{2}$$

where:

$$\phi^j = \begin{cases}\phi_S \equiv \frac{(1-\theta_S\beta)(1-\theta_S)}{\theta_S(1+\epsilon\chi)}, & for\ j = s,\ \forall s \in \boldsymbol{S} \\ \phi_B \equiv \frac{(1-\theta_B\beta)(1-\theta_B)}{\theta_B(1+\epsilon\chi)}, & for\ j = \boldsymbol{B},\end{cases}$$

and $\Phi \equiv \alpha[\gamma - (1-\alpha)(-\gamma+\sigma)]$.

Respectively, π_t^j, $\tilde{y}_t^j$, $\tilde{g}_t^j$ and $\tilde{\tau}_t^j$ are country-specific producer price inflation, output, government spending and income tax, while $\tilde{y}_t^*$ and $\tilde{g}_t^*$ are union-wide output and government spending. Parameter β stands for the intertemporal discount factor, χ is the inverse of the Frisch elasticity of labor supply, α stands for the degree of trade openness $\in$ [0,1] and (1-θ_j) is the probability of a firm resetting its price in any given period ($j = \{\mathbf{B}, s\}$). Parameters γ and ϵ are, respectively, the elasticity of substitution between domestic and foreign goods and the elasticity of substitution between goods produced within a given country. The steady-state government spending share in output is given by φ.

Combining the Euler equations for each country under the assumption of complete financial markets, we obtain the following international risk sharing conditions for households belonging to any two different countries: a small s country and the big country **B** (Eq. (3)); two small countries, s and i (Eq. (4)).

$$\tilde{c}_t^s = \tilde{c}_t^B + \sigma(1-\alpha)\left[\tilde{tt}_t^s - n\tilde{tt}_t^B\right], \forall s \in \mathbf{S} \tag{3}$$

[6] Geographic regions in Forlati (2015) are all very small countries.

[7] Here and below all references are to be on Online Appendix available online or upon request from authors.

[8] For a generic variable X_t, its gap is defined as $\tilde{x}_t = \hat{x}_t - \overline{\overline{x}}_t$, where $\hat{x}_t$ and $\overline{\overline{x}}_t$ denote, respectively, their effective and efficient values in log-deviations from the efficient steady-state which are derived from solving the union-wide social planner's problem in Appendix B.

[9] A union-wide variable, x_t^*, is defined as $x_t^* = nx_t^S + (1-n)x_t^B$, where x_t^S is in turn defined as $x_t^S = \frac{1}{n}\int_0^n x_t^s ds$.

$$\tilde{c}_t^s = \tilde{c}_t^i + \sigma(1-\alpha)\left[\widetilde{tt}_t^s - \widetilde{tt}_t^i\right], \forall s, i \in \mathbf{S} \tag{4}$$

where $\widetilde{tt}_t^s$ and $\widetilde{tt}_t^i$ are terms of trade gaps of countries s and i with respect to the union, while $\widetilde{tt}_t^B$ is the terms of trade gap for the big country **B** with respect to block **S**.

Definition of terms of trade gaps for these countries yields:

$$\widetilde{tt}_t^s = \widetilde{tt}_{t-1}^s + \pi_t^* - \pi_t^s - \left(\overline{\widetilde{tt}}_t^s - \overline{\widetilde{tt}}_{t-1}^s\right), \forall s \in \mathbf{S} \tag{5}$$

$$\widetilde{tt}_t^B = \widetilde{tt}_{t-1}^B + \frac{\pi_t^* - \pi_t^B}{n} - \left(\overline{\widetilde{tt}}_t^B - \overline{\widetilde{tt}}_{t-1}^B\right) \tag{6}$$

Eqs. (7) and (8) represent country-specific aggregate demands:

$$\tilde{y}_t^s = (1-\varphi)\tilde{c}_t^* + (1-\varphi)[\sigma(1-\alpha) + \Phi]\widetilde{tt}_t^s + \varphi\tilde{g}_t^s, \forall s \in \mathbf{S} \tag{7}$$

$$\tilde{y}_t^B = (1-\varphi)\tilde{c}_t^* + (1-\varphi)[\sigma(1-\alpha) + \Phi]n\widetilde{tt}_t^B + \varphi\tilde{g}_t^B \tag{8}$$

The flow budget constraints for national governments are given by[10]

$$\begin{aligned}\hat{d}_{g,t}^s = {} & \tilde{r}_t^* + \frac{1}{\beta}\left\{\hat{d}_{g,t-1}^s - \pi_t^s + \frac{Y^s}{D_g^s}[\varphi\tilde{g}_t^s - \tau^s\tilde{y}_t^s - \tilde{\tau}_t^s] + \alpha\widetilde{tt}_{t-1}^s - \left(\frac{1}{1+r^*}\right)\alpha\widetilde{tt}_t^s\right\} \\ & + \overline{\tilde{r}}_t^* + \frac{1}{\beta}\left\{\frac{Y^s}{D_g^s}\left[\varphi\overline{\tilde{g}}_t^s - \tau^s\overline{\tilde{y}}_t^s - \overline{\tilde{\tau}}_t^s\right] + \alpha\overline{\widetilde{tt}}_{t-1}^s - \left(\frac{1}{1+r^*}\right)\alpha\overline{\widetilde{tt}}_t^s\right\}, \forall_{s\in\mathbf{S}}\end{aligned} \tag{9}$$

$$\begin{aligned}\hat{d}_{g,t}^B = {} & \tilde{r}_t^* + \frac{1}{\beta}\left\{\hat{d}_{g,t-1}^B - \pi_t^B + \frac{Y^B}{D_g^B}\left[\varphi\tilde{g}_t^B - \tau^B\tilde{y}_t^B - \tilde{\tau}_t^B\right] + \alpha n\widetilde{tt}_{t-1}^B\left(\frac{1}{1+r^*}\right)\alpha n\widetilde{tt}_t^B\right\} \\ & + \overline{\tilde{r}}_t^* + \frac{1}{\beta}\left\{\frac{Y^B}{D_g^B}\left[\varphi\overline{\tilde{g}}_t^B - \tau^B\overline{\tilde{y}}_t^B - \overline{\tilde{\tau}}_t^B\right] + \alpha n\overline{\widetilde{tt}}_{t-1}^B - \left(\frac{1}{1+r^*}\right)\alpha n\overline{\widetilde{tt}}_t^B\right\}\end{aligned} \tag{10}$$

where $D_{g,t}^j \equiv \frac{R_t^* \mathbb{D}_{g,t}^j}{P_{c,t}^j}$ denotes the real value of country *j's* debt (expressed in consumer prices) at maturity in *per capita* terms. $R^* = \frac{1}{\beta}$, D_g^j, τ^j, Y^j and $G^j = \varphi Y^j$ are the steady-state values for the corresponding variables.

We assume the following exogenous process for technology shocks:

$$a_t^j = \rho_a a_{t-1}^j + \varepsilon_t^j, \;\; j = \{\mathbf{B}, s\}$$

Given shocks, which determine efficient equilibrium dynamics, the paths for policy instruments ($\tilde{g}_t^j$, $\tilde{\tau}_t^j$ and $\tilde{r}_t^*$) and the initial values of $\widetilde{tt}_{t-1}^j$, the system including Eqs. (1)–(10) provides solutions for the endogenous variables $\tilde{c}_t^*$, $\tilde{c}_t^j$, $\tilde{y}_t^j, \tilde{y}_t^*$, π_t^j, π_t^*, $\widetilde{tt}_t^j$ and $\widehat{d_{g,t}^j}$, for $j = \{\mathbf{B}, s\}$.

2.2. Union-wide social welfare

Following Woodford (2003), the union-wide welfare objective function, W^*, can be approximated up to second-order around the efficient deterministic steady-state, yielding[11]

$$W^* \approx -\Omega E_0\left\{\sum_{t=0}^{\infty}\beta^t L_t^*\right\}, \;\; \Omega = \frac{u_c C}{(1-\varphi)} \tag{11}$$

where

$$L_t^* = \frac{1}{2}\left[\int_0^n L_t^s ds + (1-n)L_t^B\right]$$

[10] With asset markets clearing only at the monetary union level, the only public sector intertemporal budget constraint is the union-wide consolidated debt. However, in the context of a monetary union such as the EMU, there are arguments to impose intertemporal budget constraints at the national level (see discussion in Leith and Wren-Lewis, 2011).

[11] See Appendix C.

and

$$L_t^s \left\{ \begin{array}{c} \frac{\epsilon}{\phi_S}(\pi_t^s)^2 \\ +(1-\varphi)\left[\frac{1}{\sigma}+(1-\varphi)\chi\right](\tilde{c}_t^s)^2 \\ +\varphi\left(\frac{1}{\psi}+\varphi\chi\right)(\tilde{g}_t^s)^2 \\ +(1-\varphi)\left[\gamma\alpha(\alpha-2)+2\Phi+(1-\varphi)\Phi^2\chi\right]\left(\tilde{tt}_t^s\right)^2 \\ +2\varphi(1-\varphi)\chi\tilde{c}_t^s\tilde{g}_t^s \\ +(1-\varphi)[2\alpha+2(1-\varphi)\Phi\chi]\tilde{c}_t^s\tilde{tt}_t^s \\ +2\varphi(1-\varphi)\Phi\chi\tilde{g}_t^s\tilde{tt}_t^s \end{array} \right\} \tag{12}$$

$$L_t^B \left\{ \begin{array}{c} \frac{\epsilon}{\phi_B}\left(\pi_t^B\right)^2 \\ +(1-\varphi)\left[\frac{1}{\sigma}+(1-\varphi)\chi\right]\left(\tilde{c}_t^B\right)^2 \\ +\varphi\left(\frac{1}{\psi}+\varphi\chi\right)\left(\tilde{g}_t^B\right)^2 \\ +(1-\varphi)\left[\gamma\alpha(\alpha-2)+2\Phi+(1-\varphi)\Phi^2\chi\right]\left(n\tilde{tt}_t^B\right)^2 \\ +2\varphi(1-\varphi)\chi\tilde{c}_t^B\tilde{g}_t^B \\ +(1-\varphi)[2\alpha+2(1-\varphi)\Phi\chi]\tilde{c}_t^B\left(n\tilde{tt}_t^B\right) \\ +2\varphi(1-\varphi)\Phi\chi\tilde{g}_t^B\left(n\tilde{tt}_t^B\right) \end{array} \right\} \tag{13}$$

$$\phi_S \equiv \frac{(1-\theta_S\beta)(1-\theta_S)}{\theta_S(1+\epsilon\chi)};\ \phi_B \equiv \frac{(1-\theta_B\beta)(1-\theta_B)}{\theta_B(1+\epsilon\chi)};\ \Phi \equiv \alpha[\gamma-(1-\alpha)(-\gamma+\sigma)].$$

3. Policy setup

In this paper, we have one monetary authority who sets union-wide short-term interest rate, and an independent fiscal authority in each country. Authorities cooperate if they share the union-wide objectives; authorities do not cooperate if their objectives differ. When modeling their interactions, one needs to take a stand on their national objectives, intra-period leadership structure and the type of policy. This section addresses these issues.

First, we define national objectives as country-relevant counterparts of the union-wide policy objectives, where the latter is the union-wide social welfare loss.

Second, when the authorities cooperate, the order of intra-period moves does not matter for the unique equilibrium. However, when they do not cooperate the intra-period leadership structure may shape results in quantitative and qualitative important ways. In this section, we concentrate on three policy regimes in which either monetary or fiscal authorities have intra-period advantage, or they all move simultaneously. Arguably, the fiscal leadership is a more realistic description of the EMU fiscal authorities (Beetsma and Giulidori, 2010), however there is some intuition to suggest that the monetary leadership will outperform in the monetary union (Chari and Kehoe, 2007). We examine all these possibilities in a DSGE-type policy-relevant model in this section.

Third, the policy authorities may operate with different degrees of commitment. In this paper we concentrate on the case of policy discretion. There is now substantial empirical evidence that the central bank may lack the ability to precommit (Chen et al., 2017a, 2017b; Coroneoet al., 2012; Givens, 2012; Kirsanova and le Roux, 2013). In contrast, the empirical research on optimality of fiscal policy is scarce; actual spending decisions are taken sequentially (annually with the budget) and tax rate changes are more irregular and clearly discretionary. In this paper, therefore, we explore the case where all authorities share the same inability to precommit and act discretionary.

3.1. Policy objectives

3.1.1. Union-wide objectives

Under full cooperation, benevolent authorities seek to maximize union-wide welfare (11), subject to the structural Eqs. (1)–(10). Accordingly, all policymakers share the same per-period social loss function L_t^* under cooperation: $L_t^{CB} = L_t^B = L_t^s = L_t^*$, $\forall s \in \mathbf{S}$.

3.1.2. National objectives

Alternatively, under non-cooperation, we assume that national fiscal authorities are exclusively concerned with their own citizens and, hence, their objective functions only include national targets. We further assume that an approximation for national objective functions can be obtained from splitting the union-wide welfare function (11). Thus, the underlying efficient and steady-state equilibria are kept the same as in the cooperative case.[12]

[12] Leith and Wren-Lewis (2011) suggest that this approximation may describe an agreement between countries not to exploit steady-state terms-of-trade externality. This also allows avoiding the level bias in the steady-state, so we can concentrate on the stabilization bias.

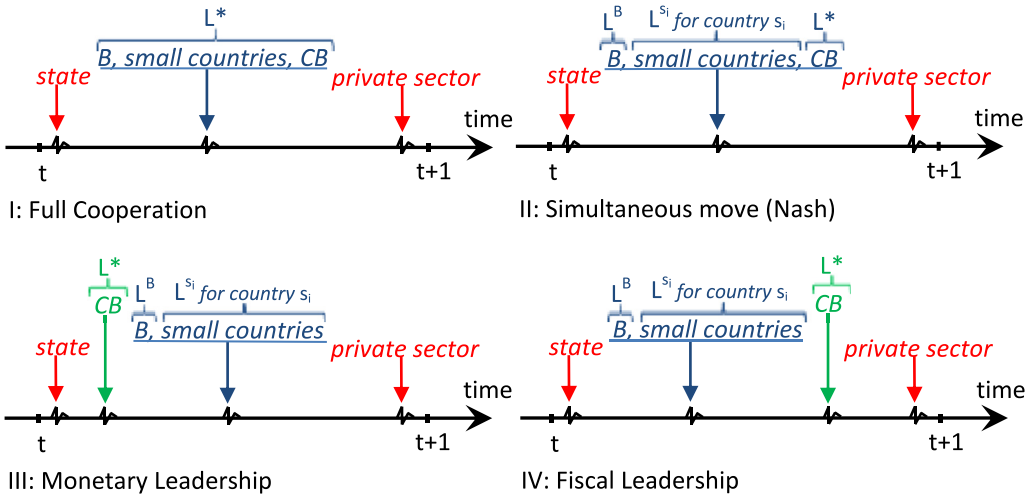

Fig. 1. Policy regimes and intra-period timing of moves.

Accordingly, for non-cooperative policymakers, $L_t^{CB} = L_t^* \neq L_t^B \neq L_t^s$, with L_t^B and L_t^s given by (12) and (13), respectively.

3.2. Policy interactions

As a benchmark, we assume that policymakers are benevolent and cooperate. The conflict of policy objectives allows for strategic interactions between policymakers. Different equilibria will arise depending on the intra-period order of policy moves.

We consider both simultaneous-move (Nash) and leadership (monetary and fiscal leadership) equilibria. The timing of the events is as follows (*cf.* Fig. 1). First, at the beginning of each time period, shocks are realized and states are observed. Second, policymakers react, anticipating the reaction of the private sector; in other words, the private sector is always the ultimate follower.[13] The moves of the policymakers depend on the policy scenario. Under Nash, the central bank and fiscal authorities set instruments simultaneously; under monetary leadership, the central bank sets the interest rate before fiscal authorities choose policy (fiscal authorities always play Nash between them), while the reverse occurs under fiscal leadership. To solve for these dynamic policy games, we follow the methodology developed in Currie and Levine (1993).[14]

To illustrate the methodology, consider the case of monetary leadership.[15] The private sector's optimization problem can be represented by the following system, written in a state-space form:

$$Z_{t+1} = \begin{bmatrix} Y_{t+1} \\ E_t\ X_{t+1} \end{bmatrix} = A \begin{bmatrix} Y_t \\ X_t \end{bmatrix} + B \begin{bmatrix} U_t^B \\ U_t^i \\ U_t^{ii} \end{bmatrix} + D\left[U_t^{CB}\right] + C\varepsilon_{t+1}, \tag{14}$$

where Y_t is the vector of predetermined variables, X_t are jump variables, U_t^B, U_t^i, and U_t^{ii} represent the instruments of the followers fiscal authorities (country **B**, country $ii \in \mathbf{S}$ and remaining counties of block **S**, i). U_t^{CB} stands for the central bank instrument and ε_t is a vector of shocks. Fiscal authorities - moving simultaneously, treating the monetary policy instrument as parametric, and anticipating the private sector's reaction -, minimize their loss functions of the form:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(Z_t' Q^j Z_t + Z_t' P^j U_t + U_t' P^{j'} Z_t + U_t' R^j U_t\right), \quad j = \{\mathbf{B}, s\} \tag{15}$$

In a linear quadratic setup, the optimal solution to the fiscal policy problem belongs to the class of linear feedback rules of the form:

$$U_t^j = -F_t^j Y_t - L_t^j U_t^{CB}, \quad j = \{\mathbf{B}, s\} \tag{16}$$

where F_t^j denotes feedback coefficients on the predetermined state variables and L_t^j is the feedback on the leader's policy which is observed at the time of fiscal decision. The leader, the monetary authority, optimizes its objective in the form of (15) but taking into the account the behavior of fiscal authorities (16). Monetary authority reaction function takes the form:

$$U_t^{CB} = -F_t^{CB} Y_t \tag{17}$$

[13] This timing is standard in the DSGE literature; see Clarida et al. (1999).
[14] Further examples are in Söderlind (1999) and Blake and Kirsanova (2011).
[15] The detailed solution algorithm for this case is in Appendix D.

Given policy, the rational expectations reaction of the private sector is found in a conventional way, so the policy feedbacks F_t^j, L_t^j and F_t^{CB} can be updated. The algorithm is iterated until convergence.

4. Baseline calibration

We assume that country **B** and block **S** have identical dimension ($n = 0.5$). The model is calibrated at a quarterly frequency: the intertemporal discount factor is set $\beta = 0.99$, which implies a 4% *per annum* steady-state interest rate. We choose $\alpha = 0.4$, which implies a 40% share of domestic consumption allocated to imported goods for the small countries, but for the large economy this value is 20%. We assume $\psi = \sigma = 0.4$, which implies a coefficient of risk aversion for private and public consumption equal to 2.5, as in Beetsma and Jensen (2005). The inverse of the labor supply elasticity, χ, is equal to 3, following Kirsanova and Wren-Lewis (2012). The elasticity of substitution between goods produced in the same country, ϵ, is equal to 11, implying a price mark-up of 10%. Following Ferrero (2009), we set the elasticity of substitution between domestic and foreign goods, γ, to 4.5. The steady-state share of public consumption in output, φ, is 0.25, a value commonly used in the literature. We consider that $\theta_S = \theta_B = 0.75$, in order to get an average length of price contracts equal to one year. The annual steady-state debt-to-output ratio, $\frac{D_g^j}{4Y^j}$, takes low and high values as benchmarks (15% and 60%, respectively). Finally, we assume a 1% standard deviation for technology shocks and set $\rho_a = 0.85$.

5. Optimal discretionary stabilization policies

We start with the benchmark case of cooperation. To understand policy trade-offs, we consider impulse responses to similar asymmetric technology shocks hitting, once at a time, only the big and a small country. Then, having identified union-wide and cross-border externalities, we analyze non-cooperative scenarios, where conflicting policy objectives generate strategic interactions between policymakers. Finally, using union-wide and national losses as metrics, we assess welfare stabilization costs across different debt levels and policy regimes.

5.1. Cooperation

Under time-consistent discretionary policies, permanent effects of shocks are fully eliminated and all variables, including debt, return to their efficient steady-state levels. The policy-mix and the speed of adjustment of the economy back to the steady-state depend on the level of the steady-state government debt (see, e.g., Leith and Wren-Lewis, 2013).

The effectiveness of monetary policy in debt-stabilization increases with debt-to-output ratios, because of the higher direct effects of interest and inflation rates on debt.[16] Conversely, as the steady-state public debt increases, fiscal policy instruments – particularly, the tax rate – become relatively less effective in debt-stabilization, as they become more powerful in offsetting inflationary consequences (cf. Leith and Wren-Lewis, 2013).[17] Following a shock that leads to both higher debt and inflation levels, conventional monetary and fiscal policy assignments apply if debt is low enough: the interest rate gap increases on impact to control for inflation ("active" monetary policy) while government spending gaps fall and the tax rate gaps increase to stabilize debt. However, for a high enough government debt, monetary policy tries to stabilize debt and the interest rate gap decreases on impact ("passive" monetary policy).[18] In turn, fiscal policy becomes relatively less effective in debt-stabilization and eventually moves towards an inflation-stabilization assignment. Hereafter, "low-debt" (annual debt-to-output ratio smaller than 28% in our simulations) refers to an environment where conventional policy assignments apply, while in the "high-debt" scenario (annual debt-to-output ratio $\geq$ 28%) monetary policy supports debt stabilization.

In what follows, in order to understand transmission mechanisms and identify externalities, we examine the impact of an asymmetric technology shock on the efficient equilibrium. Debt dynamics and the existence of nominal rigidities produce policy trade-offs and, despite we consider an identical-size shock in the big and the small country, the dynamics are different as country-size matters for propagation.

5.1.1. Technology shock at the big country

A negative technology shock at the big country B, by increasing the work effort to produce unit output, leads to a decrease on impact of the efficient levels of domestic output and, to a lesser extent, of the government spending. The terms-of-trade also fall, since the domestically produced goods (B-goods) become more expensive relative to foreign goods (S-goods), increasing output in the small countries.[19] Therefore, targeting efficient outcomes produces opposite budgetary consequences domestically and abroad: a primary government budget deficit at B, where output and tax revenues decrease, and a surplus in small countries, where the reverse occurs. Moreover, as the efficient interest rate increases on impact to ensure a lower efficient level of the union-wide private consumption, debt-service costs raise. This further enlarges B's deficit

[16] See Eqs. (9) and (10) when multiplied by Dg/Y.

[17] Higher steady-state debt levels lead to higher steady-state tax rates and, therefore, the impact of the tax rate on inflation further increases (see Eq. 2).

[18] We follow Leeper's (1991) categorization: a policy is "passive" when it supports debt-stabilization; conversely, policy is said to be "active" when it supports short-run stabilization.

[19] We assume substitutability between goods. Domestic and foreign goods are substitutes (complements) in the utility function when the trade elasticity is larger (smaller) than the intertemporal elasticity of substitution.

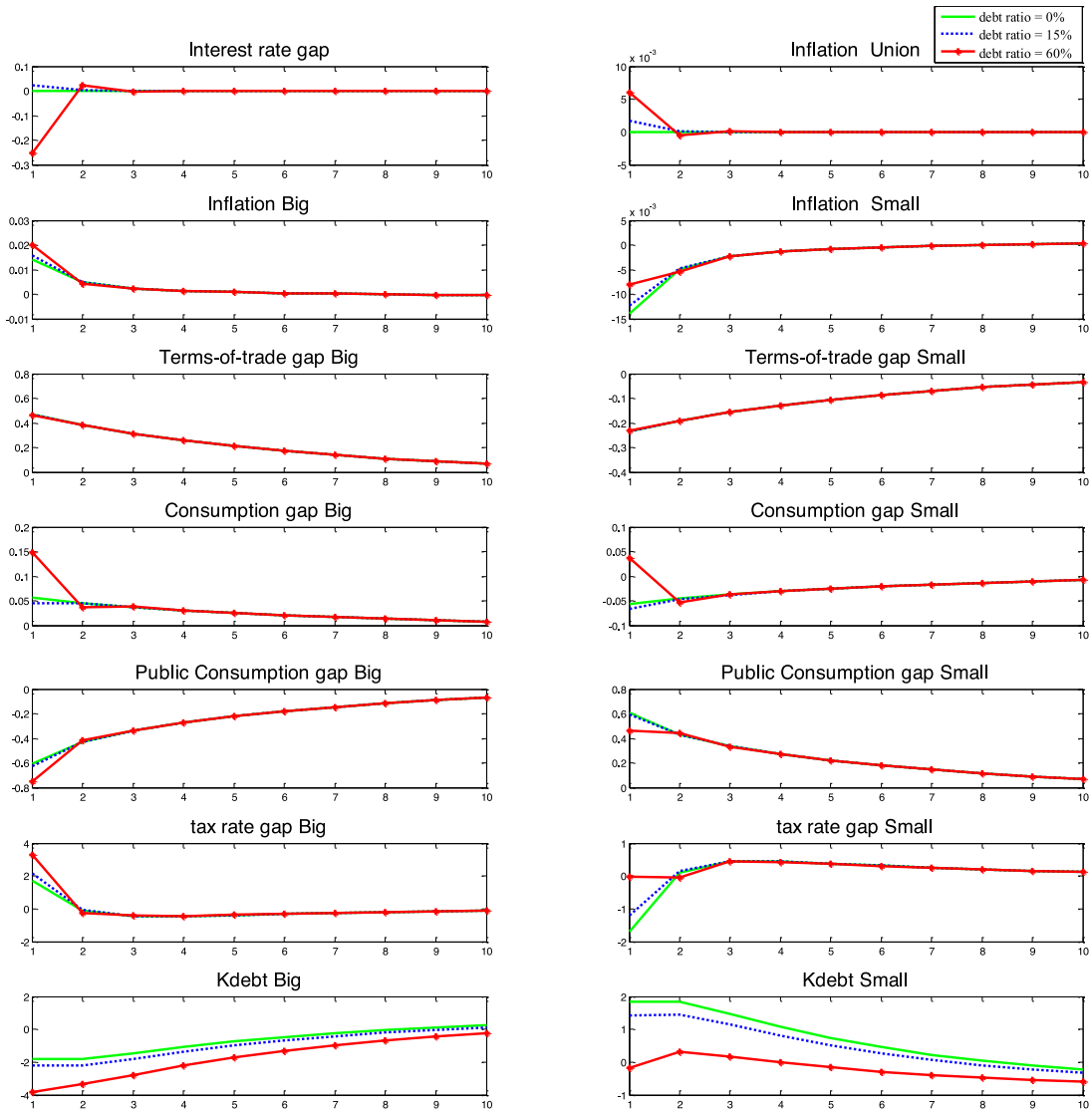

Fig. 2. Responses to a 1% negative technology shock at the Big country under optimal cooperative discretionary policy (debt-to-output ratios: 0%, 15% and 60%).

while it mitigates S's surplus. Thus, overall budgetary consequences are higher for country B than for the small countries, and union-wide debt increases on impact. Moreover, higher steady-state debt levels require higher steady-state tax rates that amplify the changes in the tax base. Hence, due to larger interest payments and to a larger decrease in tax revenues, the budgetary consequences of the shock increase with B's steady-state level of debt. For a small country, this only occurs for high enough debt levels, i.e., when debt-service costs exceed primary budget surplus.

Nominal rigidities preclude terms-of-trade from falling to their efficient level; a positive terms-of-trade gap inefficiently shifts demand from *s*-goods to B-goods, causing a positive output gap and reinforcing inflation in country B while the opposite occurs in the small countries.

Fig. 2 plots impulse responses of selected variables for different debt-to-output ratios.[20] As the shock causes a primary budget deficit in B and a surplus in the small countries, the reaction of the fiscal policy in the first period requires a positive tax rate gap (which increases firms' marginal costs and further accelerates inflation) and a negative government spending gap at country B. The reverse occurs for a small country.

The relative size of steady-state debt-to-output ratio is crucial for the direction and size of policy responses.

[20] In all figures, *K debt-j* denotes the absolute change in country j's public debt in percentage of the steady-state output.

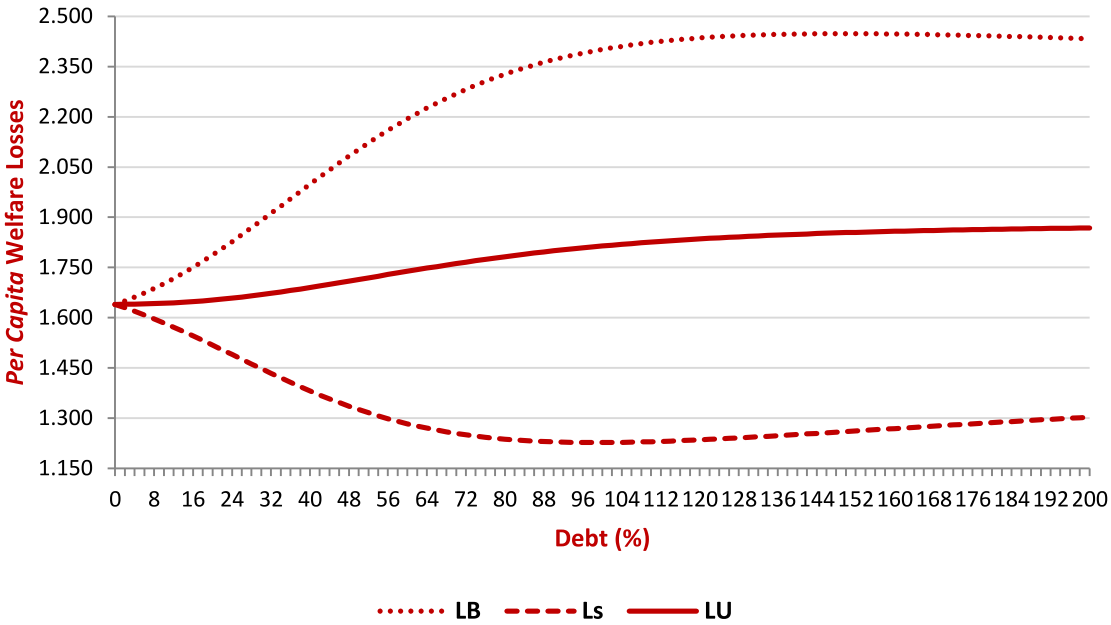

Fig. 3. Union-wide and country-specific per capita welfare losses across debt levels, under cooperative discretionary policy responses to a technology shock at the Big country.

First, in a *low-debt* monetary union, the reaction of the fiscal policy in the Big country dominates at the union level and generates union-wide inflation. To lessen the subsequent union-wide inflation, the interest rate gap increases in the first period, which further enlarges B's budget deficit while it mitigates S's fiscal surplus.

Moreover, as steady-state debt levels increase, the extent to which the shock affects national debts further amplifies this asymmetry. Therefore, with an increase in debt-to-output ratio, country B's fiscal policy becomes progressively more debt-adjusting while the reverse occurs in small countries. As a result, welfare stabilization costs increase in B while they decrease in small countries. Losses in the country B dominate at the union level and so welfare deteriorates with higher debt-to-output ratios for the union as a whole. This is shown in Fig. 3 that plots, for different debt levels, the welfare stabilization losses for the big country and a representative small country (L_B, L_s) and for the union (L_U) following a technology shock at B.

Second, in a *high-debt* monetary union, monetary policy is mostly concerned with debt-stabilization and the interest rate gap decreases, on impact, to reduce the union-wide debt level.[21] The higher the steady-state debt-to-output ratio, the greater the union-wide fiscal consequences of the shock and the more effective monetary policy is for debt-stabilization. Therefore, with greater debt-to-output ratio, monetary policy stabilizes debt in country B better, but destabilizes debt in a small country more. At the same time, with higher debt-to-output ratios, fiscal policy becomes progressively less debt-adjusting and more inflation-adjusting. As a result welfare slightly improves in country B; the opposite occurs in a small country. For the union as a whole, welfare stabilization costs increase monotonically with debt (cf. Fig. 3).

5.1.2. Technology shock at a small country

A negative technology shock at a very small (zero-dimension) country has no external effects, bringing only domestic implications. Therefore, there is neither monetary policy adjustment nor fiscal policy reactions from other countries. Similar to the case above, the fiscal authority decreases the spending gap and increases the tax gap on impact. This ensures stabilization of debt to its initial (efficient) level (*cf.* Fig. 4).

With greater debt-to-output ratio, the effect of shock on debt increases, but fiscal policy becomes less effective in controlling debt and so must react by more to debt. Therefore, welfare stabilization costs monotonically increase with the level of the steady-state debt (cf. Fig. 5).

To summarize, at the union level, welfare stabilization costs increase with the level of government indebtedness, as the aggregate budgetary consequences of the technology shocks also increase. The stabilization gains, resulting from the higher effectiveness of monetary policy for the debt-stabilization and of fiscal policy for the short-run stabilization in higher-debt environments, are not sufficiently large to outweigh the costs of stabilizing the larger budgetary consequences of shocks.

[21] This reduction of debt allows monetary policy to raise the interest rate gap in the second period which, by lowering inflation expectations, contributes to the reduction of the current union-wide inflation.

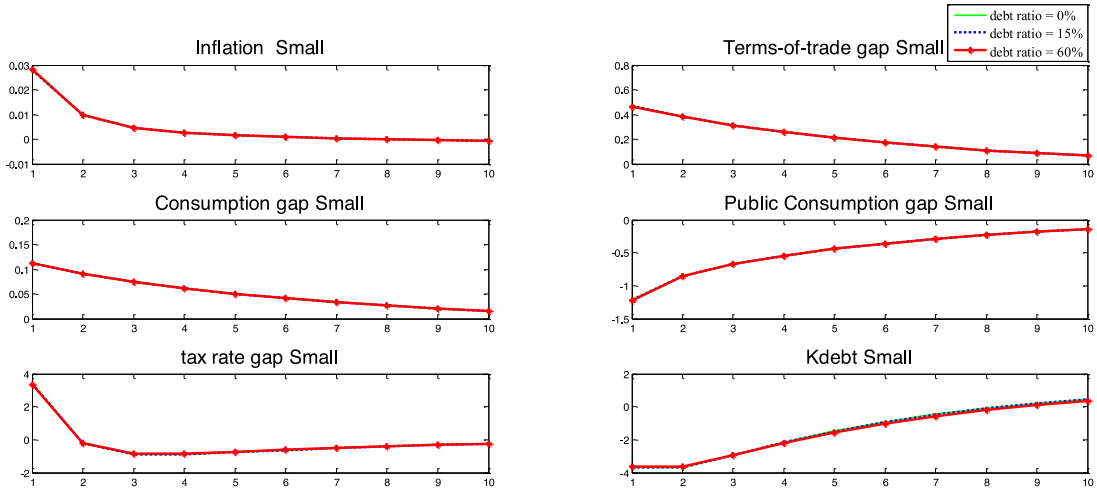

Fig. 4. Responses to a 1% negative technology shock at a small country under optimal cooperative discretionary policy (debt-to-output ratios: 0%, 15% and 60%).

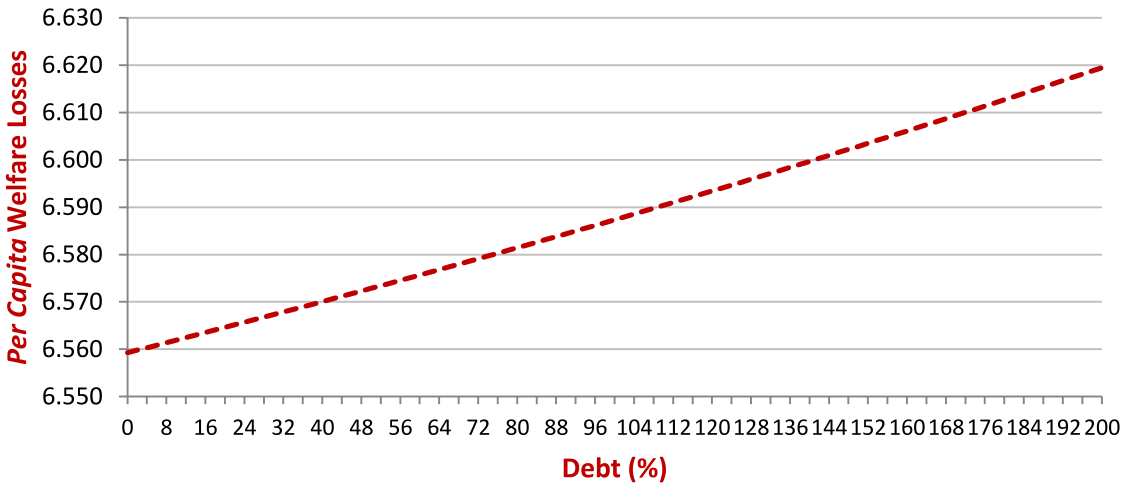

Fig. 5. Small country welfare loss across debt levels, under cooperative discretionary policy response to a domestic technology shock.

From the perspective of the big and the small countries, there are meaningful differences in the levels of welfare stabilization costs and in how they evolve with debt. In line with the findings of Canzoneri et al. (2005) and Machado and Ribeiro (2010), a small country always faces higher welfare stabilization costs than a big one, when countries are hit, simultaneously, by shocks at B and at the small country.[22] Furthermore, for realistic debt-to-output ratios, when the level of government indebtedness in a monetary union uniformly increases, then the welfare of a small country rises, while the welfare of a big country falls.[23] The reverse occurs, but only for sufficiently high debt-to-output ratios.

5.2. Non-cooperation

In non-cooperative scenarios, the benevolent monetary authority seeks to maximize the union-wide welfare but, differently from cooperation, national fiscal authorities are exclusively concerned with their national counterparts. The definition of national policy objectives disregards terms-of-trade externalities in the steady-state, but they still arise over the cycle. The extent to which fiscal policy reactions deviate from those under the cooperative regime crucially depends on the policy externalities. To identify such policy externalities, we consider symmetric and pure asymmetric technology shocks.

[22] Figs. 3 and 5 plot losses resulting from shocks to one country only. A sum of small country losses in Figs. 3 and 5 is greater than the loss of Big country in Fig. 3.

[23] In our model, all government debt is one-period so that monetary policy has high leverage over debt service costs. A one-period debt level in our setup should correspond to a higher average debt level in a model with more realistic term-structure of debt.

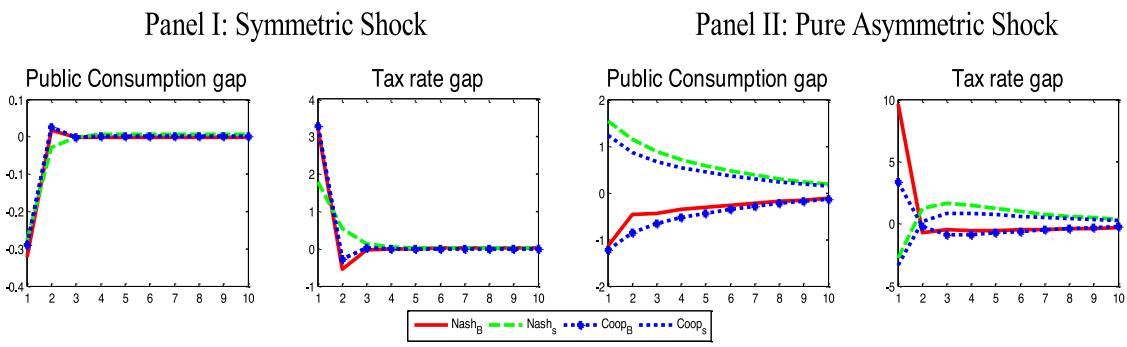

Fig. 6. Responses to a 1% symmetric negative technology shock vs. pure asymmetric shock (negative at country B and positive at Block S) – cooperation (Coop) vs. non-cooperation (Nash): debt = 60%.

We consider a global (symmetric) negative technology shock that allows us to abstract from terms-of-trade effects on impact and identify a "union-wide" externality.

This shock rises, simultaneously, inflation and debt. Fiscal policy increases the tax rate and decreases the government spending gaps to stabilize debt. As the tax affects marginal costs, it fuels inflation. Such policy mix helps to stabilize union-wide debt (so there is a positive "debt-related" externality) but further increases union-wide inflation (so there is a negative "standard" externality). The failure to internalize any of these union-wide externalities makes policy instruments to deviate from cooperation.[24] The assumptions that all debt is single-period and that policy is discretionary is important for the "debt-related" externality. Discretionary policy fails to stabilize inflation as efficiently as commitment policy does. The need to bring debt back to the steady-state requires generating the 'debt stabilization bias', as Leith and Wren-Lewis (2013) discuss. The assumption of one-period debt increases the relevance of this bias for policy interactions.

In response to this symmetric shock, the fiscal authority of a small country, while taking into account its negligible impacts on the union, abstracts from the fact that all countries react identically to identical shocks. Thus, it fails to internalize a larger externality jointly produced by all other fiscal authorities on the union-wide variables and thus it does not expect important feedback response from the interest rate. In contrast, even for identical shocks, the fiscal authority in the big country still internalizes its own effect on the union and expects that the monetary policymaker will feed back. The authority does not internalize its effect on smaller countries and ignores the aggregate response of small fiscal authorities.

Therefore, in face of a global shock, both countries have incentives to deviate from cooperation, but the small country faces a larger incentive to deviate than the big country as it fails to internalize a larger externality (it ignores the fiscal policy reaction of all the other countries while the big country only ignores that of the small countries), see Panel I of Fig. 6. With bigger debt-to-output ratios, fiscal policy of the small country becomes relatively less debt-adjusting (more "active") than that of the big country, the small country gains relative to the big country and its fiscal policy ends up by being beggar-thy-union (or the beggar-thy-big country), see results for symmetric shock in Table 1. Table 1 reports, for different non-cooperative policy regimes, *per capita* welfare losses in permanent consumption equivalents relative to cooperation.[25]

Consider now a pure asymmetric technology shock, negative at country B and positive at all small countries. Inflation and debt simultaneously rise at B while they fall in small countries. As the shock is purely asymmetric, we can abstract from union-wide effects on impact, and identify "terms-of-trade" externality.

In order to illustrate this externality, we focus on the fiscal policy reaction of country B. This policy requires a positive tax rate gap and a negative government spending gap to ensure debt stabilization (the opposite is needed in small countries). The first-period tax rate response further increases inflation at country B which, by further decreasing the effective terms-of-trade, contributes to close the positive terms of trade gap. This further shift demand towards goods produced by small countries and increases their outputs. On the one hand, this helps to close the small countries' negative output and inflation gaps (which is a positive "standard" externality) and, on the other hand, this further decrease debt in small countries and worsens the debt stabilization bias (which is a negative "debt-related" externality). In turn, government spending response produces a negative "standard" externality and a positive "debt-related" externality. The failure to internalize these externalities makes policy instruments to deviate from cooperation.

The fiscal authority of a small country ignores the effect of its policy on both the big country (which reacts in an opposite way) and on the block of the small countries (which react in a similar way). Since, as a whole, the externality ignored within the S-block is opposite to that affecting country B, the fiscal authority of a small country fails to internalize a small overall terms-of-trade externality affecting all other countries. Conversely, the fiscal authority of country B fails to internalize a large terms-of-trade externality affecting the counterparts, because the externality affecting the S-block is the only one. In

[24] The debt-related externality is absent for a zero steady-state debt level economy. In this case, efficient outcome is achieved, because monetary policy has only second-order effects on debt-accumulation.

[25] To compute these losses, we follow the approach in the technical appendix of Ferrero (2009).

Table 1
Per capita welfare losses in permanent consumption equivalents relative to cooperation: technology shock at the Big country only and symmetric shock.

			Debt-to-Output Ratio	
			15%	60%
Big Country Loss (L_B)	Symmetric Shock	Nash	0,0004%	0,0024%
	Shock at **B**	Nash	-0,026%	-0,208%
		Fiscal Leadership	-0,024%	-0,324%
		Monetary Leadership	-0,076%	0,018%
Small Country Loss (L_S)	Symmetric Shock	Nash	0,0001%	-0,0220%
	Shock at **B**	Nash	-0,016%	0,638%
		Fiscal Leadership	0,050%	0,743%
		Monetary Leadership	0,022%	0,242%
Union-wide Loss (L_U)	Symmetric Shock	Nash	0,0003%	-0,0098%
	Shock at **B**	Nash	-0,021%	0,215%
		Fiscal Leadership	0,013%	0,210%
		Monetary Leadership	-0,027%	0,130%

Notes: Dark Grey (Light Grey) cells show the best (worst) welfare results for the given debt-to-output ratio; if shadow areas are absent, the best or the worst regime is cooperation.

face of an asymmetric shock, both countries face incentives to deviate from cooperation, but the fiscal authority of country B faces a larger incentive than that of a small country's, see Panel II of Fig. 6. Welfare consequences of failure to cooperate crucially depend on the relative importance of the "standard" and "debt-related" terms-of-trade externalities, as we discuss further in this section.

To summarize, fiscal authorities face incentives to deviate from cooperation when they fail to internalize externalities. The extent of this deviation is likely to be larger, the larger the externality ignored. While fiscal policy of a small country produces negligible externalities individually, all small countries' fiscal policies may produce sizeable externalities when aggregated. In face of a symmetric shock, the fiscal authority of a small country has larger incentives to deviate from cooperation than that of a big country, because it fails to internalize a larger externality; however, for a pure asymmetric shock the effect is opposite and big country has larger incentives to deviate from cooperation.

Positive and negative externalities produce different policy incentives. In general, and relative to cooperation, fiscal policy reacts more intensively to a shock when it produces a negative externality, while the reverse occurs when it produces a positive externality.

In what follows, we will restrict policy and welfare analysis, under different non-cooperative regimes, to the case of a technology shock hitting only the big country, given that shocks in a small country produce similar effects in all policy regimes. Under this shock, that combines the characteristics of symmetric and of pure asymmetric shocks, both "union-wide" and "terms-of-trade" fiscal policy externalities are relevant. Still, this shock is more of an asymmetric nature and, thus, as we argued above, the fiscal authority of the big country is the one that deviates more from cooperation.

5.2.1. Simultaneous moves

The steady-state debt level determines whether "standard" or "debt-related" externalities dominate, and how country B's fiscal policy response under non-cooperation deviates from the one under cooperation.

First, in a *low-debt* monetary union, where budgetary consequences are less significant, the "standard" externality prevails. Therefore, relative to cooperation, a negative technology shock at country B requires a smaller tax rate gap and a larger government spending gap, in the first period, as the two policy instruments cause opposite terms-of-trade externalities. Compared with cooperation, this allows for a lower inflation at B and, thus, for a higher terms-of-trade gap that reinforces the negative output gap in the small countries. Since output increases by less in the small countries, primary budget surplus also increases by less and, therefore, fiscal policy becomes relatively less debt-adjusting (becomes more "ac-

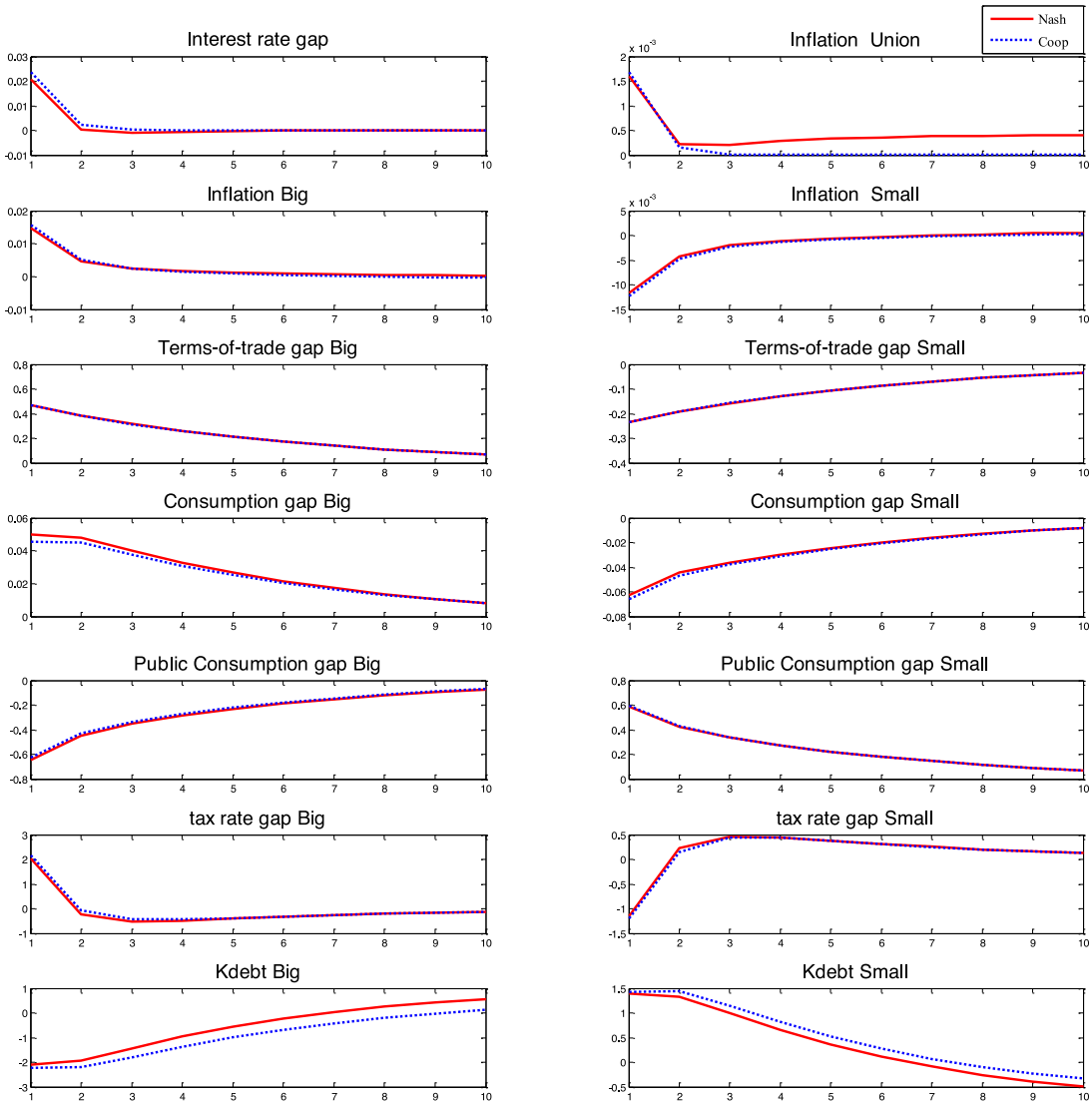

Fig. 7. Responses to a 1% negative technology shock at the Big country – cooperation (Coop) versus non-cooperation (Nash): low debt-to-output ratio = 15%.

tive") in these countries. In turn, since lower inflation in country B results in lower inflation at the union level, monetary policy becomes less "active" than under cooperation.

From the inspection of Fig. 7, it is apparent that, except for private and public consumption, all other welfare-relevant variables in B display smaller volatility under Nash than under cooperation. Table 1 (shock at B) shows that, under low debt, Nash is welfare-superior for all countries. This finding confirms that policy cooperation can be counterproductive in the presence of pre-existing distortions.[26]

Second, in a *high-debt* monetary union, where budgetary consequences are considerable, the "debt-related" externality dominates. Therefore, relative to cooperation, a negative technology shock at country B requires, domestically, a larger tax rate gap (smaller government spending gap) in the first period, as the dominant "debt-related" terms-of-trade externality is negative (positive). Compared with cooperation, this allows for a higher inflation at B, thus a lower terms-of-trade gap, increasing the demand for small countries' goods and enlarging their primary budget surpluses. As a result, fiscal policy in a small country is required to be more debt-adjusting under Nash. At the aggregate level, fiscal policy turns to be less debt-adjusting than under cooperation and, thus, the central bank decreases the interest rate gap by more in the first period

[26] The argument follows from the key contribution of Rogoff (1985), according to which cooperation among a subset of players (all policymakers) could lead to adverse reactions from the outsiders (*e.g.*, private sectors) and 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 desirability of policy coordination.

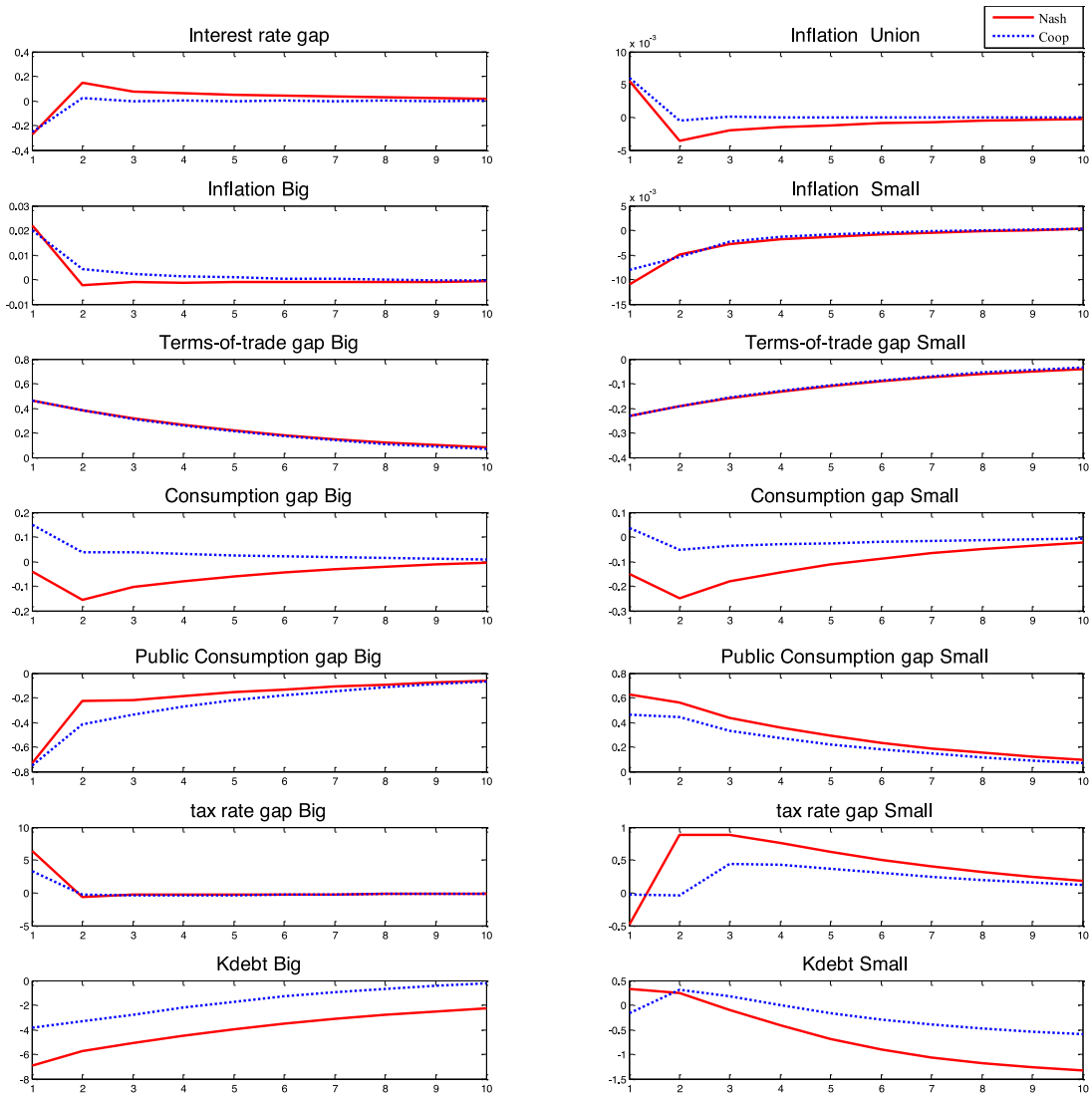

Fig. 8. Responses to a 1% negative technology shock at the Big country – cooperation (Coop) versus non-cooperation (Nash): high debt-to-output ratio = 60%.

to ensure the stabilization of aggregate debt. This allows the central bank to raise the interest rate by more in the second period, without an adverse effect on debt and helping to lower country B's inflation. Fig. 8 illustrates these differences in the high-debt scenario (debt-to-output ratio of 60%). It shows that the small countries' welfare-relevant variables display higher volatility under the simultaneous-move regime than under cooperation. Therefore, for small countries cooperation is welfare-superior to Nash, in a high-debt monetary union (cf. Table 1). This result also holds for the union as a whole, despite the lower welfare costs achieved by the big country B under the non-cooperative regime.

5.2.2. Leadership

Consider now the possibility of either monetary or fiscal policy authorities to have an intra-period first-move advantage when reacting to a negative technology shock at country B. We focus on the differences arising from leadership compared with the simultaneous-move regime (Figs. 9 and 10).

Fiscal leadership (FL): The fiscal authority of the big country faces substantial incentives to explore a first-moving advantage towards the monetary authority.

First, compared to Nash, in a *low-debt* monetary union, the leading big country's fiscal authority chooses to be relatively more debt-adjusting (especially through manipulating the costless tax rate),[27] once monetary policy controls for excessive inflation at the union-wide level. Thus, at country B, and relative to Nash, the tax rate gap increases by more, generating

[27] As Leith and Wren-Lewis (2013) have shown, the effectiveness of the tax rate in debt-stabilization is higher for lower levels of public debt.

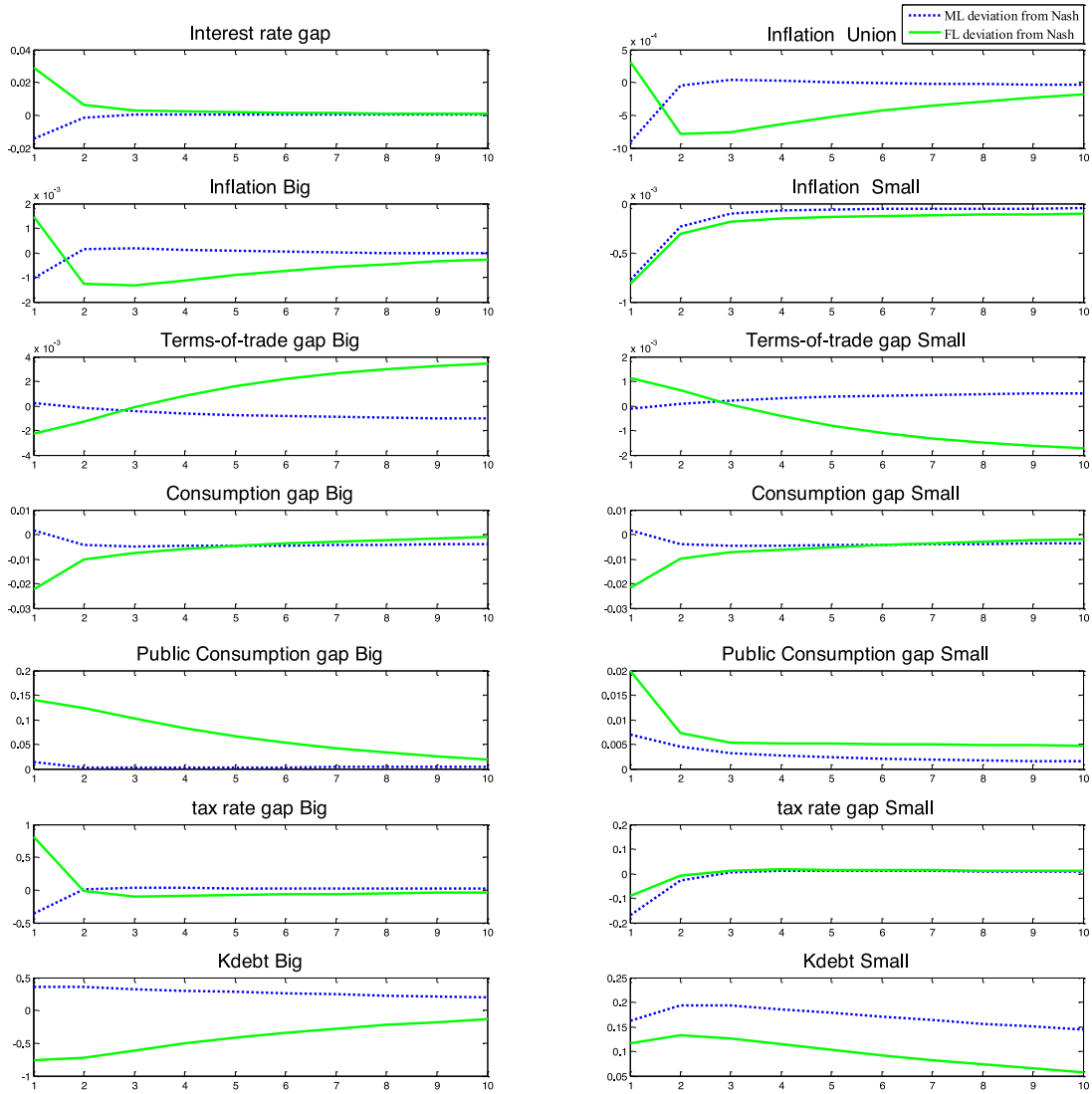

Fig. 9. Responses to a 1% negative technology shock at the Big country: fiscal leadership (FL) and monetary leadership (ML) relative to Nash (low debt-to-output ratio = 15%). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

higher domestic (and union-wide) inflation that is further enlarged by a smaller decrease in the public consumption gap. The resulting lower terms-of-trade gap boosts demand towards small countries' goods, which improves primary budget surplus. Conversely, a higher union-wide inflation induces a higher interest rate gap, which mitigates small countries' budgetary surplus. For low enough debts, the former effect dominates and, thus, fiscal policy in a small country is required to be more debt-adjusting under FL relative to Nash. The fiscal policy-mix that emerges at the aggregate level – higher positive tax rate gap and lower negative government spending gap – aggravates union-wide inflation and requires monetary authority to set a higher interest rate gap in the first period (*cf.* Figs. 9 and 7). Welfare stabilization costs are higher under FL than under Nash for all countries, under the selected low-debt scenario (see Table 1).

Second, in a *high-debt* monetary union, the leading big country's fiscal authority, by relying on a more debt-adjusting monetary policy, turns to be relatively less debt-adjusting compared to the simultaneous-move regime. Relative to Nash, both fiscal policy instruments move by less in B, globally contributing to reduce domestic inflation and to enlarge the positive terms-of-trade gap. Budgetary surplus at a small country is likely to be larger, because the interest rate gap is likely to decrease by more, dominating the budgetary consequences of a higher positive terms-of-trade gap. Hence, fiscal policy in small countries is required to be more debt-adjusting under FL relative to Nash. From the inspection of Figs. 8 and 10, country B's inflation displays lower volatility than under Nash, while the reverse occurs in a small country. Under high debt levels, FL delivers the best stabilization outcome for the big country and the worst for a small country (see Table 1). Union-wide, FL is slightly superior to the simultaneous-move regime.

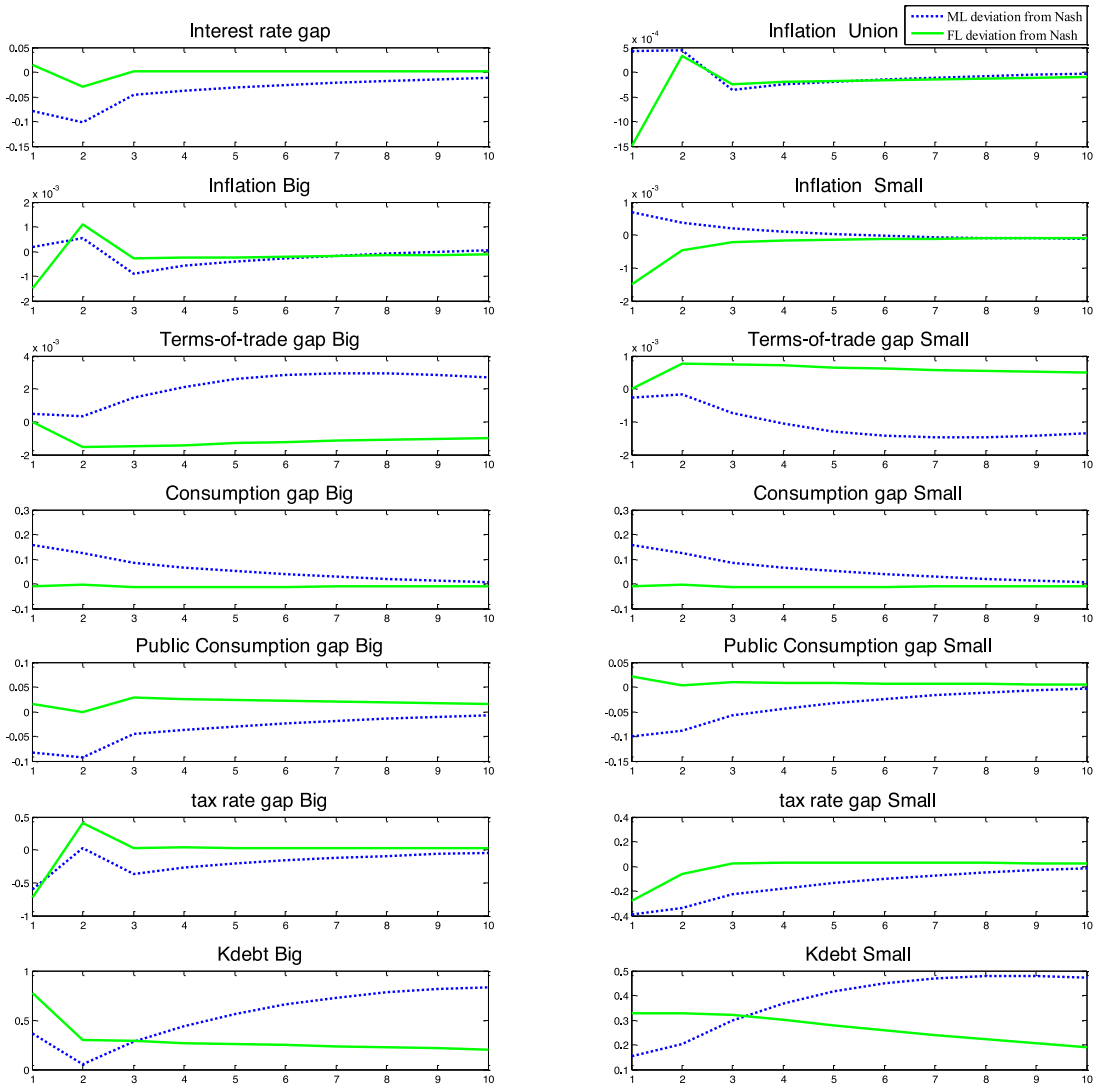

Fig. 10. Responses to a 1% negative technology shock at the Big country: fiscal leadership (FL) and monetary leadership (ML) relative to Nash (high debt-to-output ratio = 60%). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

Monetary leadership (ML): Under monetary leadership, the common central bank is aware of the big country's fiscal authority incentives to deviate from cooperation. The monetary policymaker anticipates different fiscal policy incentives in high and low debt regimes and its optimal response is qualitatively different.

First, in a *low-debt* monetary union, the leading monetary authority anticipates that the incentives faced by the fiscal authority of country B under non-cooperation will result in a union-wide welfare-superior equilibrium. Hence, the interest rate gap rises even by less than under Nash and, because of lower debt-service costs, it further enlarges the budget surplus of the small countries while it mitigates the government deficit in B. Consequently, relative to the simultaneous-move regime, the fiscal policy in small countries (country B) has to be more (less) debt-adjusting under the monetary leadership regime (cf. Fig. 9, blue dotted lines). Figs. 7 and 9 show that, in general, country-specific variables of country B display lower volatility under ML than under Nash, while the reverse occurs for a small country. So, relative to Nash, ML is welfare-improving for the big country B while welfare-deteriorating for small countries (cf. Table 1). For the union as a whole, ML is the welfare-superior regime in a low-debt scenario.

Second, in a *high-debt* monetary union, the monetary authority, anticipating union welfare-decreasing incentives faced by the fiscal authority of country B under non-cooperation, chooses to reduce by more the interest rate gap in the first period, in order to induce the big country's fiscal authority to be relatively less debt-adjusting. Monetary policy reaction mitigates country B's budget deficit while it enlarges small countries' surplus, inducing fiscal authority of country B (small country) to implement a relatively less (more) debt-adjusting policy-mix under ML (cf. Fig. 10, blue dotted lines). The resulting equi-

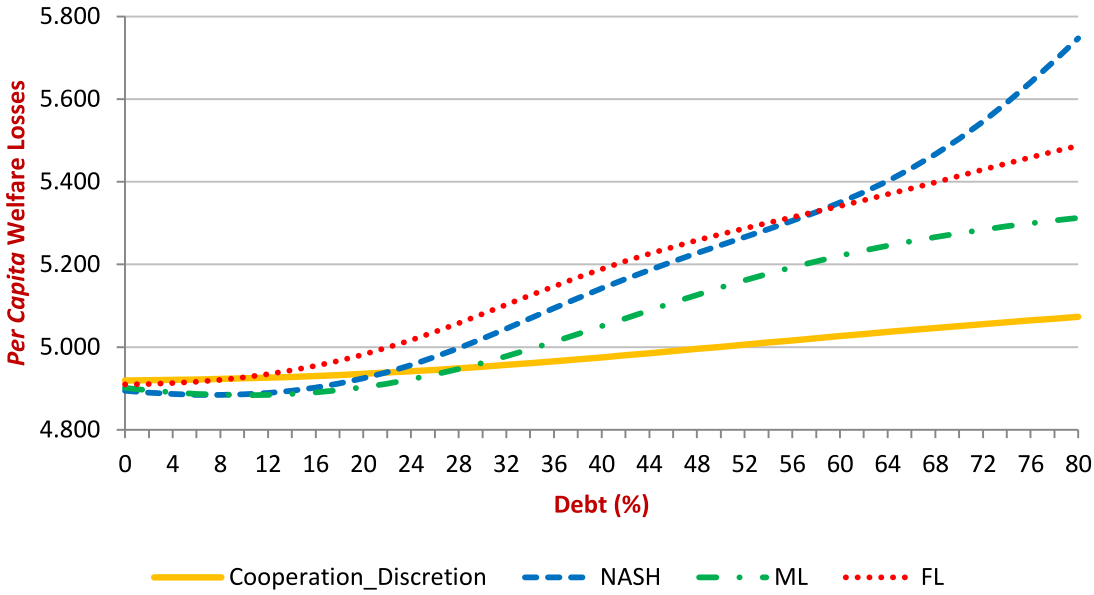

Fig. 11. Union-wide welfare loss (LU) across different policy regimes and debt levels (all technology shocks).

librium ends up by delivering, relative to Nash, higher volatility in country B while the reverse occurs in a small country.[28] In a high-debt non-cooperative scenario, small countries and overall union will be better off under central bank leadership (cf. Table 1).

5.3. Welfare stabilization costs across different debt levels and policy regimes

Considering now idiosyncratic technology shocks to all countries, we study how welfare stabilization costs change with debt levels. This analysis is meaningful within the context of the Euro Area since countries face homogeneous debt ceilings set on a supranational basis. We conjecture, from previous results, that the institutional framework for monetary and fiscal policy in the EMU is not welfare neutral for defining limits on public debt.

5.3.1. Union-wide welfare losses

Fig. 11 plots union-wide welfare losses for a range of debt-to-output levels. From its inspection, we conclude that, in general, higher government indebtedness hampers business cycle stabilization. Moreover, there are clear stabilization gains from promoting policy cooperation in a high-debt monetary union, while this could be counterproductive in a low-debt monetary union.

With monetary policy assigned to inflation-stabilization in low-debt environments, non-cooperation may alleviate time-consistency problems of optimal discretionary policies, allowing for a better stabilization performance. Overall, fiscal policy is less debt-adjusting under non-cooperation, alleviating union inflation pressures and requiring a less “active” monetary policy.

Conversely, in high-debt environments, with monetary policy assigned to debt-stabilization, a less debt-adjusting fiscal policy under non-cooperation requires a more “passive” monetary policy with negative consequences for the union’s welfare. Therefore, cooperation is welfare superior relative to non-cooperation in a high-debt monetary union.

In turn, monetary leadership delivers a better stabilization performance than fiscal leadership, regardless the level of the government debt.

5.3.2. Big country welfare losses

Domestic shocks are the ones causing stabilization costs for the big country B, as shocks hitting a zero-dimension country produce no external effects. The dominance of domestic shocks is thus crucial for the observed non-monotonic relationship between welfare stabilization costs and debt across policy regimes, despite the increasing budgetary consequences of the shocks with debt (cf. Figs. 3 and 12). When debt becomes high enough, the increased effectiveness of monetary policy in debt-stabilization may allow fiscal policy to become, progressively, less debt-adjusting. When the gains of alleviating domestic fiscal policy from time-consistency problems become sufficiently large, welfare stabilization costs decrease with the level of government indebtedness in country B.

[28] This result only occurs for sufficiently high (low) government spending gap at country B (s).

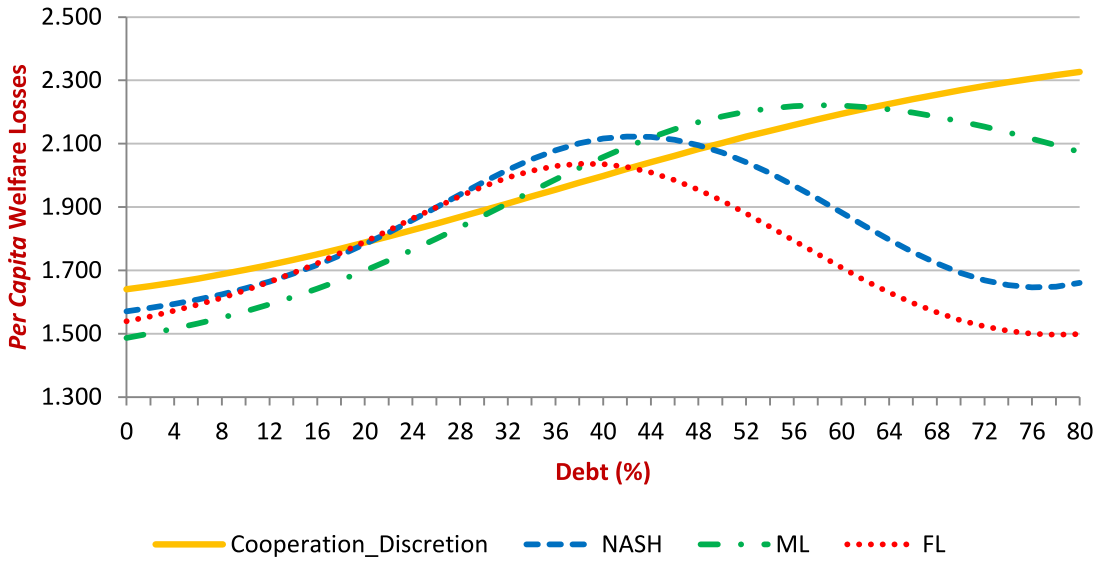

Fig. 12. Big country welfare loss (LB) across different policy regimes and debt levels (all technology shocks).

As in the case of the union, for sufficiently low-debt levels, non-cooperation dominates cooperation and monetary leadership is the welfare-superior regime for the big country. Fiscal leadership is preferable to Nash, but only for very low debt levels (cf. Fig. 12).

Non-cooperation also dominates cooperation for high enough debt levels, when the positive "debt-related" terms-of-trade externality dominates and allows for a lower government-spending gap in B under non-cooperation. In contrast, for intermediate-debt levels, the negative "standard" terms-of-trade externality dominates and the negative government-spending gap becomes larger under non-cooperation.[29] In a high-debt monetary union, FL dominates for the big country (cf. Fig. 12).

5.3.3. Small country welfare losses

For a small country, external shocks at the big country are those that dominate differences between cooperation and non-cooperation and that matter for the non-monotonic relationship observed between welfare losses and debt (cf. Figs. 3 and 13). A domestic shock, despite entailing high stabilization costs, fails to produce relevant externalities.

As mentioned before, in a low-debt scenario, the budgetary consequences for small countries from shocks at the big country diminish with the steady-state debt level. Therefore, welfare stabilization costs decrease in small countries, as the steady-state debt level increases.

However, in a high-debt scenario, the "passive" monetary policy reaction to the shock enlarges a small country's primary budget surplus and, for high enough debt levels, fiscal policy becomes progressively more debt-adjusting. Therefore, welfare stabilization costs increase with government indebtedness for a small country (cf. Fig. 13).

In general, a small country faces lower stabilization costs under cooperation. Only for a small range of low debt levels, Nash is welfare-superior. Under non-cooperation, small countries benefit from ML in a high-debt monetary union. FL is the welfare-inferior regime for a wide range of debts (cf. Fig. 13).

5.4. Sensitivity analysis

In this section, we briefly report the robustness of our results to changes in selected model parameters.[30] Varying the degree of nominal rigidity between $\theta = 2/3$ and 0.75 does not change the welfare ranking between policy regimes.

The inverse of the Frisch labor elasticity is set to $\chi = 1.5$, 3 and 5. Cooperation becomes welfare superior to non-cooperation for higher debt levels as the elasticity of labor supply decreases, but key qualitative results are preserved. This is as expected because, as a lower value of the elasticity of labor supply reduces the cost of private consumption fluctuation relative to inflation fluctuation, it reduces the incentives for monetary policy to stabilize debt. Consequently, the threshold debt levels for which monetary policy becomes "passive" increase with the reduction of the elasticity of labor supply.

Welfare ranking also remains unchanged for alternative values of the elasticity of substitution between domestic and foreign goods, $\gamma = 0.2$ and 4.5.

[29] This is probably a consequence of how effectiveness towards debt-stabilization of the two fiscal policy instruments – government spending and tax rate – changes with the level of debt (see Leith and Wren-Lewis, 2013).

[30] These results are contained in Appendix E.

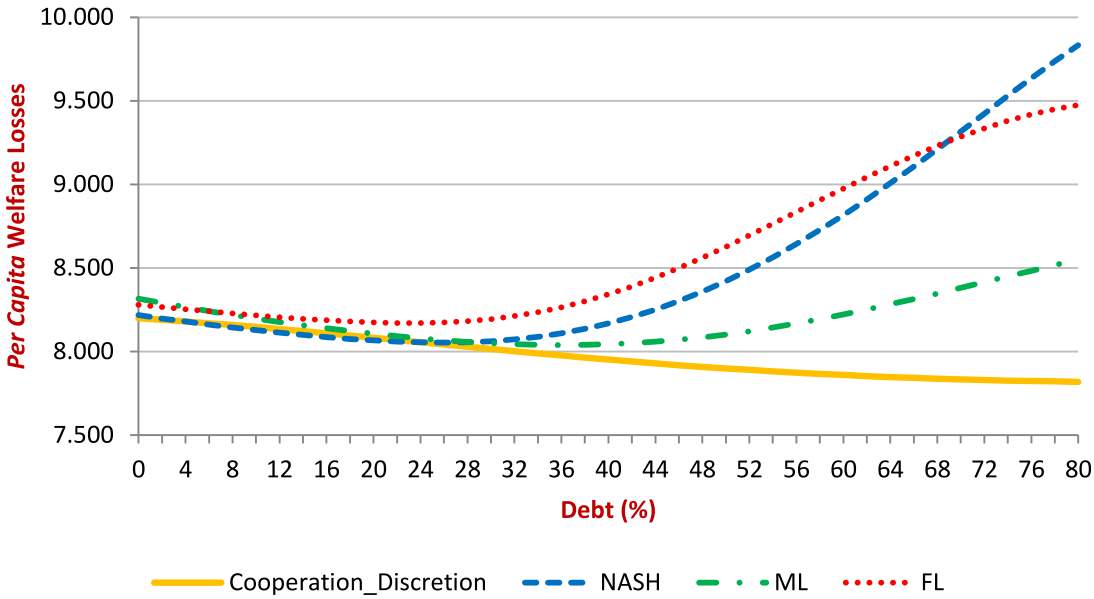

Fig. 13. Small country welfare loss (Ls) across different policy regimes and debt levels (all technology shocks).

We consider three alternative sizes for the big country: $(1-n)=0.35$, 0.5 and 0.65. The larger the size of country B is, the larger are the terms-of-trade and union-wide externalities. Our experiments show that this makes the distribution of welfare costs across countries even more asymmetric: the welfare stabilization costs of a small (big) country are higher and increasing (lower and decreasing) with the size of country B, independently of the debt level. Our results also suggest that the larger country B is, the larger will be its potential opposition to cooperation. Conversely, and for a wide range of debts, cooperation is more beneficial for small countries and the union as a whole, the larger country B is. In general, the welfare rankings of the different policy regimes reveal to be robust to the relative size of country B.

Finally, in order to make the analysis of the importance of country-size asymmetry for policy interactions more comprehensive, we compare the external effects of a shock hitting country B with those of a shock hitting, simultaneously, all small economies (S-block shock). As expected, in spite these effects being equal for the two symmetric "blocks" under cooperation, they are meaningfully different under non-cooperation. Results show that, in face of such external shocks: i) welfare losses for small countries are larger than for country B; ii) country B prefers non-cooperation to cooperation, while the reverse occurs for a small country; iii) welfare losses increase with debt for a small country, while they decrease for country B. This reinforces insights on the importance of country-size asymmetry. Considering both the external and domestic effects of these shocks, results lend support for those obtained under the baseline calibration.

6. Concluding remarks

This paper fills a gap in the literature by proposing a model that allows the analysis of fiscal and monetary policy interactions in country-size heterogeneous monetary union: with countries having either negligible or meaningful impact on each other and on the union as a whole. This model provides a more realistic description of the heterogeneous-size EMU and allows us to get further insights on how debt accumulation, such as observed in the course of 2008–2009 crisis, may shape policy interactions between national governments and the central bank.

The size of the steady-state level of debt determines both (i) the budgetary consequences of the shocks and (ii) the effectiveness of the different policy instruments towards debt-adjustment. In a high-debt environment, the potential stabilization gains for the union, resulting from the higher effectiveness of monetary policy to stabilize debt and of fiscal policy to support the short-run stabilization, are not sufficiently large to outweigh the costs of stabilizing the larger budgetary consequences of technology shocks. Our results suggest that, in general, higher government indebtedness hampers union-wide business cycle stabilization.

Shocks at larger economies are crucial for the uneven distribution of stabilization costs between small and big countries across debt levels: welfare costs decrease with debt for a small country and increase for the big country, in a low-debt monetary union; the reverse occurs in a high-debt monetary union. Thus, a higher level of debt, as the one experienced in the EMU is more likely to penalize the stabilization performance of the small country-members than that of the large.

Strategic policy interactions, arising from different policy objectives set by nationally-oriented fiscal authorities, also disclose different welfare consequences for the large and the small countries. In general, under non-cooperative policy regimes,

the non-internalization of larger externalities by country B makes its fiscal authority to proceed with beggar-thy-neighbor policies that improve B's welfare at the expenses of S's welfare.

The large country can benefit from non-cooperation if debt levels are either high or low enough, but not for intermediate ranges. For the union as a whole, there are clear stabilization gains from promoting policy cooperation under the high-debt scenario, though this could be counterproductive in a low-debt monetary union.

The intra-period leadership structure has also important stabilization consequences. Fiscal leadership imposes higher stabilization costs than monetary leadership, for the union as whole and for the small countries. In turn, in high-debt environments, the big country clearly prefers fiscal leadership, where it can explore a larger strategic power vis-a-vis a debt-accommodative monetary authority, suggesting that it may be hard to get political support for a cooperative arrangement that enhances union-wide welfare stabilization gains.

Acknowledgments

We acknowledge helpful discussion from Max Breitenlechner and Tatiana Kirsanova at the 21st Annual International Conference on Macroeconomic Analysis and International Finance (ICMAIF), Rethymno/Crete, May 2017. We also thank to the anonymous referees for their comments and suggestions which have substantially improved this paper.

This research has been financed by Portuguese Public Funds through FCT (Fundação para a Ciência e a Tecnologia) and by the European Regional Development Fund through COMPETE 2020 – Programa Operacional Competitividade e Internacionalização (POCI) – in the framework of the project POCI-01-0145-FEDER-006890.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jedc.2018.01.043.

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