Should the ECB Coordinate EMU Fiscal Policies?*

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In a monetary union where fiscal authorities act strategically, fiscal cooperation is unlikely to emerge as an equilibrium. Even when the cooperative outcome is the best for a national fiscal authority, it is either not a Nash equilibrium or only one of several Nash equilibriums. The monetary authority may have an important coordinating role; however, the Pareto-preferred equilibrium will not necessarily involve cooperation.

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1. Introduction

One of the aims behind the creation of the EMU has been better policy coordination of the member countries, leading to the ultimate synchronization of their business cycles. However, almost two decades of its existence has shown that the degree of policy

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cooperation between countries is far from desired. There are frequent conflicts of interest, with outcomes leaving member countries unhappy. This is particularly true about fiscal coordination, failures of which are frequently blamed for wide heterogeneity in public debt levels across countries. There are, therefore, calls for greater fiscal unification, or for a fiscal union.[1]

Policy coordination in a monetary union has been a long-standing issue in economic research. The literature is vast; it frequently addresses the issue of desirability of coordination and argues that the cooperative outcome is high on the list of Pareto-ranked options available to national and/or union-wide policymakers.[2]

In this paper we investigate whether cooperation is sustainable. We argue that in a monetary union where fiscal policymakers act strategically, fiscal cooperation is unlikely to emerge as an equilibrium. Even when the cooperative outcome is the best for a national fiscal authority, it is either not a Nash equilibrium or only one of several Nash equilibriums. In the latter case the monetary authority may have an important coordinating role; however, the Pareto-preferred equilibrium will not necessarily involve cooperation.

These results arise in a standard two-country DSGE model of a monetary union where policymakers act strategically but are unable to precommit. A fiscal policymaker in each country has a choice between pursuing national objectives and adopting union-wide objectives, and between earlier and later dates for setting national fiscal policy. The choice of a date allows either to exploit information about the other country's policy or to provide a clear signal to the market. Once made, these choices are built into institutional arrangements for the future. Fiscal policymakers cooperate if they share objectives, and they act non-cooperatively if their objectives differ. Financial markets can be fully or partially integrated.

More specifically, we demonstrate that the outcome of policy interactions is shock dependent. Efficient technology shocks lead to the unique Nash equilibrium in which both fiscal policymakers

[1]See discussion in Bargain et al. (2013).

[2]See, e.g., Dixit and Lambertini (2003), Beetsma and Debrun (2004), and Chari and Kehoe (2007), to mention only a few. The equilibrium outcome depends on whether the fiscal authorities and the monetary authority can internalize each other's actions, on the type of policy framework, and on other factors. See the recent survey by Beetsma and Giuliodori (2010) and references therein.

choose to follow their national objectives and to act simultaneously. Although each fiscal policymaker would individually prefer the cooperative outcome with shared union-wide objectives, they are unable to sustain it because of the prisoner's-dilemma-type coordination problem.

In contrast, inefficient cost-push shocks lead to either a unique equilibrium or multiple Nash equilibriums. The equilibrium is unique if financial markets are fully integrated, and with imperfect financial integration there are multiple Nash equilibriums. The unique equilibrium is characterized by the countries retaining national objectives and the large country having an intraperiod advantage over the small country. This equilibrium also exists under incomplete financial markets, and another one is the cooperative equilibrium; however, the latter equilibrium it is not the best union-wide outcome under these shocks and is Pareto dominated by the former.

The difference in equilibrium outcomes is mainly explained by the shock-specific policy tradeoffs and the country-size asymmetry which, in turn, imply a very particular ranking of policy regimes for each fiscal policymaker. Under efficient technology shocks the desire and the ability of an intraperiod fiscal leader to influence monetary policy responses results in substantial negative spillovers across the border, opening wider gaps for real variables in the fiscal follower's country. The fiscal leader's gain becomes the fiscal follower's loss. As a result, there is a unique Nash equilibrium in which both fiscal policymakers pursue national objectives and fight for the leadership role, choosing to set their policies at the very beginning of each decision period, and thus losing an intraperiod advantage over each other. This equilibrium is robust to country-size asymmetries and to the degree of financial integration.

In contrast, under inefficient cost-push shocks the fiscal leader's ability to manipulate monetary policy to its advantage results in positive spillovers across the border, closing the gaps of real variables for the fiscal follower's country. In the regimes with unilateral fiscal leadership, both countries gain relative to the regime of simultaneous fiscal moves. Therefore, there is no fight over the fiscal leadership, and multiple Nash equilibriums—with fiscal leadership of either country—arise. The relative ability of each fiscal policymaker to manipulate the monetary authority and the set of equilibriums are sensitive to the country-size asymmetries, financial openness, and global imbalances. Multiplicity of equilibriums, however, remains robust to these factors.

We therefore argue that the pervasive multiplicity of policy equilibriums and coordination failures suggests an important coordinating role for a supranational authority. In a monetary union with full and complete information, this role can be naturally taken by the central bank, as it has access to the same information as the fiscal authorities and can easily communicate with them. We illustrate how an additional asymmetric policy instrument of a central bank might work in our model to improve overall welfare and affect sustainability of policy equilibriums.

This paper provides normative, rather than positive, analysis. It complements the existing analysis of optimal cooperative policy in a monetary union by extending it to some selected cases of strategic interactions, still in the environment with complete and perfect information, certainty equivalence, and with welfare analysis based on microfounded policy objectives.[3] Its aim is to present policy coordination tradeoffs that strategic policymakers, which are unable to precommit, face within a monetary union.

The paper is organized as follows. In the next section we outline the model. Section 3 defines all policy scenarios of interest, and section 4 presents the analysis. Section 5 presents several extensions of the model, and section 6 concludes.

2. Model Highlights

We use a workhorse two-country model, based on Benigno and Benigno (2003) but with incomplete financial markets as in Benigno (2009). The modeling of the fiscal side follows Woodford (2001) and Leeper and Leith (2016), allowing for variable maturity of government debt.

Specifically, the world economy is populated by a continuum of agents on the interval of $[0; 1]$. The population on the segment $[0; n)$ belongs to country H (home), while the rest of the population on $[n; 1]$ belongs to country F (foreign). Each economy is populated

[3] Ferrero (2009) provides a comprehensive study of the role of distortionary taxes in a monetary union where all policymakers are able to precommit; optimal simple rules for spending are analyzed in Kirsanova et al. (2007).

by households and firms. Households' preferences reflect home bias in consumption. Firms are monopolistically competitive and only use labor to produce differentiated tradable goods. The law of one price holds. Each country has an independent fiscal authority, which finances spending by bonds and distortionary taxes. The government debt is tradable and has geometric maturity structure. Financial markets are incomplete,[4] and the portfolio allocation is determined by transaction costs. All profits received by home-country firms and financial intermediaries are rebated to home households. Countries are subject to technology and cost-push shocks. We assume that countries form a currency union, so there is only one central bank and permanently fixed nominal exchange rate. Full details of underlying microfoundations of the model are given in appendix A, and only the linearized model is presented here.[5]

2.1 Private-Sector Equilibrium

The household optimization problem for country H yields consumption Euler equation

$$\hat{C}_t = \mathbb{E}_t \hat{C}_{t+1} + \sigma\gamma \left(\hat{\pi}^*_{Ft+1} - \hat{\pi}_{Ht+1}\right) - \sigma \left(\hat{\imath}_t - \mathbb{E}_t \hat{\pi}_{Ht+1}\right) \qquad (1)$$

and the arbitrage condition,

$$\hat{\imath}_t = \mathbb{E}_t \left(\hat{R}_{t+1} + \hat{\pi}_{Ht+1}\right), \qquad (2)$$

where $\hat{C}_t$ denotes consumption, $\hat{S}_t$ is the terms of trade (relative price of foreign producer price in terms of home producer price), $\hat{\pi}_{Ht}$ is home producer price inflation, $\hat{R}_t$ is the real return on long-term bonds with geometric maturity structure, and $\hat{\imath}_t$ is the short-term nominal interest rate.[6]

[4] Baele et al. (2004) argues that in the beginning of the 2000s the public debt market was fairly integrated. However, since the Greek government debt restructuring, there is a perceived non-zero probability of a sovereign debt default of an individual country.

[5] Here and elsewhere we refer to the online appendix, available at http://www.ijcb.org.

[6] The linearization is around zero-inflation efficient steady state, ensured by suitable assumptions; see appendix A. Here and below, hatted variables indicate that they have been linearized relative to their steady states, and the steady states are denoted by letters without time subscript.

The firms' optimization problem yields the standard New Keynesian Phillips curve for the producer price inflation,

$$\hat{\pi}_{Ht} = \hat{\upsilon}_t + \lambda\left(\varsigma\hat{Y}_t + \gamma\hat{S}_t + \frac{1}{\sigma}\hat{C}_t + \frac{\tau^l}{\mu}\hat{\tau}_t^l - (\varsigma+1)\,\hat{z}_t\right) + \beta\mathbb{E}_t\hat{\pi}_{Ht+1}, \tag{3}$$

where $\hat{Y}_t$ is output and $\hat{\tau}_t^l$ is distortionary labor income tax. Here $\hat{z}_t$ and $\hat{\upsilon}_t$ are AR(1) home technology and cost-push shock, respectively. Parameter σ is inverse of the intertemporal elasticity of substitution, ς is inverse of the Frisch elasticity of labor supply, and $\gamma = (1-n)\alpha$ is the import share, which depends on country size n and the degree of trade openness α. Parameter $\mu = \frac{\epsilon}{\epsilon-1}$ is monopolistic markup and is related to the elasticity of substitution between home goods ϵ. Parameter β is the household discount factor, and the slope of Phillips curve $\lambda = (1-\theta\beta)(1-\theta)/\theta$ is a function of the Calvo (1983) probability of price change θ.

There is also an aggregate resource constraint

$$\hat{Y}_t = \left(\frac{C}{Y}\eta(1-\gamma)\gamma + \frac{C^*}{Y^*}\frac{Y^*}{Y}\eta\gamma^*(1-\gamma^*)\right)\hat{S}_t + (1-\gamma)\frac{C}{Y}\hat{C}_t + \gamma^*\frac{C^*}{Y}\hat{C}_t^* + \frac{G}{Y}\hat{G}_t, \tag{4}$$

and the government budget constraint

$$\hat{d}_{Ht} + \frac{Y^*}{Y}\hat{d}_{Ht}^* = 4\frac{\delta_H}{\beta}\hat{R}_t + \frac{1}{\beta}\hat{d}_{Ht-1} + \frac{1}{\beta}\frac{Y^*}{Y}\hat{d}_{Ht-1}^* + \frac{G}{Y}\hat{G}_t - \frac{\tau^l}{\mu}\left(\gamma\hat{S}_t + (\varsigma+1)\left(\hat{Y}_t - \hat{z}_t\right) + \frac{1}{\sigma}\hat{C}_t + \left(1+\frac{\tau^l}{\mu}\right)\hat{\tau}_t^l\right), \tag{5}$$

where $\hat{d}_{Ht}$ is normalized real home debt held by residents, $\hat{d}_{Ht}^*$ is normalized real home debt held by non-residents,[7] and $\hat{G}_t$ is government spending. Respectively, $\hat{C}_t^*$, $\hat{G}_t^*$, $\hat{\tau}_t^{*l}$, $\hat{Y}_t^*$, and $\hat{\pi}_{Ft}^*$ are foreign

[7] See appendix A for the normalization formula.

consumption, government spending, labor income tax, output, and producer price inflation. Parameter η is the trade elasticity, and the foreign-country import share is $\gamma^* = n\alpha$. Parameters m_H and m_F are maturity of home- and foreign-issued bonds, and δ_H and δ_F are *annualized* market values of debt to output ratios for respective countries.

For the other country the corresponding equations are

$$\hat{C}_t^* = \mathbb{E}_t\hat{C}_{t+1}^* - \sigma\gamma^*\left(\hat{\pi}_{Ft+1}^* - \hat{\pi}_{Ht+1}\right) - \sigma\left(\hat{\imath}_t^* - \mathbb{E}_t\hat{\pi}_{Ft+1}^*\right), \tag{6}$$

$$\hat{\imath}_t^* = \mathbb{E}_t\left(\hat{R}_{t+1}^* + \hat{\pi}_{Ft+1}^*\right), \tag{7}$$

$$\begin{aligned}\hat{\pi}_{Ft}^* = \hat{\upsilon}_t^* + \lambda\left(\varsigma\hat{Y}_t^* - \gamma^*\hat{S}_t + \frac{1}{\sigma}\hat{C}_t^* + \frac{\tau^{*l}}{\mu}\hat{\tau}_t^{*l} - (\varsigma+1)\,\hat{z}_t^*\right)\\ + \beta\mathbb{E}_t\hat{\pi}_{Ft+1}^*,\end{aligned} \tag{8}$$

$$\begin{aligned}\hat{Y}_t^* = -\left(\frac{C}{Y}\frac{Y}{Y^*}\eta\,(1-\gamma)\,\gamma + \frac{C^*}{Y^*}\eta\gamma^*\,(1-\gamma^*)\right)\hat{S}_t\\ + (1-\gamma^*)\,\frac{C^*}{Y^*}\hat{C}_t^* + \gamma\frac{C}{Y^*}\hat{C}_t + \frac{G^*}{Y^*}\hat{G}_t^*,\end{aligned} \tag{9}$$

$$\begin{aligned}\frac{Y}{Y^*}\hat{d}_{Ft} + \hat{d}_{Ft}^* = 4\frac{\delta_F}{\beta}\hat{R}_t^* + \frac{1}{\beta}\frac{Y}{Y^*}\hat{d}_{Ft-1} + \frac{1}{\beta}\hat{d}_{Ft-1}^* + \frac{G^*}{Y^*}\hat{G}_t^*\\ - \frac{\tau^{l*}}{\mu}\Bigg(- \gamma^*\hat{S}_t + (\varsigma+1)\left(\hat{Y}_t^* - \hat{z}_t^*\right)\\ + \frac{1}{\sigma}\hat{C}_t^* + \left(1 + \frac{\tau^{*l}}{\mu}\right)\hat{\tau}_t^{*l}\Bigg),\end{aligned} \tag{10}$$

where $\hat{d}_{Ft}^*$ is normalized real foreign debt held by residents, and $\hat{d}_{Ft}$ is normalized real foreign debt held by non-residents. $\hat{z}_t^*$ and $\hat{\upsilon}_t^*$ are AR(1) foreign technology and cost-push shock, respectively.

The model is closed by the definition of the terms of trade under fixed exchange rate regime,

$$\hat{S}_t = \hat{S}_{t-1} - \hat{\pi}_{Ht} + \hat{\pi}_{Ft}^*, \tag{11}$$

two risk premium equations,

$$\hat{\imath}_t^* = \hat{\imath}_t + \chi Y^*\left(\hat{d}_{Ft} + 4\omega\varrho\delta_F\frac{Y}{Y^*}\,(1-\gamma)\,\hat{S}_t\right), \tag{12}$$

$$\hat{\imath}_t = \hat{\imath}_t^* + \chi^* \left(\hat{d}_{Ht}^* - 4\varrho\delta_H \frac{Y}{Y^*} \left(1-\gamma^*\right) \hat{S}_t \right), \tag{13}$$

and the current account equation,

$$\begin{aligned} 0 = &\left(\gamma C \left(\left(1-\eta\right)\left(1-\gamma\right)+\gamma\right) - C^*\eta\gamma^*\left(1-\gamma^*\right)\right)\hat{S}_t + \gamma C \hat{C}_t \\ &- \gamma^* C^* \hat{C}_t^* + Y\left(\hat{d}_{Ft} - \frac{1}{\beta}\hat{d}_{Ft-1} - 4\omega\varrho\frac{\delta_F}{\beta}\left(\hat{R}_t^* + \left(1-\beta\right)\hat{S}_t\right)\right) \\ &- Y^*\left(\hat{d}_{Ht}^* - \frac{1}{\beta}\hat{d}_{Ht-1}^* - 4\varrho\frac{\delta_H}{\beta}\frac{Y}{Y^*}\hat{R}_t\right), \end{aligned} \tag{14}$$

where χ and χ^* are home and foreign portfolio adjustment cost parameters, ϱ is international exposure, and ω measures external imbalances; their definition is given further in section 2.3. Equation (11) implies that the terms of trade only changes with inflation and is a state variable; equations (12)–(13) imply that in a monetary union with incomplete financial markets, households face different short-term interest rates.

With no loss of generality we assume that the central bank controls $\hat{\imath}_t$. Each of the two independent fiscal authorities in countries H and F controls labor income tax rate and government spending, $\{\hat{\tau}_t^l, \hat{G}_t\}$ and $\{\hat{\tau}_t^{*l}, \hat{G}_t^*\}$, respectively.

System (1)–(14) describes private-sector equilibrium and determines deviations $\hat{C}_t$, $\hat{Y}_t$, $\hat{\pi}_{Ht}$, $\hat{R}_t$, $\hat{d}_{Ht}$, $\hat{d}_{Ft}$, $\hat{C}_t^*$, $\hat{Y}_t^*$, $\hat{\pi}_{Ft}^*$, $\hat{R}_t^*$, $\hat{d}_{Ht}^*$, $\hat{d}_{Ft}^*$, $\hat{\imath}_t^*$, and $\hat{S}_t$, given policy $\hat{\imath}_t$, $\hat{G}_t$, $\hat{G}_t^*$, $\hat{\tau}_t^l$, $\hat{\tau}_t^{l*}$ and exogenous stochastic processes $\hat{z}_t, \hat{z}_t^*, \hat{\upsilon}_t$, and $\hat{\upsilon}_t^*$.

2.2 Social Objectives

The social objective is assumed to be the country-size weighted sum of national intertemporary utility objectives,

$$W = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(nU\left(c_t, g_t, y_t\right) + \left(1-n\right)U^*\left(c_t^*, g_t^*, y_t^*\right)\right),$$

where $U\left(c_t, g_t, y_t\right)$ and $U^*\left(c_t^*, g_t^*, y_t^*\right)$ are flow national objectives, which depend on per capita private and public consumption and output.

It is straightforward to demonstrate that quadratic approximation (up to third-order terms) to the social loss function $-W$ around the efficient deterministic steady state can be written as

$$-W \approx n\frac{\epsilon}{2\lambda}y\left(c\xi\right)^{-\frac{1}{\sigma}}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t V_t^H + \left(1-n\right)\frac{\epsilon}{2\lambda}y^*\left(c^*\xi^*\right)^{-\frac{1}{\sigma}}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t V_t^F + tip, \tag{15}$$

where *tip* denotes "terms independent of policy."[8] Quadratic intraperiod terms V_t^H and V_t^F are

$$\begin{aligned}
V_t^H &= \frac{\lambda}{\epsilon}\frac{1-\sigma}{\sigma}\frac{C}{Y}\hat{C}_t^2 + \frac{\lambda}{\epsilon\sigma}\frac{G}{Y}\hat{G}_t^2 + \frac{\varsigma\lambda}{\epsilon}\left(\hat{Y}_t - \frac{1+\varsigma}{\varsigma}\hat{Z}_t\right)^2 \\
&\quad + \frac{\lambda}{\epsilon}\left(1-\gamma\right)\frac{C}{Y}\left(\hat{C}_t + \gamma\eta\hat{S}_t\right)^2 + \frac{\lambda}{\epsilon}\gamma\frac{C}{Y}\left(\hat{C}_t^* + \eta\left(1-\gamma^*\right)\hat{S}_t\right)^2 \\
&\quad + \frac{\lambda}{\epsilon}\frac{C}{Y}\eta\left(1-\eta\right)\gamma\left(\left(1-\gamma\right)^2 + \left(1-\gamma^*\right)\gamma^*\right)\hat{S}_t^2 + \hat{\pi}_{Ht}^2, \\
V_t^F &= \frac{\lambda}{\epsilon}\frac{C^*}{Y^*}\frac{1-\sigma}{\sigma}\hat{C}_t^{*2} + \frac{\lambda}{\epsilon\sigma}\frac{G^*}{Y^*}\hat{G}_t^{*2} + \frac{\varsigma\lambda}{\epsilon}\left(\hat{Y}_t^* - \frac{1+\varsigma}{\varsigma}\hat{Z}_t^*\right)^2 \\
&\quad + \frac{\lambda}{\epsilon}\left(1-\gamma^*\right)\frac{C^*}{Y^*}\left(\hat{C}_t^* - \eta\gamma^*\hat{S}_t\right)^2 + \frac{\lambda}{\epsilon}\gamma^*\frac{C^*}{Y^*}\left(\hat{C}_t - \eta\left(1-\gamma\right)\hat{S}_t\right)^2 \\
&\quad + \frac{\lambda}{\epsilon}\frac{C^*}{Y^*}\eta\left(1-\eta\right)\gamma^*\left(\left(1-\gamma^*\right)^2 + \gamma\left(1-\gamma\right)\right)\hat{S}_t^2 + \hat{\pi}_{Ft}^{*2}.
\end{aligned}$$

2.3 Calibration

2.3.1 Steady-State Restrictions and Fiscal Side

The fiscal side of the model is characterized by government-spending-to-output ratios $\Theta_H = G_H/Y$ and $\Theta_F = G_F/Y$, labor

[8]To obtain this expression, we employ the device of a steady-state employment subsidy and preference level shocks ξ and ξ^* (Benigno 2009); see appendix B. This allows us to generate a valid linear-quadratic (LQ) approximation to the underlying policy problem across all the types of policy we consider. In distorted steady state, the second-order approximation to social welfare would include linear terms which would prevent us calculating a valid second-order approximation to welfare using a linearized model and would also introduce an inflation bias to our policy problem. Eliminating the level bias allows us to focus on the stabilization bias.

income taxes τ^l and τ^{*l}, maturity of debt m_H and m_F, *annualized* steady-state debt-to-output ratios $\delta_H = \beta m_H \frac{(B_H + B_H^*)}{4Y}$ and $\delta_F = \beta m_F \frac{(B_F + B_F^*)}{4Y^*}$, the share of home-issued debt held by non-residents $\varrho = \frac{B_H^*}{B_H + B_H^*}$, and the share of home-held foreign debt to foreign-held home debt $\omega = \frac{m_H B_F S}{m_F B_H^*}$. Here B_H are home-issued bonds held by home residents, B_H^* are home-issued bonds held by foreign residents, B_F^* are foreign-issued bonds held by foreign residents, and B_F are foreign-issued bonds held by home residents.

In the symmetric-countries model we assume that both countries are of equal size and have zero steady-state government debt held by non-residents, $\varrho = 0.0$. The total government debt-to-output ratio is set to 60 percent on an annual basis ($\delta_H = \delta_F = 0.6$).

In the baseline asymmetric-countries model we calibrate the model to real data, assuming that small country H consists of Portugal, Greece, Ireland, Italy, and Spain, also labeled "the periphery," and large country F consists of the rest of the EMU, also labeled "the core." The calibration is based on data presented in appendix C.

The total-debt-to-output ratio for small country H is calibrated $\delta_H = 1.10$, which is consistent with employment-weighted average debt level in the periphery countries. The large foreign country has $\delta_H = 0.6$, consistent with the debt level in the core. The currently observed domestic debt levels are treated as steady-state values rather than initial conditions, partly because the current projections (see IMF Fiscal Monitor data) suggest that this level of government debt is expected to persist for at least a decade, thus making these values an (implicit) target of policy authorities, as it is expected that all variables are to return to these (steady-state) values in the long run. As a significant proportion of the government debt is held by non-residents, we set the value for the periphery government debt held by non-residents to $\varrho = 0.5$. The IMF survey data reported in appendix C suggest that the imbalances in long-term debt holdings imply $\omega = 0.5$, so that the small home country is a net debtor.

For both models we calibrate the share of government spending to GDP, $\Theta_H = \Theta_F = 0.20$. The average maturity of government debt is set to seven years ($m_H = m_F = 28$, on a quarterly basis). The adjustment cost parameter $\chi = \chi^* = 0.01$ following Benigno (2009).

The steady-state tax level needed to service debt is

$$\frac{\tau^l}{\mu} = \Theta_H + 4\frac{(1-\beta)}{\beta}\delta_H, \qquad \frac{\tau^{*l}}{\mu} = \Theta_F + 4\frac{(1-\beta)}{\beta}\delta_F,$$

and steady-state values of all debt components are

$$\frac{B_H}{Y} = 4\,(1-\varrho)\,\frac{\delta_H}{\beta m_H}, \quad \frac{B_H^*}{Y} = 4\varrho\frac{\delta_H}{\beta m_H}, \quad \frac{B_F}{Y^*} = 4\omega\varrho\frac{Y}{Y^*}\frac{\delta_F}{\beta m_F},$$
$$\frac{B_F^*}{Y^*} = 4\left(1-\omega\varrho\frac{Y}{Y^*}\right)\frac{\delta_F}{\beta m_F}.$$

2.3.2 Structural Parameters and Shocks

Calibration of structural parameters is standard. The model frequency is quarterly. The household's discount factor β is set to 0.99, which gives the steady-state interest rate of 4 percent. The Calvo parameter θ is set to 0.75, which implies the average length of fixed price contracts of about one year. Openness is set to $\alpha = 0.3$. Inverse of the intertemporal elasticity is calibrated $\sigma = 0.5$, based on evidence in Attanasio and Weber (1995). Elasticity between home goods $\epsilon = 11$ and inverse of the Frisch elasticity of labor supply $\zeta = 3$ are calibrated consistently with most estimations of DSGE models (Justiniano and Preston 2010, Liu and Mumtaz 2011, and Chen, Kirsanova, and Leith 2017a). The intertemporal elasticity of substitution between domestic and foreign goods η is set to 1.5; see Adolfson et al. (2008) and Albonico, Paccagnini, and Tirelli (2016).

The relative size of each country is calibrated depending on the nature of the analysis. We use symmetric monetary union consisting of two identical countries with $n = 0.5$ when we discuss our main results and the transmission mechanisms. We also study country-size asymmetric monetary union with "large foreign" and "small home" countries, where the home country has size $n = 0.3$, as the relative size in terms of population or employment of Greece, Ireland, Italy, and Portugal is about one-third of the total population of the EMU countries.

The model has four AR(1) shocks:

$$\text{Technology Shocks:} \quad \hat{z}_t = \rho_z \hat{z}_t + \sigma_z \nu_t, \quad \hat{z}_t^* = \rho_z \hat{z}_t^* + \sigma_z \nu_t^*,$$
$$\nu_t, \nu_t^* \sim iid(0,1),$$

$$\text{Cost-Push Shocks:} \quad \hat{\upsilon}_t = \rho_\upsilon \hat{\upsilon}_t + \sigma_\upsilon \varepsilon_t, \quad \hat{\upsilon}_t^* = \rho_\upsilon \hat{\upsilon}_t^* + \sigma_\upsilon \varepsilon_t^*,$$
$$\varepsilon_t, \varepsilon_t^* \sim iid(0,1).$$

To calibrate stationary technology shocks, we use results from estimation of DSGE models where stochastic trend is removed from the output data; see, e.g., Lubik and Schorfheide (2006). This research typically obtains the persistence of an AR(1) technology shock ρ_z in range [0.3–0.9]; see, e.g., Lubik and Schorfheide (2006), Bianchi (2013), and Chen, Kirsanova, and Leith (2017a). We calibrate $\rho_z = 0.85$ and $\sigma_z = 0.003$. The cost-push shock is calibrated to have $\rho_\upsilon = 0.85$ and $\sigma_\upsilon = 0.0025$, consistently with Chen, Kirsanova, and Leith (2017a).[9] The four shocks are assumed to be independent. All results which we discuss in the paper are robust to calibration of shock parameters.

3. Policy Specification

3.1 Policy Objectives

Monetary and fiscal authorities are assumed to set their policies in order to minimize their respective loss functions, given the dynamic structure of the economies.

While the benevolent monetary authority seeks to maximize the union-wide welfare, it is reasonable to assume that national fiscal authorities are exclusively concerned with welfare of their residents and, hence, their objective functions should only include national counterparts. In what follows, therefore, we allocate objectives

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t V_t^H \text{ and } \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t V_t^F$$

to home and foreign fiscal authorities, respectively, and use the social objective

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(n V_t^H + (1-n) V_t^F \right)$$

[9]The implied unconditional variance of the shock is much smaller than the 0.0217 reported in Smets and Wouters (2003).

as a union-wide objective. Here V_t^H and V_t^F are the same as used in objective (15).[10]

3.2 Timing of Moves, Policy Regimes, and the Degree of Precommitment

The timing of main events in this model is conventional: at the beginning of each period the state is realized and observed by all economic agents, the policymakers, and the private sector. Knowing the state realization, and anticipating the private sector's reaction—as described by households' and firms' first-order conditions—the policymakers choose the level of instruments. Then, at the end of the period, the private sector chooses consumption and prices.[11] The equilibrium responses of all agents result in a new level of states by the beginning of the next period.

Therefore, policymakers always move after the state is realized and before the private sector makes decisions. There are three policymakers: the central bank and two fiscal authorities. In order to stabilize the economy following shocks, they may or may not act in a cooperative way.

Policymakers act cooperatively if they share common objectives. Policymakers act strategically, rather than cooperatively, if their objectives differ. If they do not cooperate, they can make decisions either simultaneously without taking each other's actions into account, or they can anticipate each others' policy decisions, as some of the authorities may have intraperiod leadership.

Taking a stand on intraperiod leadership in interactions of monetary and fiscal policymakers deserves some discussion.[12] In theory, an intraperiod leader knows the reaction function of the follower and takes it as a constraint on optimization when choosing its policy.[13]

[10] We follow, e.g., Leith and Wren-Lewis (2011).

[11] This timing is standard in the literature on dynamic monetary policy; see, e.g., Clarida, Galí, and Gertler (1999).

[12] Although it is clearly interesting to study all possibilities, in this paper we restrict our analysis to selected policy scenarios to keep clear focus and avoid too many cases. The discussion of our choice of the leadership structure has been substantially expanded following the discussant's comments.

[13] See the discussion in Beetsma and Giuliodori (2010). It should be stressed that fiscal leadership is not the same as fiscal dominance, and we are not assuming that the central bank is forced to accommodate the actions of the fiscal

In practice, does any policymaker have any first-move advantage? Conditional on the assumption that monetary and fiscal policymakers optimize, our arguments run along the following lines.

All major central banks proclaim short-term stabilization as one of their main aims. The actual conduct of the stabilization policy has always been under investigation by numerous researchers, and there is general consensus that conventional monetary policy reaction function can be reasonably well explained by a Taylor-rule-type linear relationship. It is also well known (e.g., Svensson 2003) that a Taylor-rule-type linear relationship can be a "targeting rule," i.e., results from policy optimization. In other words, there is substantial empirical evidence that monetary policy behaves in a systematic way, and we have some reasonably detailed information about its reaction function, and that the reaction function is consistent with optimizing behavior of a central bank. In our framework, this signals in favor of fiscal leadership: a fiscal policymaker has this information and, as a big player, *can* condition fiscal policy responses on the known monetary policy reaction function.

However, one may argue that fiscal policy is also predictable simply because there are restrictions on its conduct: a limit on borrowing and/or on fiscal deficits. Such restrictions do provide us with information about the fiscal policy reaction function. In the LQ framework, the information about fiscal constraints can most easily be captured by adding appropriate terms to the fiscal policy objective function. For example, an additional term penalizing high fiscal deficits will impose corresponding restrictions on the conduct of fiscal policy. Fiscal policy reaction function, resulting from optimization, will be affected by the form of policy objective. This suggests that monetary leadership would also be possible.

Choosing between these two descriptions of monetary-fiscal policy interactions in a linear-quadratic rational expectations (LQ RE) framework, we decided not to study the intraperiod monetary leadership in this paper. Despite the fact that each policymaker's reaction could be predicted by the counterpart to some extent, we believe that this extent, and more precisely the certainty of this extent,

authority. It is simply that, for example, the fiscal authority may anticipate that the central bank will react to a fiscal stimulus by attempting to stabilize any inflation that it generates.

is different. First, fiscal policy has not been *systematically* used for short-term stabilization, certainly not until the Great Recession, and therefore is much less studied by monetary economists. As a result, it is much less predictable by monetary policymakers despite the known constraints on fiscal policy. Moreover, these constraints are frequently violated, so the actual effect of these constraints on fiscal policy reaction function is uncertain. Second, actual fiscal policy operates at much lower frequency than monetary policy, so that the actual monetary policymaker, who needs to make a decision now and wants to take into account fiscal policy response, remains uncertain about the exact timing and the extent of the future fiscal response. Actual monetary policy may need to move several times before the response of fiscal policy is certain. These two arguments are based on the uncertainty of timing and of the strength of fiscal policy reactions. Working with an LQ RE model, we rule out the regime of monetary leadership as the one which is less likely to be adequately explained by a model with full and complete information.

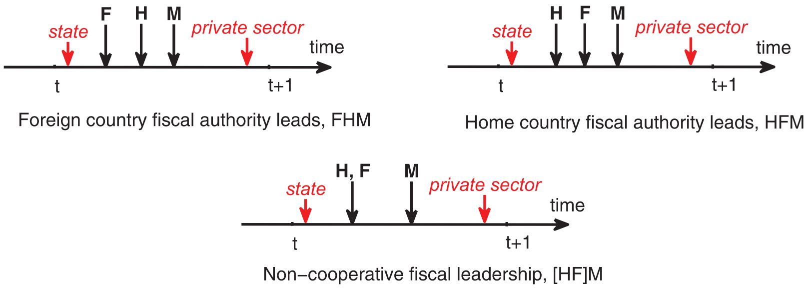
Ruling out monetary leadership leaves us with fiscal leadership and with the regime of simultaneous moves, in which neither policymaker takes into account actions of the counterpart. As the baseline case in this paper, we concentrate on the regime of fiscal leadership, but we also discuss how our results are amended in the case of simultaneous moves.[14]

Having decided to focus on the regime of fiscal leadership, we however remain flexible about the relative intraperiod positions of the two fiscal policymakers and consider all possibilities; see figure 1, which illustrates timing in all regimes that we consider. Moreover, intraperiod positions of the two fiscal policymakers will be determined endogenously, as an equilibrium outcome in policy game. We label fiscal authorities H and F, and label the monetary authority M.

In what follows, we label three non-cooperative regimes explicitly exploiting the order of moves: FHM, HFM, and [HF]M, where in the last regime we use square brackets to indicate that fiscal authorities H and F make moves simultaneously; see figure 1.

[14]There is some empirical evidence in favor of fiscal leadership against monetary leadership and the regime of simultaneous moves, although only for the United Kingdom and Sweden, which are economies with independent monetary policymakers; see Fragetta and Kirsanova (2010).

Figure 1. Non-cooperative Policy Regimes and Intraperiod Timing of Moves



The cooperative regime is not plotted in figure 1. The fiscal (and therefore complete) cooperation can be implemented by either giving up national policy instruments to a supranational agent with a union-wide objective or by simply adopting the union-wide objective instead of national by each fiscal authority. When all agents share objectives, then the order of moves is inconsequential.[15] We label the cooperative regime C.

Finally, we need to take a stand on the degree of policy precommitment. Although there is little doubt that major central banks are able to precommit to an inflation target, the way they actually manage the private sector's *expectations of policies* to achieve the target remains on research agenda. The early statements of many central banks do not suggest that banks precommit to a plan which is chosen once and forever. Once the Bank of England gained independence, King (1997) proclaimed a regime of "constrained discretion," accepting discretionary reactions to inevitable "distractions," but claiming that they will not dominate its policy. Bernanke and Mishkin (1997) gave similar arguments to describe the U.S. monetary policy as discretionary. More recently, some European central banks described their policy as commitment, implemented by means of communicating the "predictable response pattern"; see Bergo (2007) for the view of the Norges Bank and Svensson (2009) for

[15]However, in what follows, it is more intuitive to assume that the order of moves under cooperation is the same as under non-cooperation with national policy objectives, such that the only policy change is the adoption of the union-wide objective by fiscal authorities without any change in the timing of moves.

policy recommendations for the Riksbank to follow in the footsteps of Norges Bank by generating optimal policy projections.

Empirical analysis, however, predominantly describes monetary policy as discretionary; see Chen, Kirsanova, and Leith (2017a) for Europe, and Givens (2012), Coroneo, Corradi, and Santos Monteiro (2013), and Chen, Kirsanova, and Leith (2017b) for the United States.[16] Fiscal policy's degree of precommitment is less frequently discussed in the empirical literature; one example is Kirsanova and le Roux (2013), which demonstrates that non-cooperative discretion dominates non-cooperative commitment in the United Kingdom. More recently, Chen, Leeper, and Leith (2015) demonstrate that the empirical model of the U.S. economy with non-cooperative monetary and fiscal policy operating under discretion dominates the one where fiscal policy operates with rules, while monetary policy operates under discretion. Based on these empirical studies, we assume in this paper that all monetary and fiscal policy decisions are made under discretion.

3.3 Solution Algorithm

Our definition of discretionary policy is conventional and is widely used in the monetary policy literature; see, for example, Oudiz and Sachs (1985), Backus and Driffill (1986), Clarida, Galí, and Gertler (1999), and Woodford (2003). Solving the cooperative case is straightforward, and the numerical algorithm follows Söderlind (1999). The algorithm can be adapted to solve multi-player models; see Currie and Levine (1993) and one implementation in Blake and Kirsanova (2011). For a multi-player game of k participants, the following points are important.

The private sector in a discretionary setup knows that policymakers behave in a time-consistent manner, and sets its aggregate instrument, vector p_t, which contains inflation, consumption, and prices of long-term bonds for our model as a feedback rule on the vector

[16] Using medium-scale macro models, Bache, Brubakk, and Maith (2010) for Norges Bank and Adolfson et al. (2011) for Riksbank find that the past policy of these banks is better explained as optimal policy under commitment than as simple rules, but no comparison with discretion is made. Debortoli and Lakdawala (2016) find only a limited degree of precommitment using a medium-scale model for the United States.

of states of the economy, s_t, which are bonds, terms of trade, and shocks in our model, and on all policy instruments, $u_t = [u_{1t,}...u_{kt,}]$, which are the short-term interest rate, government spending, and taxes:

$$p_t = \alpha_s s_t + \alpha_u u_t. \tag{16}$$

Any policymaker $1 \leq m \leq k$ with instruments $u_{mt,}$ who follows one or many other policymakers, treats the vector of leaders' policy instruments ($l_t \subset u_t$) as additional states, and its policy reaction function can be written as a linear rule:

$$u_{mt} = \gamma_s s_t + \gamma_l l_t. \tag{17}$$

Therefore, any intraperiod leading policymaker with instruments in l_t influences decisions $u_{mt,}$ of the follower. Any intraperiod leader takes this influence into account when formulating its policy. For each policymaker the optimization problem can be described by a conventional Bellman equation with constraints given by the private-sector reaction function in form (16) and by policy reaction functions of all policymaker-followers in form (17). The optimization results in the system of first-order conditions, which in an LQ RE setting is a system of matrix Riccati equations in the unknown coefficients of decision rules α-s and γ-s and in coefficients of value function matrices. A fixed-point solution to this system, if one exists, satisfies economic agents' expectations and the policymakers' Bellman equations. Solved-out value function matrices must be positive semi-definite. More details of the solution algorithm are provided in appendix D.

4. Policy Coordination

This section presents main results on policy coordination in the baseline scenario. It begins by identifying whether policy cooperation is desirable and sustainable in a monetary union with two identical countries. It then explains the economic underpinnings of these results, with inferences about the nature of the policy problem faced by policymakers.

4.1 Coordination Failures

Table 1 reports welfare losses for different policy regimes studied in this paper. Each column presents the loss attributed to the corresponding policymaker, M, H, and F, where subscripts U and N denote the type of objective—union or national—which is used by this policymaker. Here and everywhere else, the loss attributed to a policymaker is computed using its "true" loss metrics: union-wide loss for M and national loss for H and F.

These results suggest, as we further discuss in this section, that cooperation in a symmetric monetary union is unlikely to arise. Cooperation is Pareto preferred in the case of technology shocks, but this equilibrium is not sustainable. The cooperative outcome can emerge if cost-push shocks dominate, but it is only one of the sustainable equilibriums and is not Pareto preferred in the union as a whole. To facilitate the discussion, we present the results in a reduced-form-game loss matrix in table 2.

Assuming that fiscal authorities adhere to their national objectives, outcomes of the policy coordination in a 2x2 game are given in panel A in table 2, where each entry reports losses (home, foreign). Suppose each fiscal authority has two strategies, to lead (L) or to follow (F), which are loosely interpreted as a strategy to set the fiscal policy committee meeting either before or after the other country's fiscal policy committee has met. The loss matrices in panel A in table 2 are filled using entries from columns 1–3 in panels A and B in table 1. The off-diagonal boxes contain losses of fiscal authorities in regimes FHM and HFM, while the diagonal boxes contain the losses in regime [HF]M.[17]

If the economy is subject to technology shocks, then there is a unique Nash equilibrium in which both authorities engage in non-cooperative fiscal leadership (L_N, L_N), which corresponds to regime [HF]M; see panel A1 in table 2.[18] Trying to schedule the fiscal policy committee meeting ahead of the other country, each fiscal policymaker ends up scheduling it in the morning of the first working day of each fiscal period.

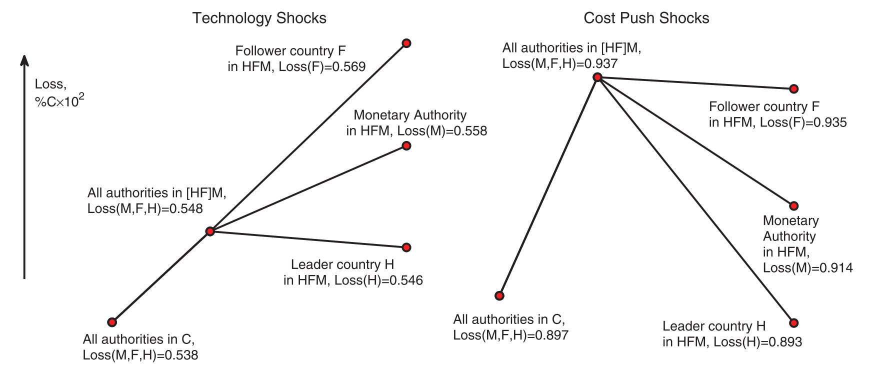
[17]In regime [HF]M both fiscal authorities move simultaneously, treating the other player as given. It is straightforward to demonstrate that this is a limiting case of the leadership game.

[18]We limit our analysis to pure strategies.

Table 1. Welfare Losses by Policymaker and by Policy Regime, Symmetric Monetary Union

Regime	National Objectives			Home: Union Obj.			Foreign: Union Obj.			Cooperation		
	M_U (1)	H_N (2)	F_N (3)	M_U (4)	H_N (5)	F_N (6)	M_U (7)	H_N (8)	F_N (9)	M_U (10)	H_N (11)	F_N (12)
A. Policymakers' Losses Due to Technology Shocks, $\%C\times10^2$												
FHM	0.558	0.569	0.546	0.557	0.602	0.512	0.543	0.525	0.561	0.538	0.538	0.538
[HF]M	0.548	0.548	0.548	0.543	0.571	0.516	0.543	0.516	0.571	0.538	0.538	0.538
HFM	0.558	0.546	0.569	0.543	0.561	0.525	0.557	0.512	0.602	0.538	0.538	0.538
B. Policymakers' Losses Due to Cost-Push Shocks, $\%C\times10^2$												
FHM	0.914	0.935	0.893	0.896	0.917	0.876	0.910	0.936	0.883	0.898	0.898	0.898
[HF]M	0.937	0.937	0.937	0.927	0.918	0.937	0.927	0.937	0.918	0.898	0.898	0.898
HFM	0.914	0.893	0.935	0.910	0.883	0.936	0.896	0.876	0.917	0.898	0.898	0.898

C. Welfare Ranking of Selected Policy Regimes



Note: Here and in all subsequent tables, all losses are measured in percentage of steady-state consumption that the consumer would be willing to give up to move from the actual regime to the steady-state allocation.

Table 2. Main Results on Policy Coordination, Symmetric Monetary Union

A. Equilibriums in 2x2 Game					
		A1. Technology Shocks		*A2. Cost-Push Shocks*	
		Foreign Country		Foreign Country	
		L_N	F_N	L_N	F_N
Home Country	L_N	**(0.548,0.548)**	(0.546,0.569)	(0.937,0.937)	**(0.893,0.935)**
	F_N	(0.569,0.546)	(0.548,0.548)	**(0.935,0.893)**	(0.937,0.937)
B. Equilibriums in 4x4 Game					
B1. Technology Shocks					
		Foreign Country			
		L_N	L_U	F_N	F_U
Home Country	L_N	**(0.548,0.548)**	(0.516,0.571)	(0.546,0.569)	(0.512,0.602)
	L_U	(0.571,0.516)	(0.538,0.538)	(0.561,0.525)	(0.538,0.538)
	F_N	(0.569,0.546)	(0.525,0.561)	(0.548,0.548)	(0.516,0.571)
	F_U	(0.602,0.512)	(0.538,0.538)	(0.571,0.516)	(0.538,0.538)
B2. Cost-Push Shocks					
		Foreign Country			
		L_N	L_U	F_N	F_U
Home Country	L_N	(0.937,0.937)	(0.937,0.918)	(0.893,0.935)	**(0.876,0.917)** [0.896]
	L_U	(0.918,0.937)	**(0.898,0.898)** [0.898]	(0.883,0.936)	(0.898,0.898)
	F_N	(0.935,0.893)	(0.936,0.883)	(0.937,0.937)	(0.937,0.918)
	F_U	**(0.917,0.876)** [0.896]	(0.898,0.898)	(0.918,0.937)	(0.898,0.898)

Notes: Here and in other tables, losses to (home, foreign); losses in Nash equilibriums are shown in bold fonts, $\%C\times10^2$. The number in square brackets is the union-wide loss attributed to the monetary policymaker in a Nash equilibrium.

The prevalence of cost-push shocks, however, results in multiple Nash equilibriums (F_N, L_N) and (L_N, F_N), and therefore in coordination failures; see panel A2 in table 2. Each country can wait and let the other move first, but if there is an anticipation that the other country will ignore the information available to them about the prospective follower's reaction function when formulating policy, then the better strategy for the country is to move first.

Table 1 suggests that union-wide welfare loss is lower under cooperation than it is for some of these Nash equilibriums. Cooperation requires each policymaker to be willing to either delegate its policy instruments to a supranational decisionmaker or, equivalently, adopt the union-wide objectives. Columns 4–9 in table 1 report losses attributed to policymakers in the case where either home or foreign fiscal authority adopts the union-wide objective unilaterally, while the monetary authority retains the union-wide objective. These losses are then used to construct reduced-form-game matrices for the extended 4x4 game; see panel B in table 2, where each policymaker is assumed to have four strategies: it can decide to either lead or follow (L or F) and to either adopt the union-wide objective or adhere to the national objective (U or N). Decisions on leadership and objectives are made simultaneously, so we use the type of objective as a subscript to the leadership strategy. Once the decision on leadership and policy objective is made, it is built into institutional arrangements. These arrangements determine the stabilization loss attributed to each policymaker.[19]

Panel B1 in table 2 shows that under technology shocks the unique equilibrium with national objectives (L_N, L_N) is robust to the new possibility of adopting union-wide objectives. No fiscal authority will give up national objectives; each will continue trying to conduct itself as an intraperiod leader, so that the regime of simultaneous fiscal leadership [HF]M will realize.

The multiplicity of Nash equilibriums under cost-push shocks is also robust to the new set of strategies; see panel B2 in table 2. Specifically, there are three Nash equilibriums in pure strategies. There are two symmetric equilibriums (F_U, L_N) and (L_N, F_U) in which the leader maximizes the national welfare and anticipates that it will be optimal for the other country to adopt union-wide objectives and follow, without attempting to challenge the first country's leadership position. In the third equilibrium (L_U, L_U), each fiscal policymaker adopts union-wide objectives and attempts to lead,

[19]The extended-form game includes period 0 in which the decision on institutional structure is made. The subsequent periods are parts of the infinite-horizon monetary-fiscal non-cooperative policy interactions with no precommitment.

ending up scheduling the fiscal policy committee meeting at the first day of each fiscal period. Because objectives are shared, this equilibrium yields the cooperative outcome. If the home country anticipates that its leadership will be challenged, it will choose to adopt the union-wide objectives, and vice versa.

Out of the three Nash equilibriums, the two non-cooperative equilibriums (F_U, L_N) and (L_N, F_U) are the best for the central bank, as they deliver the lowest union-wide loss (losses attributed to the monetary policymaker are reported in square brackets in table 2, panel B2). Fiscal policymakers can coordinate on any of these three equilibriums, not necessarily on the Pareto preferred.

To summarize, cooperation in the symmetric monetary union under discretionary policy is unlikely to arise. It is Pareto preferred under technology shocks, but it is not sustainable. The cooperative outcome can emerge under cost-push shocks, but it is not preferred by the monetary authority and the union as a whole. Multiplicity of Nash equilibriums and coordination failures suggest a possible coordinating role for a supranational authority, which in this environment can be taken by the central bank, as it naturally has access to the same information and can communicate easily with the fiscal authorities.[20]

It turns out that the type of equilibrium outcome is robust to changes in model parameterization and is mostly explained by shock-dependent policy tradeoffs, which in turn imply a very particular ranking of policy regimes for each fiscal policymaker. We discuss these tradeoffs next.

4.2 Transmission Mechanisms

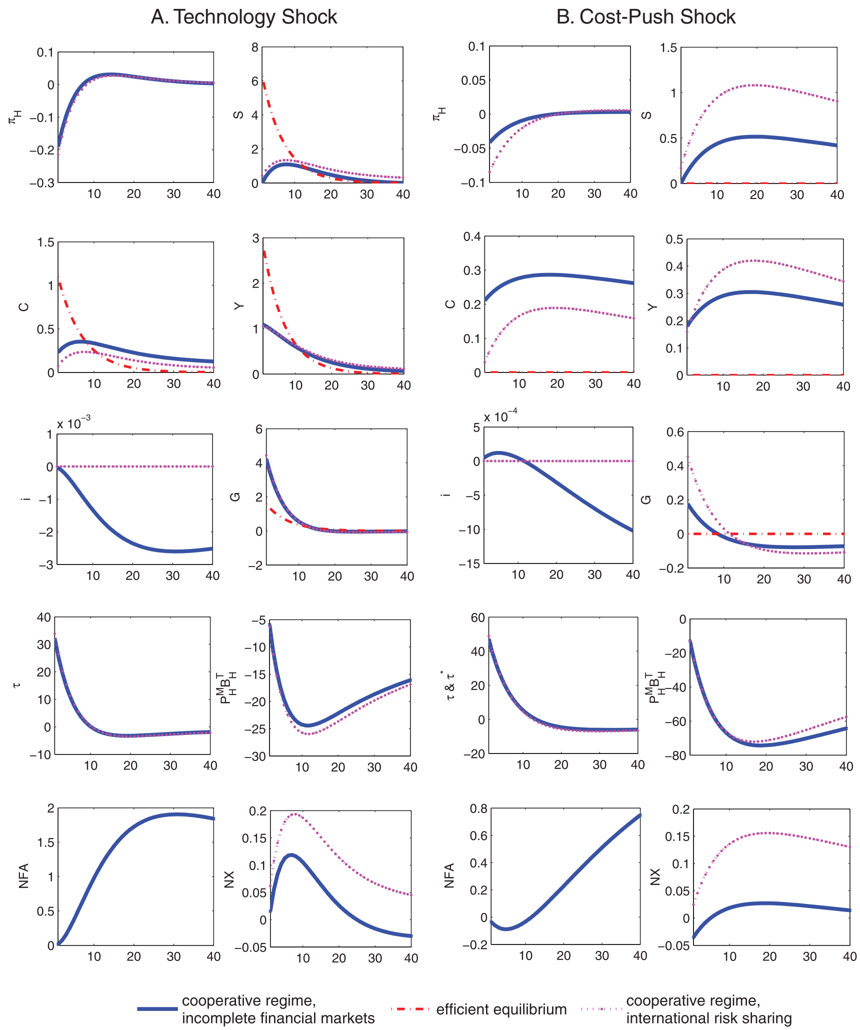
4.2.1 Cooperation under Technology Shocks

We start with an asymmetric technology shock, positive in country H but negative in country F; see figure 2, which only plots impulse responses for country H. We also plot responses in the efficient equilibrium and under international risk sharing.[21]

[20]See Aumann (1974, 1987).

[21]Although not explicitly discussed in this paper, well-studied international risk sharing provides a convenient benchmark. We use it in figure 1 only to facilitate the discussion; the specification of the model in this case is given in appendix A.

Figure 2. Transmission Mechanism under Cooperation (C)



Notes: Panel A presents impulse responses in country H to an asymmetric technology shock of size $\frac{1}{\lambda(\varsigma+1)}$, positive in H but negative in F. Panel B presents impulse responses in country H to an asymmetric cost-push shock of size 1, negative in H but positive in F.

The transmission mechanism is relatively straightforward, with opposite effects in countries H and F. Following the shock, the home producer price falls. In the absence of nominal rigidities, the terms of trade $S_t = P_{Ft}/P_{Ht}$ increase efficiently, so as to share the cost of work effort between the two countries, leading to an increase of demand and output in the home country. The real exchange rate depreciates.

Nominal rigidities preclude that, in face of the shock, the terms of trade increase as much as their efficient level. Consequently, a negative output gap and deflation arise at H, while the opposite happens at F. Income of H households also increases and, therefore, they consume and save more. However, under incomplete financial markets, H households are not allowed to lend abroad as much as they would do under international risk sharing. As a result, consumption is closer to its efficient level but is much higher than under international risk sharing. A larger consumption at H reduces the marginal utility of consumption and lowers labor supply, exerting an upward pressure on wages and mitigating deflation at H. Thus, incomplete financial markets enable a better stabilization of producer inflation rates, which makes terms of trade deviate more from their efficient level.

Government spending and taxes increase to stabilize H inflation (the opposite occurs in country F), but this further widens the negative terms of trade gap. As the shock produces smaller effects on inflation under incomplete financial markets than under international risk sharing, policy instruments move by less than under risk sharing but still more than in the efficient equilibrium.

Since net exports increase, country H becomes the net lender, liabilities towards country F decrease, and holdings of net foreign assets increase. Consequently, under incomplete financial markets, a lower risk premium is levied on H government debt, decreasing the interest rate in country H (the reverse occurs in country F).

Despite yielding slightly better stabilization of inflation, government spending, and output, incomplete financial markets increase the terms of trade gap and yield an excessively high relative consumption. These effects make welfare losses higher than those under risk sharing.[22]

[22]Further details are given in appendix E.

4.2.2 Non-cooperative Regimes and Their Ranking under Technology Shocks

In this model, fiscal policy produces two types of spillovers. Consider again an asymmetric technology shock, positive in country H and negative in country F. First, fiscal policy produces a negative cross-border effect: increasing taxes and spending in the home country stabilizes H producer inflation, which accentuates negative terms of trade gap and reinforces positive foreign output gap; as this pushes further up F producer inflation, it requires a stronger intervention from F fiscal authority. Second, fiscal policy also produces a positive union-wide externality: increasing taxes and spending in the home country stabilizes H producer and union-wide average inflation, reducing the need for adjustments from the common monetary policy.

Both above-mentioned spillovers are taken into account when authorities cooperate. However, in the absence of cooperation and pursuing national objectives, national fiscal authorities are unable to internalize the cross-border consequences of their policies and face an incentive to deviate from the cooperative outcome.

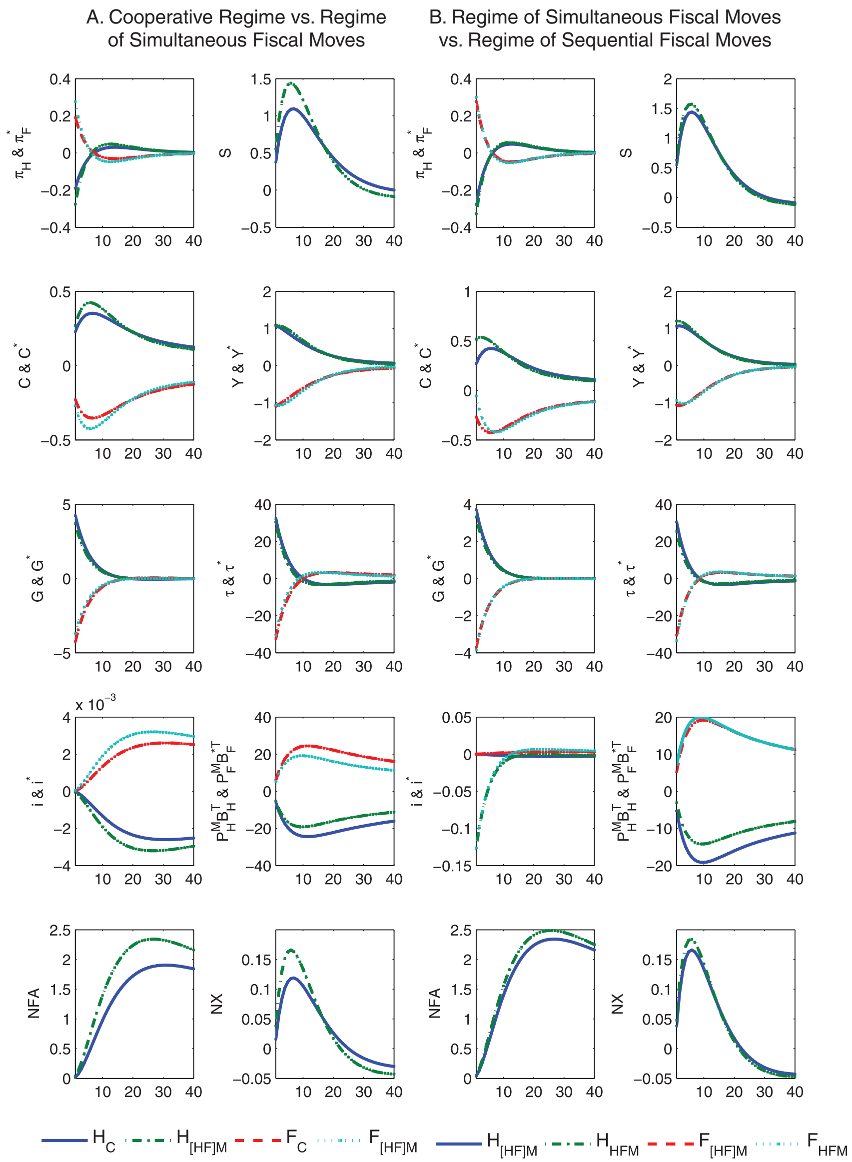
Panel A of figure 3 shows impulse responses under [HF]M and cooperation to an asymmetric technology shock. Similarly, panel B of figure 3 shows impulse responses under HFM and [HF]M.

When nationally oriented fiscal authorities move simultaneously and lead the monetary authority, each of them tries to exploit the first move to take advantage of the union-wide positive externality. Specifically, H fiscal authority anticipates that if the average union-wide inflation is reduced, then the monetary authority will intervene and reduce the interest rate, which helps stabilize H producer inflation. Therefore, H fiscal authority moves both fiscal instruments by less, making them deviate less from their efficient levels than under cooperation.

As plotted in panel A of figure 3, relative to the cooperative regime (C), [HF]M results in more volatile producer inflation in both countries but better-stabilized terms of trade gap, output, consumption, and spending gaps. However, the loss from higher inflation volatility outweighs all other gains, and welfare deteriorates.

When there is a regime with sequential fiscal moves (HFM), the leader, H fiscal authority, knows that its control for inflation causes a

Figure 3. Impulse Responses to an Asymmetric Technology Shock of Size $\frac{1}{\lambda(\varsigma+1)}$, Positive in Country H and Negative in Country F



Note: Countries are identical, with $\varrho = 0$ and $\omega = 1$.

negative cross-border effect, further increasing F and, consequently, union-wide inflation. H fiscal authority anticipates that an upward pressure on the interest rate, due to the reaction of the monetary authority to an expected increase of the union-wide inflation, will destabilize H inflation. Thus, to ensure that monetary policy helps stabilize H inflation, H fiscal authority moves its policy instruments by even less, closer to their efficient levels, compared to [HF]M. In this regime fiscal policies are no longer symmetric and the central bank lowers the interest rate in reaction to a negative average inflation; see panel B in figure 3. This monetary policy response increases consumption in both countries and helps to stabilize H inflation while destabilizing F inflation. F fiscal policy has to react in order to undo the harm done by monetary policy.

As plotted in panel B of figure 3, regime HFM results in more volatile producer inflation in both countries but in better-stabilized terms of trade gap, relative to regime [HF]M. Consumption, output, and government spending are closer to their efficient levels, and thus are better stabilized at home, while the reverse occurs in the foreign country. The gain of better stabilization of real variables outweighs the loss from greater inflation volatility in country H, while the opposite happens in F. Therefore, this regime, compared to [HF]M, allows for higher welfare to the leader country H (yet lower than under cooperation), and lower welfare in the follower country F. Since the losses in F outweigh the gains in H due to an excessively volatile H inflation, the union-wide welfare worsens relative to [HF]M.

Policy Equilibrium under Technology Shock. The abovementioned relative ranking of non-cooperative regimes with fiscal leadership, HFM, FHM, and [HF]M, produces the unique Nash equilibrium (L_N, L_N) in the game where two fiscal policymakers are only allowed to choose the time of their policy decisions; see table 2, panel A1.

Despite the fact that the cooperative outcome is preferred by each of the policymakers, it is not a Nash equilibrium in the extended 4x4 game, where each fiscal policymaker also decides whether to adopt the union-wide objective. Consider the leadership regime with simultaneous fiscal moves, but where country F shares the union-wide objective function of the monetary policymaker, while country H uses the national objective, (L_N, L_U). In this scenario, H policymaker still exploits the first-move advantage over the monetary policymaker, raising fiscal instruments by less than it would do under cooperation. Because country F and the monetary policymaker now share objectives and react on averages, H and F policy responses are no longer symmetric and monetary policy ends up helping stabilization of the home country's inflation. Despite the fact that cooperation is a better outcome for F, it delivers worse stabilization for H and, therefore, H fiscal authority faces incentives to deviate from cooperation by unilaterally adopting national objectives. Very similar dynamics can be observed under either HFM or FHM where, either leading or following, country H exploits the monetary policy reaction function and has incentives to adopt the national objectives unilaterally.

This incentive of a fiscal policymaker to deviate from cooperative outcome (L_U, L_U) prevents it from becoming a Nash equilibrium in the 4x4 game; see panel B1 in table 2. Fiscal authorities have prisoner's dilemma: despite the fact that the joint adoption of union-wide objectives is better than any non-cooperative outcome under national objectives, the unilateral deviation from union-wide objectives delivers even greater gain to the deviating policymaker. Cooperation, therefore, does not realize under technology shocks, and the non-cooperative fiscal leadership under national objectives [HF]M remains the unique Nash equilibrium.

4.2.3 Cost-Push Shocks and Fiscal Stabilization

An asymmetric cost-push shock, negative in country H but positive in country F, reduces marginal costs and home inflation and increases the terms of trade, which—by shifting demand from F to H—contributes to inflation stabilization both at home and abroad. Since cost-push shocks have no effect on the efficient flexible-price equilibrium, a positive output gap (and deflation) arises at home; see panel B of figure 2.[23]

Income increases at home and so does consumption and savings, since domestic and foreign goods are substitutes in utility. However, under incomplete financial markets, H households are not allowed to lend abroad as much as they would do under international risk

[23] We can think of efficient tax rates as the ones that eliminate the costs imposed by fluctuations in firms' desired markup; see Leith and Wren-Lewis (2011).

sharing. As a result, consumption increases by much more than under international risk sharing. As in the case of technology shocks, a larger consumption at H reduces the marginal utility of consumption and exerts an upward pressure on wages, mitigating deflation at H. Thus, incomplete financial markets enable a better stabilization of producer inflation rates and also of the terms of trade.

Using taxes, it is possible to completely offset the effect of these shocks on inflation, but there are consequences for debt accumulation in this model. Government spending complements the stabilization role of taxes by stabilizing both inflation and debt. As a result, taxes move less than required to offset the shock, keeping part of "surprise inflation," as it helps to inflate the real debt (see Leeper and Leith 2016), and government spending in country H also increases. As the shock produces smaller effects on inflation under incomplete financial markets, fiscal policy instruments adjust by less than under international risk sharing. This is particularly evident in the response of government spending, which is the costly fiscal instrument.

Due to the inefficiently high consumption and the better stabilization of terms of trade under incomplete financial markets, net exports decrease at H during the first periods. However, once the terms of trade become high enough, a current account surplus emerges, due to a weaker demand of F goods in H. Initially, country H is the net debtor and increases its liabilities towards F while decreasing its holdings in foreign assets (net foreign assets fall); the opposite (net foreign assets increase) occurs afterwards. During the initial periods, under incomplete financial markets, a higher risk premium is thus levied on H government debt, increasing the interest rate at H; the reverse occurs subsequently.

In spite of causing higher volatility of consumption and an inefficiently high relative consumption, incomplete financial markets promote a better stabilization of inflation, terms of trade, output, and government spending. As the gains in welfare from the latter outweigh the costs of the former, welfare losses are lower than those under international risk sharing.[24]

Under non-cooperation, fiscal authorities fail to internalize cross-border and union-wide spillovers. When both fiscal authorities move

[24] Auray and Eyquem (2014) showed that incomplete markets (autarky) may produce lower welfare costs than complete markets.

simultaneously and lead the monetary authority, they try to exploit the first-move advantage by moderating its overall fiscal policy reaction, relying on the stabilization effort of monetary policy. While taxes react slightly more, government spending is strongly moderated, with both becoming closer to their efficient levels. As policy authorities act symmetrically, monetary policy ends up being neutral. Relative to cooperation, terms of trade are more volatile and inflation is slightly more volatile, while consumption, output, and government spending become more stable; see panel A in figure 4, which plots impulse responses in regime [HF]M and under cooperation (C). The welfare losses from larger inflation and terms of trade volatility outweigh the gains from better stabilization of the other variables, and overall welfare deteriorates relative to the cooperative regime.[25]

Panel B of figure 4 compares the impulse responses under the regime with unilateral leadership of country H, HFM, with those under the regime of simultaneous non-cooperative fiscal leadership, [HF]M.

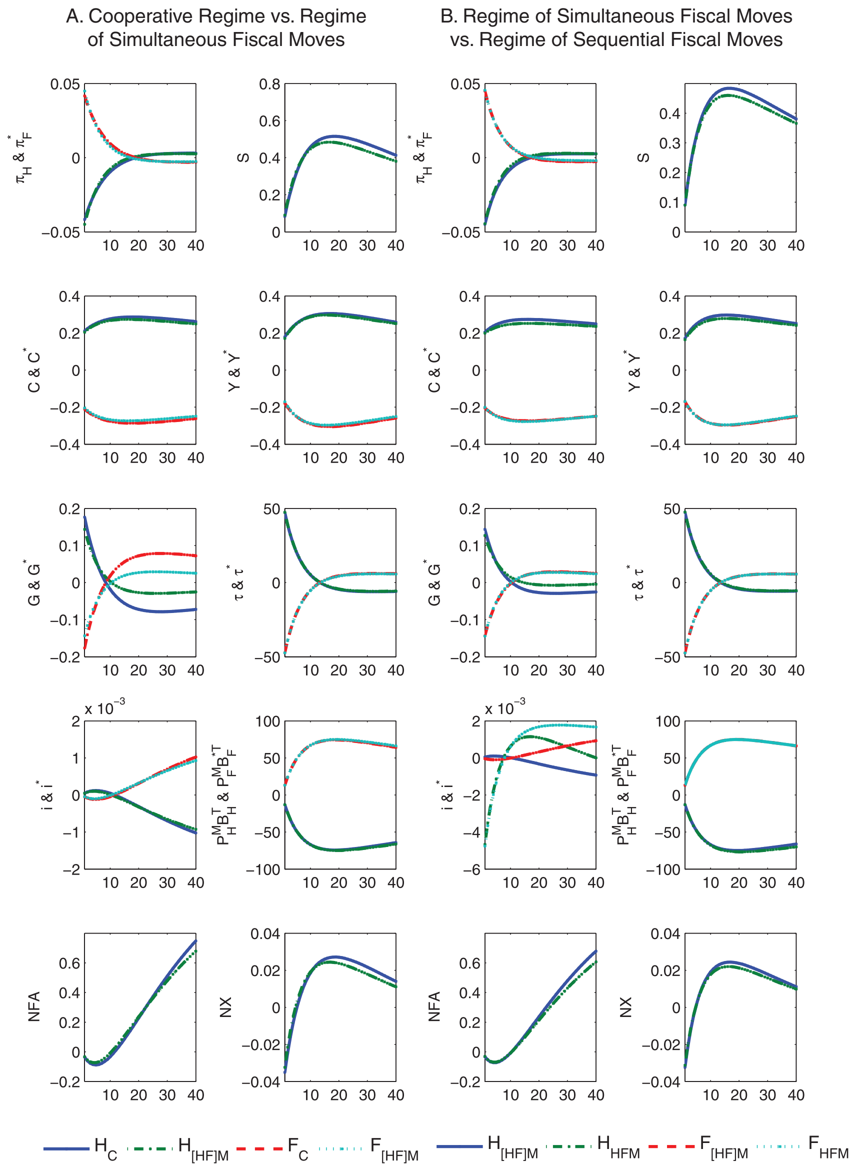
The leader, H fiscal authority, can substantially improve its welfare relative to the one in regime [HF]M, similarly to what is achieved under technology shocks. Since H anticipates that its policy reaction will have a pressure on F inflation and, consequently, union-wide inflation, H will react even by less than under [HF]M. H government spending is thus raised by less than under [HF]M, resulting in negative average inflation, and the central bank lowers the interest rate. H taxes, however, rise by even more, moving closer to the efficient level.

As a result, HFM yields much less volatile inflation at home, and only slightly more volatile inflation in country F. Volatility of the terms of trade falls, which helps to stabilize demand in both countries. The leader gains more not only relative to [HF]M but also relative to cooperation, as there is a substantial reduction in overall volatility. The reduction in the interest rate does not allow the follower's consumption to reduce too much, so there are welfare stabilization gains even for the follower, and for the monetary policymaker relative to [HF]M.

The resulting ranking of non-cooperative regimes is given in panel C (graph on the right), table 1. As the follower F also gains

[25] The numbers are given in panel C, table 1.

Figure 4. Impulse Responses to an Asymmetric Cost-Push Shock of Size 1, Negative in Country H and Positive in Country F



Note: Countries are identical, with $\varrho = 0$ and $\omega = 1$.

in equilibrium (L_N, F_N), there is no incentive to fight over the leadership, and there are two Nash equilibriums with sequential moves of policymakers, (L_N, F_N) and (F_N, L_N); see table 2, panel A2.

These two Nash equilibriums do not survive in the extended 4x4 game, where each fiscal policymaker can also decide whether to adopt the union-wide objective. Equilibrium (F_N, L_N) is dominated by unilateral adoption of the union-wide objective by country H; equilibrium (F_U, L_N) is Pareto preferred to (F_N, L_N) and is a new Nash equilibrium.

When the follower adopts the union-wide objective function, it now attaches some weight to the objectives of the leading country. The leader anticipates this and, since cross-border effects of the fiscal policy of the follower are large, it will now react much less than if the follower is nationally oriented. On the one hand, this will improve the stabilization of the follower, and, on the other hand, it will also improve the stabilization of the leader through a stronger interest rate reaction. Both countries achieve better stabilization in (F_U, L_N) compared to (F_N, L_N). Similarly, (L_N, F_U) dominates $L_N, F_N)$; see table 2, panel B2.

Apart from the two asymmetric equilibriums (L_N, F_U) and (F_U, L_N), there is a Nash equilibrium which replicates the cooperative outcome as all authorities adopt the same union-wide objectives, (L_U, L_U). If a policymaker cannot convey itself as an intraperiod leader, the cooperative outcome will realize in which both fiscal policymakers move simultaneously and use union-wide objectives. As discussed above, equilibrium (L_U, L_U) produces lower welfare stabilization costs than the equilibrium where both fiscal policymakers adopt national objectives, (L_N, F_N). Unilateral deviation (L_N, L_U) from (L_U, L_U) is not beneficial: fiscal policy responses are no longer symmetric, therefore monetary policy is non-neutral and ends up by improving the stabilization of the country with union-wide objectives.

5. Extensions

5.1 Regime of Simultaneous Moves

Suppose all three policymakers move simultaneously, unable to take into account each other's policy reaction function. This regime of simultaneous moves leads to relatively high welfare losses, compared

Table 3. Regime of Simultaneous Moves, Fiscal Choice of National and Union-Wide Objective

		Technology Shocks, %C×10²		**Cost-Push Shocks, %C×10²**	
		Foreign Country		Foreign Country	
		N	*U*	*N*	*U*
Home Country	*N*	(0.553,0.553)	(0.586,0.510)	(1.007,1.007)	(0.995,0.884)
	U	(0.510,0.586)	**(0.538,0.538)**	(0.884,0.995)	**(0.937,0.937)**

to the cooperative regime and to the regime with fiscal leadership [HF]M.[26]

Table 3 reports outcomes in 2x2 games in which the fiscal policymaker, being unable to choose the date of the fiscal policy committee meeting and to exploit other policymakers' reaction functions, is still able to decide whether to unilaterally adopt the union-wide policy objective (strategy U) or retain the national objective (strategy N). Equilibrium (N, N), therefore, describes the regime of simultaneous moves of all policymakers, while equilibrium (U, U) describes cooperation. This table suggests that cooperation is sustainable under both types of shock.

However, our previous results suggest that any optimizing fiscal policymaker who has an ability to use information about the monetary policy will be better off using it, and the cooperative equilibrium is not sustainable in an environment with these additional strategies.

5.2 Heterogeneous Monetary Union

The analysis in section 4 uses a symmetric monetary union model with zero steady-state holdings of foreign debt, $\varrho = 0$. We now investigate how the results change in an asymmetric monetary union, calibrated to the actual data for core and periphery EMU country blocks; see section 2.3.

[26]This is consistent with findings in the literature; see, e.g., Dixit and Lambertini (2003).

Table 4. Policy Coordination in Country-Size Asymmetric Monetary Union

A. Choice of Leadership, %C×10²					
		A1. Technology Shocks		*A2. Cost-Push Shocks*	
		Large Foreign Country		Large Foreign Country	
		L_N	F_N	L_N	F_N
Small Home Country	L_N	**(0.730,0.444)**	(0.729,0.447)	(1.051,0.945)	**(1.037,0.944)** [0.971]
	F_N	(0.749,0.443)	(0.730,0.444)	**(1.047,0.899)** [0.941]	(1.051,0.945)
B. Choice of Leadership and the Type of Objective, %C×10²					
B1. Technology Shocks					
		Large Foreign Country			
		L_N	L_U	F_N	F_U
Small Home Country	L_N	**(0.730,0.444)**	(0.667,0.459)	(0.729,0.447)	(0.658,0.474)
	L_U	(0.740,0.438)	(0.680,0.452)	(0.735,0.440)	(0.680,0.452)
	F_N	(0.749,0.443)	(0.676,0.455)	(0.730,0.444)	(0.667,0.459)
	F_U	(0.759,0.438)	(0.680,0.452)	(0.740,0.438)	(0.680,0.452)
B2. Cost-Push Shocks					
		Large Foreign Country			
		L_N	L_U	F_N	F_U
Small Home Country	L_N	(1.051,0.945)	(1.049,0.933)	(1.037,0.944)	**(1.006,0.931)** [0.952]
	L_U	(1.051,0.946)	**(1.033,0.915)** [0.949]	(1.034,0.946)	(1.033,0.915)
	F_N	**(1.047,0.899)** [0.941]	(1.048,0.901)	(1.051,0.945)	(1.049,0.933)
	F_U	(1.054,0.897)	(1.033,0.915)	(1.051,0.946)	(1.033,0.915)

Table 4 presents the results for the country-size asymmetric monetary union. The qualitative results are similar to those reported in table 2 for the symmetric monetary union: cooperation is not a sustainable Nash equilibrium under technology shocks, and there is multiplicity of Nash equilibriums under cost-push shocks, although the best sustainable equilibrium is now (F_N, L_N) instead of (F_U, L_N) for symmetric countries. There are also some quantitative differences. The level of losses depends on parameterization—in particular, on the degree of country-size asymmetry—and on the level of debt, external exposure, and imbalances.

In a country-size asymmetric monetary union, the smaller country suffers more from the consequences of an asymmetric shock, because the change in the terms of trade has a bigger effect on the marginal cost and therefore on its inflation rate. In addition, asymmetric shocks result in union-wide effects, to which the central bank reacts, effectively stabilizing the larger country's economy. Because of these two reasons, the smaller country's fiscal policy has to intervene more, which usually results in greater volatility of fiscal instruments and higher stabilization costs. Therefore, the first number in matrix entries in table 4 is always greater than the second number.

The scaling of losses does not change the individual ranking of policy regimes, but the country-size effects are more than simple scaling. A change in the relative country size affects the relative ability of policymakers to exploit reaction functions of each other and of the monetary policymaker, which may result in different Nash equilibriums in an asymmetric monetary union.

In the case of technology shocks, the country-size effects on the equilibrium outcome in table 4 are limited. The outcome is determined by the individual ranking of outcomes in non-cooperative regimes [HF]M, HFM, and FHM. Regardless of country size, the leader gains and the follower loses in the sequential regimes HFM and FHM relative to their payoffs in [HF]M.

If there are no steady-state non-resident holdings of debt, $\varrho = 0$, then under cost-push shocks the country-size effects result in only two Nash equilibriums in the extended 4x4 game, (L_U, L_U) and (L_N, F_U). Greater non-resident holdings of debt ($\varrho > 0$) but equal steady-state external debts ($\omega = 1$) does not affect the ranking of regimes.[27]

However, making the home country the net external debtor with $\varrho > 0$ and $\omega < 1$ results in additional asymmetries and results in

[27] Additional figures and tables are given in appendix E.

(re-)appearence of the third equilibrium (F_N, L_N) under cost-push shocks. In this case the net external debtor has to generate current account surplus to pay for the debt service. The small home country becomes even "smaller" with lower steady-state consumption and spending. As a net debtor under cost-push shocks, the small H country now has fewer incentives to adopt the union-wide objectives. Indeed, as cross-border effects of its policy are small, and the H country attaches a large relative weight to the objectives of the large F country under union-wide metrics, H reacts much less than it does under national objectives, and optimal actions of the larger country have destabilizing effects on H. These asymmetries become sufficiently large and the small-size country H sees the reduction of losses if it keeps the national objective; therefore outcome (F_N, L_N) emerges as a Nash equilibrium.

Finally, a unilateral increase of steady-state debt-to-output ratio in small country H yields higher stabilization losses for both types of shocks, while large country F gains under technology shocks and loses under cost-push shocks. However, the relative change is numerically small, without implications for the ranking of regimes and for stability of policy equilibriums.

5.3 Coordinating Role of a Central Bank

In this section we illustrate one way the central bank can affect the equilibrium outcome if an additional monetary instrument is provided. This is an extreme simplification of ideas presented in Corsetti, Higgins, and Pesenti (2017).[28]

Suppose that in the setup of our model, the central bank can buy government bonds using a fund backed by lump-sum taxes. The two linearized government budget constraints, equations (5) and (10), become

$$\hat{d}_{Ht} + \frac{Y^*}{Y}\hat{d}^*_{Ht} = 4\frac{\delta_H}{\beta}\hat{R}_t + \frac{1}{\beta}\hat{d}_{Ht-1} + \frac{1}{\beta}\frac{Y^*}{Y}\hat{d}^*_{Ht-1} + \frac{G}{Y}\hat{G}_t$$
$$- \frac{\tau^l}{\mu}\left(\gamma\hat{S}_t + (\varsigma+1)\left(\hat{Y}_t - \hat{Z}_t\right) + \frac{1}{\sigma}\hat{C}_t + \left(1 + \frac{\tau^l}{\mu}\right)\hat{\tau}^l_t\right) + \hat{L}_t,$$

[28]The section was added following the discussant's suggestions. We leave the detailed analysis of this policy proposal for future research, as it deserves much more thought and deeper investigation than a section in this paper might allow.

$$\frac{Y}{Y^*}\hat{d}_{Ft} + \hat{d}^*_{Ft} = 4\frac{\delta_F}{\beta}\hat{R}^*_t + \frac{1}{\beta}\frac{Y}{Y^*}\hat{d}_{Ft-1} + \frac{1}{\beta}\hat{d}^*_{Ft-1} + \frac{G^*}{Y^*}\hat{G}^*_t$$
$$- \frac{\tau^{l*}}{\mu}\left(-\gamma^*\hat{S}_t + (\varsigma+1)\left(\hat{Y}^*_t - \hat{Z}^*_t\right) + \frac{1}{\sigma}\hat{C}^*_t + \left(1 + \frac{\tau^{*l}}{\mu}\right)\hat{\tau}^{*l}_t\right)$$
$$- \frac{Y}{Y^*}\hat{L}_t.$$

Here $\hat{L}_t$ is the (normalized) net borrowing of country H from the fund. Because of the zero union-wide net supply of funds, country F's net lending—channeled via the fund—is $\frac{Y}{Y^*}\hat{L}_t$. We assume that the central bank can use $\hat{L}_t$ as an additional (asymmetric) policy instrument.

This instrument has a potential to completely offset effects of cost-push shocks. As discussed in section 4, taxes do not offset cost-push shocks only because of debt sustainability issues. Once the new instrument, which can ensure debt sustainability in the case of asymmetric shocks, is provided, complete stabilization can be achieved. We do not impose any realistic constraints on the use of $\hat{L}_t$, and we keep the same leadership assumption: the central bank is a follower in monetary-fiscal policy interactions but now has two policy instruments instead of one.[29] The results for cost-push shocks are presented in table 5, which can be compared to table 2.[30]

As anticipated, the level of overall losses reduce substantially. However, the ranking of policy regimes also changes. Policymakers will choose union-wide objective unilaterally and coordinate on the unique cooperative equilibrium (L_U, L_U), which is the best for the central bank.

The new instrument does not affect qualitative results in the case of technology shocks, although the level of losses falls.[31] Complete stabilization is impossible, and fiscal policymakers still face prisoner's dilemma and do not coordinate on the Pareto-preferred cooperative equilibrium.

[29]Realistic treatment would require imposing budget constraints on each country's borrowing from the fund and setting some criteria for access to the fund. We therefore also ignore any reduction in risk premium which may be associated with borrowing from such fund.

[30]We impose a small penalty on movements of $\hat{L}_t$ to prevent complete stabilization.

[31]Results are given in appendix G.

Table 5. Policy Coordination under Cost-Push Shocks, Central Bank Has Two Instruments

A. Fiscal Choice of Leadership, $\%C\times 10^3$			
		Foreign Country	
		L_N	F_N
Home Country	L_N	(0.11662,0.11662)	**(0.11370,0.11660)**
	F_N	**(0.11660,0.11370)**	(0.11662,0.11662)

B. Fiscal Choice of Leadership and the Type of Objective, $\%C\times 10^3$					
		Foreign Country			
		L_N	L_U	F_N	F_U
Home Country	L_N	(0.11662,0.11662)	(0.11638,0.11621)	(0.11370,0.11660)	(0.11247,0.11622)
	L_U	(0.11621,0.11638)	**(0.11497,0.11497)**	(0.11416,0.11650)	(0.11497,0.11497)
	F_N	(0.11660,0.11370)	(0.11650,0.11416)	(0.11662,0.11662)	(0.11638,0.11621)
	F_U	(0.11622,0.11247)	(0.11497,0.11497)	(0.11621,0.11638)	(0.11497,0.11497)

6. Conclusion

This paper studies monetary and fiscal policy coordination in a monetary union. We demonstrate that cooperation of fiscal policymakers is unlikely to be sustainable as a Nash equilibrium. The outcome is, however, shock dependent. Under efficient technology shocks, the fiscal authorities have a prisoner's-dilemma-type coordination problem, and the socially and individually preferred cooperative outcome is not a Nash equilibrium. Under inefficient cost-push shocks, multiple Nash equilibriums arise. The cooperative outcome can be achieved in one of these equilibriums, but it is not the union-wide preferred. We argue that the pervasive multiplicity of policy equilibriums and coordination failures suggest an important coordinating role for a supranational authority. This role can be naturally assumed by the central bank, as it has access to the same information as the fiscal authorities and can easily communicate with them.

Of course, the latter conclusion is tailored to our normative analysis, with perfect and complete information about each agent's information set and the set of strategies. However, even in our setup, this paper does not design policy coordination mechanism, either for the central bank or for any other coordinator, apart from illustrating how an additional policy instrument of a central bank might work. We had a more modest aim: to investigate sustainability of policy equilibriums and demonstrate the existence of coordination failures and the need for a coordinator. Our model, therefore, abstracts from many features that a realistic economy has; in particular, national fiscal authorities' policy objectives may be more realistically described as having penalties on large movements of fiscal instruments, thus reflecting restricted fiscal space. However, once the nature of policy interactions and coordination failures are well understood, we will be better equipped to solve a range of practical problems.

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