Sustainable Policy Coordination in a Monetary Union*

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Abstract

In a monetary union where fiscal and monetary authorities act strategically fiscal cooperation is unlikely to emerge as an equilibrium. Under technology shocks the one fiscal policymaker's gain is another fiscal policymaker's loss so the Fiscal Fight equilibrium – in which both fiscal policymakers try to exploit leadership against each other and end up acting simultaneously – is sustainable for both monetary and fiscal leadership regimes. The monetary leadership regimes only dominate fiscal leadership regimes if the substitutability of home and foreign goods is low and more aggressive policies are needed. If the fiscal policymakers are able to exploit the leadership over monetary policy, then they will fail to cooperate even if the cooperation is preferred by all agents. The Fiscal Fight equilibrium is unique in high substitutability of goods economy. The need for aggressive policies with the reduction in degree if substitutability between goods makes multiple Nash fiscal leadership equilibria to arise, and creates a potential role for a supra-national policy coordinator

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1 Introduction

Policy coordination in a monetary union is one of classic issues in the macroeconomic policy research. The literature is vast, 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 the type of policy framework, on whether the fiscal authorities and the monetary authority can internalize each other's actions, on the form of policy objectives and many other factors. The literature frequently argues that the cooperative outcome is high on the list of Pareto-ranked options available to national and/or union-wide policymakers.[1] However, very little analysis goes beyond establishing the ranking.

In this paper we identify sustainable policy equilibria. We focus the analysis on strategic behavior of fiscal policymakers and investigate which policy equilibria constitute a Nash equilibrium. We argue that in a monetary union where fiscal policymakers act strategically, cooperation is unlikely to emerge as an equilibrium. Even if it is Pareto-preferred, it is not a Nash equilibrium. Moreover, multiplicity of Nash equilibria may arise. 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 with incomplete financial markets where policymakers act strategically but unable to precommit, and where stochastic disturbances are due to technology shocks. 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. Similarly, the fiscal policymakers can either exploit an intra-period leadership over the monetary policymaker, or they may move simultaneously, or they follow.

The difference in equilibrium outcomes is mainly explained by the expenditure-switching-specific policy tradeoffs and the type of intra-period policy leadership of monetary and fiscal policy. Under efficient technology shocks the desire and the ability of an intra-period 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

[1] See recent survey by Beetsma and Giuliodori (2010) and references therein.

becomes the fiscal follower's loss, for all degrees of goods substitutability, but in fiscal leadership regimes. As a result, there is a 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 intra-period advantage over each other – the Fiscal Fight Equilibrium. The cooperative equilibrium dominates the Fiscal Fight Equilibrium, but there is Prisoner-dilemma type of interactions, making cooperation non-sustainable.

With high degree of substitutability the fiscal policymakers are locked into a Prisoner's dilemma for both fiscal and monetary leadership policy regimes. Although the type of leadership matters – and fiscal leadership regimes welfare-dominate monetary leadership regimes – the fiscal policymakers have clear preferences to either unilaterally lead or follow, leading to sustainability of the Fiscal Fight Equilibrium, not 'cooperation'. In contrast, with low degree of substitutability of goods, the cooperative equilibrium is dominated by monetary leadership equilibria.

With low substitutability between home and foreign goods, the policy spillovers are much reduced and policy equilibria in which the authorities are either unable or unwilling to exploit each other actions generally lead to more aggressive policies and lower welfare costs. Thus, in monetary leadership regimes the monetary policymaker is practically unable to exploit its leadership over the fiscal players, as technology shocks do not require much intervention on the union-level. The monetary leadership regimes approximate the regime with simultaneous moves which yields an aggressive behavior and therefore low welfare loss. Fiscal leadership regimes do exploit the leadership over the monetary policy, but lead to relatively smooth policy and therefore are dominated in an environment with weak cross-border spillovers. Multiple Nash equilibria arise among fiscal leadership regimes once the difference in fiscal policy objectives is large enough to generate greater conflict and more aggressive behaviour.

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.[2] Its aim is to present policy coordination tradeoffs that strategic policymakers, which are unable to precommit, face with in 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 concludes.

[2] 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).

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 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 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[3], 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.[4]

2.1 Private Sector Equilibrium

The household optimization problem for country H yields consumption Euler equation

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

and the arbitrage condition,

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

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 real return on long-term bonds with geometric maturity structure and $\hat{\imath}_t$ is short term nominal interest rate.[5]

[3] Baele et al. (2004) argues that in the beginning of 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.

[4] Here and elsewhere we refer to the Online Appendix.

[5] 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

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

where $\hat{Y}_t$ is output, $\hat{\tau}^l_t$ is distortionary labour 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

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

where $\hat{d}_{Ht}$ is normalized real Home debt held by residents, $\hat{d}^*_{Ht}$ is normalized real Home debt held by non-residents[6], $\hat{G}_t$ is government spending. Respectively, $\hat{C}^*_t$, $\hat{G}^*_t$, $\hat{\tau}^{*l}_t$, $\hat{Y}^*_t$ and $\hat{\pi}^*_{Ft}$ are Foreign consumption, government spending, labour 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

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

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

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

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

[6] See Appendix A for the normalization formula.

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

where $\hat{d}^*_{Ft}$ is normalized real Foreign debt held by residents, $\hat{d}_{Ft}$ 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

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

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

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, $\{\hat{\tau}^l_t,\hat{G}_t\}$ and $\{\hat{\tau}^{*l}_t,\hat{G}^*_t\}$, 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 $\hat{\imath}_t$, $\hat{G}_t$, $\hat{G}^*_t$, $\hat{\tau}^l_t$, $\hat{\tau}^{l*}_t$ 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 weighed 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 $U(c_t, g_t, y_t)$ and $U^*(c_t^*, g_t^*, y_t^*)$ 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

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

where *tip* denotes 'terms independent of policy'.[7] Quadratic intra-period terms V_t^H and V_t^F are

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

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 $\Theta_F = G_F/Y$, labour 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% on 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 labelled 'the

[7] 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 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 both 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.

Periphery', and large country F consists of the rest of the EMU, also labelled '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 $\delta_H = 0.6$, consistently 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 to be 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 7 years ($m_H = m_F = 28$, on 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

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

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%. 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 labour supply $\zeta = 3$ are calibrated consistently with most estimations of DSGE models (Liu and Mumtaz (2011), Justiniano and Preston (2010), Chen et al. (2017a)). We consider two distinct values for the intertemporal elasticity of substitution between domestic and foreign goods, η. High degree of substitutability is modeled with $\eta = 1.5$, and low

degree of substitutability assumes $\eta = 0.4$, see e.g. Albonico et al. (2016) and Adolfson et al. (2008).

The model has two AR(1) technology shocks

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

which are assumed to be independent. To calibrate them we use results from estimation of DSGE models where stochastic trend is removed from the output data so shocks are stationary. This research typically obtains the persistence of an AR(1) technology shocks ρ_z in range [0.3-0.9], see e.g. Chen et al. (2017a), Bianchi (2013) and Lubik and Schorfheide (2005). We calibrate $\rho_z = 0.85$ and $\sigma_z = 0.003$. 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

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

as a union-wide objective. Here V_t^H and V_t^F are the same as used in objective (15).[8]

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

[8] We postulate this split, rather than try to justify it as the only reasonable way. In this we follow Leith and Wren-Lewis (2011).

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.[9] 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 takes 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 others' actions into account, or they can anticipate each others' policy decisions, as some of the authorities may have intra-period leadership.

We do not take a stand on whether the monetary policymaker leads or follows, we consider both possibilities.[10] However, we only study either monetary or fiscal leadership, or the regime of simultaneous moves. We therefore, omit all 'mixed' regimes, for example where the monetary policymaker moves second, following one fiscal policymaker and leading the other one. In other words, we assume that if one fiscal policymaker has learnt how to exploit the leadership over the monetary policymaker, so has done the second policymaker, and vice versa, if the monetary policymaker has an intra-period leadership over one fiscal policymaker, it has it over the other. This leaves us with three classes of regimes: Monetary Leadership (ML), Fiscal Leadership (FL), and the Regime of simultaneous moves (S). Within monetary and fiscal leadership regimes we remain flexible about the relative intra-period positions of the two fiscal policymakers and consider all possibilities, see Figure 1 which illustrates timing in all regimes which we consider. Moreover, intra-period positions of the two fiscal policymakers will be determined endogenously, as an equilibrium outcome in a policy game. We label fiscal authorities H and F, and label the monetary authority M.

In what follows, we label three FL 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. Similarly, for three ML regimes we use notation MFH, MHF and M[HF], see Figure 1.

[9] This timing is standard in the literature on dynamic monetary policy, see e.g. Clarida et al. (1999)

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

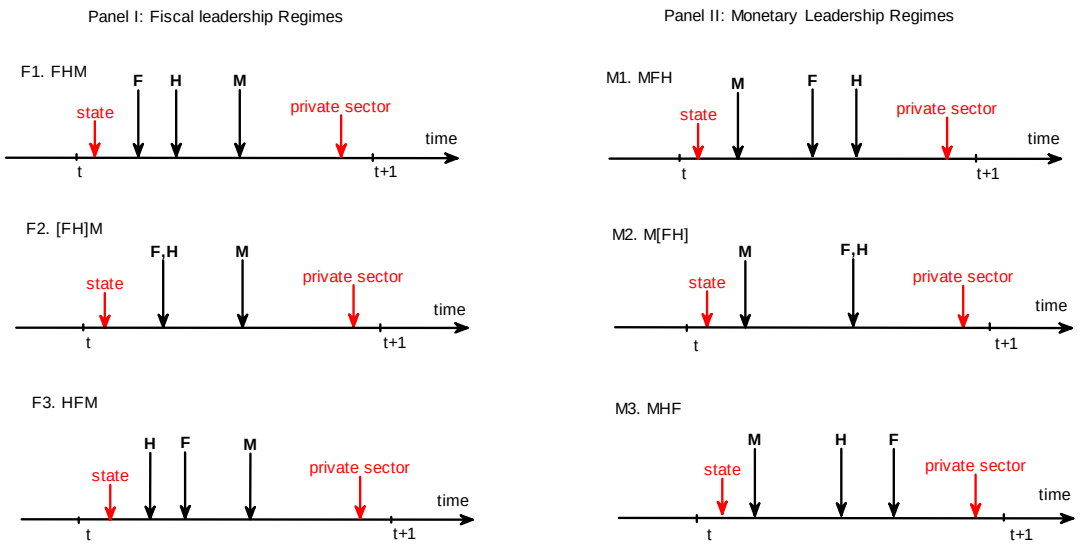

Figure 1: Non-coopeartive policy regimes and intra-period timing of moves

There is only one S regime which we can also label [HFM], regime S is not plotted in Figure 1.

The cooperative regime is also 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 simply by adopting the union-wide objective instead of national by each fiscal authority. When all agents share objectives then the order of moves is inconsequential.[11] We label the cooperative regime C.

We call regimes C, [HFM], [HF]M and M[HF] 'symmetric', as both fiscal authorities get the same payoff provided they have identical objectives.[12]

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,

[11] 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 union-wide objective by fiscal authorities without any change in the timing of moves.

[12] In this paper the country size is always 1/2, so whether fiscal authorities gat the same payoff only depends on the the leadership structure and the type of policy objective.

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 US 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 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 et al. (2017a) for the Europe, Givens (2012), Coroneo et al. (2013) and Chen et al. (2017b) for the US.[13] Fiscal policy's degree of precommitment is less frequently discussed in the empirical literature; one example is Le Roux and Kirsanova (2013) which demonstrates that non-cooperative discretion dominates non-cooperative commitment in the UK. More recently, Chen et al. (2015) demonstrate that empirical model of the US 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 discretionary in the sense of Backus and Driffill (1986).

3.3 Solution Algorithm

Our definition of discretionary policy is conventional and is widely used in the monetary policy literature, see, for example, Backus and Driffill (1986), Oudiz and Sachs (1985), Clarida et al. (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 of states of the economy, s_t, which are bonds, terms of trade and shocks in our model, and on all policy instruments,

[13] Using medium-scale macro models, Bache et al. (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 limited degree of precommitment using medium-scale model for the US.

$u_t = [u_{1t,}...u_{kt,}]$, 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 intra-period leading policymaker with instruments in l_t influences decisions $u_{mt,}$ of the follower. Any intra-period 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 is in 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 exists, satisfies economic agents' expectations and the policy makers' 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 results on policy coordination in the baseline scenario. It begins by ranking policy regimes and 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 facing by policymakers.

4.1 Main Results

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 and national – which is used by this policymaker in the reported policy regime. 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.

Columns (1)-(6) report outcomes in policy regimes illustrated in Figure 1. Once national policymakers use union-wide objectives (columns (4)-(6)), then the order of moves does not

Table 1: Welfare losses by policymaker and by policy regime, symmetric monetary union

Panel *A*: Policymakers' losses, high substitutability of goods, %C×10^2

	National Objectives (non-cooperation)			Union-wide objectives (cooperation)			Home: Union obj. (non-cooperation)			Foreign: Union obj. (non-cooperation)		
Regime	M_U	H_N	F_N	M_U	H_U	F_U	M_U	H_U	F_N	M_U	H_N	F_U
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Regime of simultaneous moves												
[HFM]	0.553	0.553	0.553	0.538	0.538	0.538	0.548	0.510	0.585	0.548	0.585	0.510
Fiscal leadership regimes												
FHM	0.558	0.569	0.546	0.538	0.538	0.538	0.557	0.602	0.512	0.543	0.525	0.561
[HF]M	0.548	0.548	0.548	0.538	0.538	0.538	0.543	0.571	0.516	0.543	0.516	0.571
HFM	0.558	0.546	0.569	0.538	0.538	0.538	0.543	0.561	0.525	0.557	0.512	0.602
Monetary leadership regimes												
MFH	0.551	0.548	0.553	0.538	0.538	0.538	0.543	0.555	0.530	0.547	0.527	0.566
M[HF]	0.552	0.552	0.552	0.538	0.538	0.538	0.546	0.562	0.530	0.546	0.530	0.562
MHF	0.551	0.553	0.548	0.538	0.538	0.538	0.547	0.566	0.527	0.543	0.530	0.555

Panel *B*: Policymakers' losses, low substitutability of goods, %C×10^2

	National Objectives (non-cooperation)			Union-wide objectives (cooperation)			Home: Union obj. (non-cooperation)			Foreign: Union obj. (non-cooperation)		
Regime	M_U	H_N	F_N	M_U	H_U	F_U	M_U	H_U	F_N	M_U	H_N	F_U
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Regime of simultaneous moves												
[HFM]	0.161	0.161	0.161	0.320	0.320	0.320	0.377	0.543	0.211	0.377	0.211	0.543
Fiscal leadership regimes												
FHM	0.906	1.226	0.586	0.320	0.320	0.320	0.752	1.243	0.261	0.318	0.166	0.470
[HF]M	0.695	0.695	0.695	0.320	0.320	0.320	0.569	0.902	0.236	0.569	0.236	0.902
HFM	0.906	0.586	1.226	0.320	0.320	0.320	0.318	0.470	0.166	0.752	0.261	1.243
Monetary leadership regimes												
MFH	0.211	0.324	0.098	0.320	0.320	0.320	0.293	0.493	0.093	0.361	0.099	0.624
M[HF]	0.164	0.164	0.164	0.320	0.320	0.320	0.274	0.453	0.095	0.274	0.095	0.453
MHF	0.211	0.098	0.324	0.320	0.320	0.320	0.361	0.624	0.099	0.293	0.093	0.493

Notes: 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.

matter and cooperation is implemented. Columns (7)-(12) report losses for scenarios in which one of fiscal policymakers adopts the union-wide objective.

Columns (1)-(6) in Table 1 suggest that the ranking of symmetric policy regimes (C, [HFM],

[HF]M, M[HF]) depends on the degree of substitutability between goods as summarized by:

$$\text{Ranking of union-wide losses} \begin{cases} \eta = 1.5: & \text{C} < \text{[HF]M} < \text{M[HF]} \lesssim \text{[HFM]}, \\ \eta = 0.4: & \text{[HFM]} \lesssim \text{M[HF]} < \text{C} < \text{[HF]M}, \end{cases}$$

where we used sign $\lesssim$ to emphasize that despite one regime is better than another, both regimes deliver losses which are much closer to each other than to a loss in any other regime. The following observations are apparent.

First, there is close resemblance between the regime of monetary leadership M[HF] and the regime of simultaneous moves [HFM]. Numerically, the union-wide losses in these two regimes are close to each other and noticeably different from losses in other regimes. Moreover, as we shall see below, these two regimes also deliver very similar dynamics of adjustment to shocks. This result holds for different degrees of substitutability between goods.

Second, with lower degree of substitutability the symmetric fiscal leadership regime becomes very costly.

Third, the cooperative regime is union-wide preferred only under the high degree of substitutability of home and foreign goods.

More generally, the ranking of regimes in columns (1)-(12) in Table 1 suggests that fiscal cooperation in a monetary union is unlikely to arise. In order to cooperate, all policymakers must share the union-wide objectives, so that each fiscal policymaker, unilaterally, should find it optimal to give up its national objectives and adopt the union-wide ones. To investigate whether this is the case, we consider a policy game between the two fiscal policymakers, in which they have two choices: they can choose the date of fiscal policy committee meeting, and whether unilaterally adopt the union-wide objective.[14]

We present the results in a reduced-form-game loss matrices in Table 2, where each entry reports *losses* (Home, Foreign). Specifically, each fiscal authority has four 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, to keep the national objective (N) or to adopt the union-wide objective (U). Decisions on leadership and objectives are taken simultaneously, so we use the type of objective as a subscript to the leadership strategy. Once the decision on leadership and policy objective is taken, it is built into institutional arrangements.[15] These arrangements determine the stabilization loss attributed to

[14] As we discussed in Section 3.2, the fiscal polcymakers are unable to change the leadership structure of interactions vis-à-vis the monetary policymaker.

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

each policymaker. The loss matrices in Table 2 are filled using entries in Table 1.

Table 2: Main results on policy coordination,

Panel *A*: High substitutability of goods, %C×10^2

Panel A1: Fiscal Leadership Regimes

		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)

Panel A2: Monetary Leadership Regimes

		Foreign Country			
		L_N	L_U	F_N	F_U
Home Country	L_N	(0.552,0.552)	(0.530,0.562)	(0.553,0.548)	(0.530,0.555)
	L_U	(0.562,0.530)	(0.538,0.538)	(0.566,0.527)	(0.538,0.538)
	F_N	(0.548,0.553)	(0.527,0.566)	**(0.552,0.552)**	(0.530,0.562)
	F_U	(0.555,0.530)	(0.538,0.538)	(0.562,0.530)	(0.538,0.538)

Panel *B*: Low substitutability of goods, %C×10^2

Panel B1: Fiscal Leadership Regimes

		Foreign Country			
		L_N	L_U	F_N	F_U
Home Country	L_N	**(0.695,0.695)**	(0.236,0.902)	(0.585,1.226)	(0.261,1.243)
	L_U	(0.902,0.236)	(0.320 ,0.320)	**(0.470,0.166)**	(0.320,0.320)
	F_N.	(1.226,0.585)	**(0.166,0.470)**	(0.695,0.695)	(0.236,0.902)
	F_U	(1.243 ,0.261)	(0.320,0.320)	(0.902,0.236)	(0.320 ,0.320)

Panel B2: Monetary Leadership Regimes

		Foreign Country			
		L_N	L_U	F_N	F_U
Home Country	L_N	**(0.164,0.164)**	(0.095,0.453)	(0.098,0.324)	(0.093,0.493)
	L_U	(0.453,0.095)	(0.320,0.320)	(0.624,0.099)	(0.320,0.320)
	F_N	(0.324,0.098)	(0.099,0.624)	(0.164,0.164)	(0.095,0.453)
	F_U	(0.493 ,0.093)	(0.320,0.320)	(0.453,0.095)	(0.320 ,0.320)

Notes: Here and in other tables, Losses to (Home, Foreign); losses in Nash equilibria are shown in bold fonts, losses in union-wide preferred equilibria are framed.

There is a unique Nash equilibrium in which both authorities retain national objectives and engage in non-cooperative fiscal leadership (L_N, L_N), which corresponds to regime [HF]M, see

Panel A1 in Table 2.[16] 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. We call it Fiscal Fight Equilibrium as it involves simultaneouls moves of both fiscal policymakers.

Under monetary leadership, however, the fiscal authorities will try to schedule this meeting in the afternoon of the last working day of each fiscal period, see Panel A2 in Table 2. Each country prefers to wait and let the other move first. It is also a Fiscal Fight Equilibrium as it involves simultaneouls moves of both fiscal policymakers.

Overall, Panel A in Table 1 suggests that the union-wide welfare loss is lower under cooperation than it is for these Nash equilibria. No fiscal authority will give up national objectives, each of them will continue trying to conduct itself as an intra-period leader over the other fiscal authority, so that the regime of simultaneous fiscal leadership [HF]M and M[HF] will realize.

With lower degree of substitutability between home and foreign goods the ranking of policy regimes change. Overall, with lower η, all monetary leadership regimes deliver relatively low losses, while all fiscal leadership regimes are relatively costly. The regime of simultaneous moves [HFM] becomes welfare-inceasing, it dominates the cooperative regime. Although it cannot be chosen by fiscal policymakers as the leadership over the monetary authority is built into the institutional structure, this regime is closely approximated by the symmetric monetary leadership regime M[HF]. Both fiscal and monetary leadership regimes produce Nash equilibrium (L_N, L_N) – a Fiscal fight Equilibrium – so the fiscal authorities refuse to cooperate with each other. In fiscal leadership regimes, however, another two Nash equilibria arise. In these equilibria the fiscal leader unilaterally adopts the union-wide welfare, while the fiscal follower retains the national objective. Among the three Nash equilibria in fiscal leadership regimes, these two equilibria are preferred by all three players, but the authorities may fail to coordinate on either of them. In monetary leadership regimes, the reduction of η shifts the Nash equilibrium from (F_N, F_N) to (L_N, L_N), however they both are Fiscal Fight Equilibria with the identical welfare loss.

To summarize, the degree of substitutability between home and foreign goods is important for ranking of leadership regimes: with reduction in the degree of substitutability fiscal leadership regimes lose the relative advantage. Monetary leadership regimes are similar to regimes of simultaneous moves. Cooperation in the symmetric monetary union is unlikely to arise. If goods are high substitutes, then cooperation is union–wide preferred but not sustainable. If goods are low substitutes, cooperation is neither desirable nor sustainable.

[16] We limit our analysis to pure strategies.

It turns out that the type of an equilibrium outcome is robust to changes in model parameterization, and is mostly explained by policy trade-offs, which in turn imply a very particular ranking of policy regimes leading the fiscal policymakers to engage in a fight. This explains the outcome of policy games, and the absence of the sustainable policy cooperation.

4.2 Transmission Mechanisms

4.2.1 Cooperation

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. We start with high substitutability between home and foreign goods.[17]

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. Since, under high substitutability, there is a strong relative demand shift towards H-produced goods, income of H-households increases and, therefore, they consume and save more. However, under incomplete financial markets, H-households are not allowed to lend abroad so much than 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 labour 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 to deviate more from their efficient level.

Government spending and taxes increase to stabilize H-inflation (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.

[17] 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.

Since net exports increase, country H becomes 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 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.[18]

With lower degree of substitution between home and foreign goods, there is bigger role of incomplete financial markets. As borrowing from abroad is difficult and goods are low-substitutes, there is a reduction in consumption at H following the shock. In addition to the inflation stabilization task, fiscal policy at H needs to counteract the reduction in consumption. As result, taxes decrease in an attempt to raise disposable income of households. This yields large reduction in inflation but also accelerates the rate of debt accumulation. The total government debt rises in H while it falls in F. Home country becomes net borrower. A higher risk premium is demanded on Home-issued debt, and so Home interest rate rises.

4.2.2 Non-cooperative regimes

To understand non-cooperative regimes, it is convenient to consider them in turn, focussing on new features of each consecutive regime relative to the previous. For each degree of substitutability between home and foreign goods, the sequence is the following

$$\text{C} \rightarrow \text{[HFM]} \begin{array}{lll} \nearrow & \text{FL}: \quad \text{[HF]M} & \rightarrow \quad \text{HFM} \\ \searrow & \text{ML}: \quad \text{M[HF]} & \rightarrow \quad \text{MHF} \end{array}$$

Relative to cooperation and for any degree of substitutability between goods, nationally-oriented fiscal policies, under the regime of simultaneous moves [HFM], react more (less) aggressively to a shock when they cause negative (positive) externalities. In this model, negative terms of trade gap creates a pressure on home deflation and induces the Home policymaker to stabilize H-inflation. Inflation stabilization at H further widens the negative terms of trade gap and produces a *negative cross-border externality* as it reinforces the effect of positive output gap on inflation in country F, and causes bigger intervention of the F-policymaker to stabilize F-inflation. This negative spillover on the other country's inflation is taken into account when the fiscal authorities cooperate, however, in the absence of cooperation and under national objectives, the national fiscal authorities face an incentive to deviate from the cooperative equilibrium.

[18] Further details are given in Appendix E.

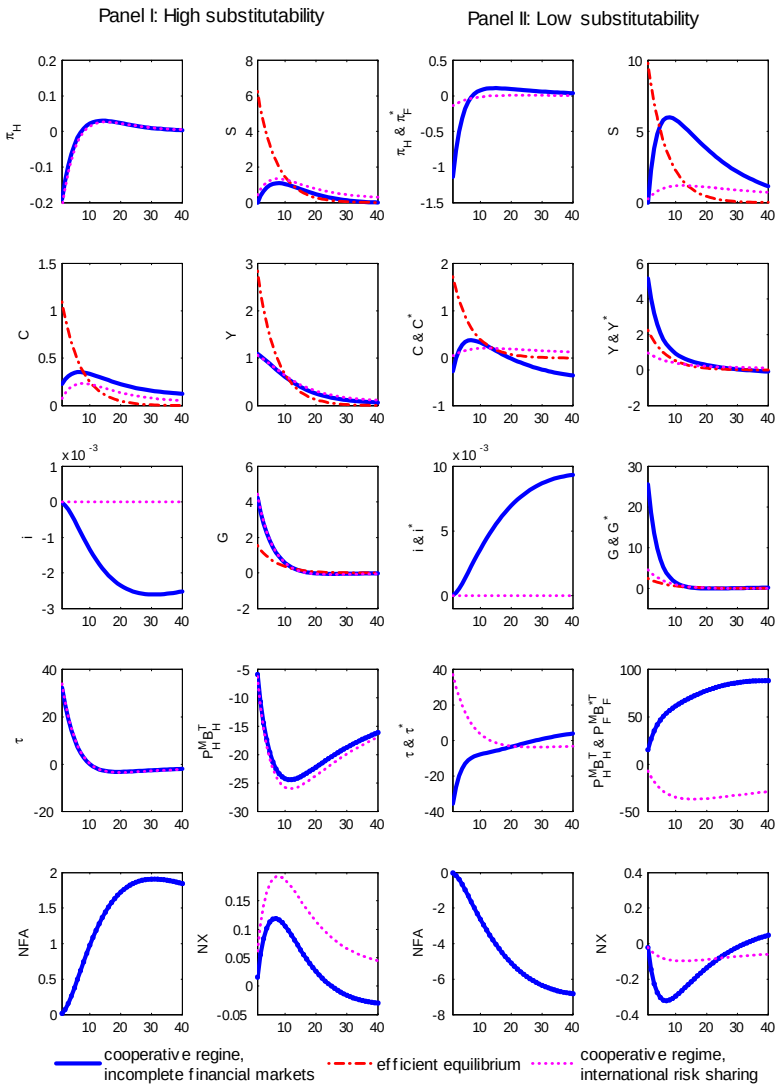

Figure 2: Transmission mechanism under cooperation (C). Impulse responses in country H to an asymmetric technology shock of size $\frac{1}{\lambda(\varsigma+1)}$, positive in H but negative in F. Panel I is for $\eta = 1.5$, Panel II is for $\eta = 0.4$.

Consider Panel I in Figure 3 which presents the cooperative regime and non-cooperation regime [HFM] for the high substitutability of goods case. In face of a positive technology shock at Home, both policy instruments increase at Home and dampen domestic deflation, increasing further the negative terms-of-trade gap. As a consequence, there is an inefficient shift of demand from Home to Foreign goods that further increases inflation in Foreign country. This cross-border effect is ignored under non-cooperation and the fiscal authority of Home country moves both policy instruments by more than under cooperation. Symmetric fiscal policy is set in Foreign country.[19] Table 1 suggests that there is a welfare loss in non-cooperative regime [HFM] relative to cooperation C: although the volatility of inflation is lower, the other welfare-relevant terms deviate by more from their efficient levels creating losses which dominate the gains from lower inflation volatility.

When one of policy authorities has an intra-period leadership, it has an incentive to let intra-period followers to bear the costs of stabilization.

Consider *fiscal leadership* regimes. Panel I in Figure 3, which also compares two non-cooperative regimes [HFM] and [HF]M for the high substitutability of goods case, shows that both fiscal policy instruments move less under the regime with non-cooperative fiscal leadership [HF]M than under [HFM]. Despite we plot an asymmetric shock, and so that monetary policy does not intervene, fiscal reactions in regimes [HFM] and [HF]M are different. This is because fiscal policymaker H manipulates the monetary policymaker, but does not take into account that policymaker F does the same. The fiscal policymaker H anticipates that if it does less and raises taxes and government spending by less, the Home inflation will fall by more and the terms-of-trade gap will become less negative. Without relying on that the F-fiscal policymaker would also do the same, it anticipates that the average inflation will become negative and the central bank will decrease interest rate, which will help the stabilization of inflation at H. As a result, fiscal policymaker H does not raise taxes and government spending high expecting the help of monetary policy. As fiscal policymaker F does the same, the fiscal policy movements are smaller than under [HFM], and this pushes the equilibrium closer to the cooperative one. In the resulting equilibrium, inflation is more volatile but the negative terms of trade spillover is mitigated and the overall outcome is better than under [HFM], but still worse than under cooperation.

The joint leadership [HF]M is preferred to [HFM] by both fiscal authorities, and each fiscal authority prefers to lead unilaterally and let the adjustment cost carried by the others. In the unilateral fiscal leadership regime HFM, H-fiscal authority tries to explore, additionally, a

[19] See e.g. Beetsma and Jensen (2005) for discussion of externalities in a simular model.

first-move advantage towards F-fiscal authority. Because an increase in H-tax has a negative cross-border effect and destabilizes F-inflation, fiscal leader H reacts by less than under [HF]M; it raises spending and taxes by less, this leads to bigger negative inflation but less negative terms of trade gap, see Panel I in Figure 4. Observing smaller increase in H inflation and anticipating more negative union-wide inflation and thus more negative interest rate with destabilizing effect on positive F-inflation, F-fiscal decreases taxes by more than in [HF]M regime. The follower monetary authority then lowers the interest rate to control for the resulting negative union-wide inflation. This does destabilize F-inflation and stabilizes H-inflation (although by not that much as higher H-taxes would have achieved it) and substantially reduces H-consumption and term of trade gaps. Both terms of trade gap and consumption gap effects are quantitatively very significant, leading to overall superiority of the unilateral fiscal leadership regime, HFM. As a result, country H achieves the minimum loss in regime HFM at expense of the two other policymakers: the loss attributed to each of the followers in this regime – fiscal authority in country F and the central bank – is the greatest for each of them, see Panel A in Table 1.

The *monetary leadership* regimes, however, do not result in any substantial increase in the social welfare relative to the regime of simultaneous moves [HFM]. Given that pure asymmetric shocks have no union-wide effects, there are no benefits for the monetary authority from being an intra-period leader. Moreover, very little monetary reaction to symmetric technology shocks is needed[20], so the ability to manipulate the fiscal policymakers is inconsequential. Therefore, the differences of M[HF] relative to [HFM] are small, both in terms of dynamic reactions and in terms of welfare losses, see Panel I in Figure 3. (This is in contrast to fiscal leadership regimes where, despite no union-wide effects of asymmetric shocks, each fiscal authority ignores the fact that the other will react symmetrically.) Similar to interactions in regimes HFM and [HF]M discussed above, fiscal leader H in MHF regime reacts by less than in M[HF] regime, see Panel II in Figure 4. As H-tax increase produces negative externality on F-inflation, H-fiscal authority anticipates the F-reaction and so it raises spending and taxes by less than under M[HF]. This leads to a bigger negative H-inflation but to a less negative terms of trade gap. The central bank anticipates that the average inflation will be lower and so it lowers interest rate and helps to stabilize H-inflation. Compared to the case of fiscal leadership HFM discussed above, the reduction in interest rate is small. This is because knowing that monetary authorities cannot be manipulated, and unlike under HFM, the reduction in H-fiscal movements is not substantial. As

[20] Under commitment, optimal monetary policy reaction to technology shocks in closed economy with available lump sum taxes is null , see Woodford (2003), the absence of lump sum taxes and debt stabilization bias under discretionary policy (Leith and Wren-Lewis 2011) will generate policy response, but it is very small numerically.

a result, the deviation of policy reactions and welfare in MHF from those in M[HF] are very small quantitatively. The insufficiently strong H-tax reaction still destabilizes H-inflation, and this loss outweighs the relative gain in stabilization of the terms of trade and consumption gaps of country H, so H-policymaker in MHF is worse off than under M[HF]. Compared to fiscal leadership regimes there is reverse ranking of monetary leadership regimes with unilateral fiscal leadership: the fiscal leader loses, see Panel A in Table 1. Such ranking of unilateral fiscal leadership regimes give incentives to delay fiscal policy decisions.

With lower degree of substitution between home and foreign goods and under non-cooperative regime [HFM] when policymakers do not internalize each other's actions, an increase in H-tax – with the aim to offset inflation by widening the negative terms of trade gap – produces negative cross-border externality which reinforces decisions of F-policymaker to stabilize F-inflation and induces the further increase of H-tax. As a result, taxes rise aggressively under [HFM], unlike under cooperation, see Panel II in Figure 3. As a result, regime [HFM] dominates the cooperative regime primarily because of much better inflation stabilization.

Once the fiscal authorities have a first-move advantage over the monetary policy, they try to exploit the leadership and internalize the effects of their policy on the monetary policymaker. Home fiscal authority, anticipating that the central bank will help to stabilize inflation, is more likely to decrease the tax with the aim to reduce quantitatively large and welfare-relevant consumption imbalances and leave inflation stabilization job for the monetary policymaker. However, the fiscal authorities still do not internalize each other actions, and the negative cross-border externality results in aggressive reduction of H-taxes, taxes fall by much more than under cooperation, see Panel II in Figure 3. As country F reacts in a symmetric way, the monetary policymaker does not intervene. As a result, there are large welfare losses in the symmetric fiscal leadership regime [HF]M due to the excessively volatile inflation.

In the regime of unilateral fiscal leadership, HFM, H-policymaker anticipates the reaction of the fiscal follower, and moves fiscal instrument by less than under [HF]M, see Panel I in Figure 5. The H-policymaker also anticipates that F-policymaker will react by more which will result in higher terms of trade and will help H-policymaker to stabilize H-inflation. The fiscal follower reacts by more, and as a result, the union-wide inflation rises. The monetary policymaker raises interest rate, thus eliminating the inflation stabilization gain at Home. Relative to [HF]M regime, there is still a small gain for H-policymaker due to the reduced volatility of fiscal instrument and smaller terms of trade gap and so there are incentives to take decisions earlier in the fiscal period. However, all fiscal leadership regimes result in large welfare losses relative to cooperation due to

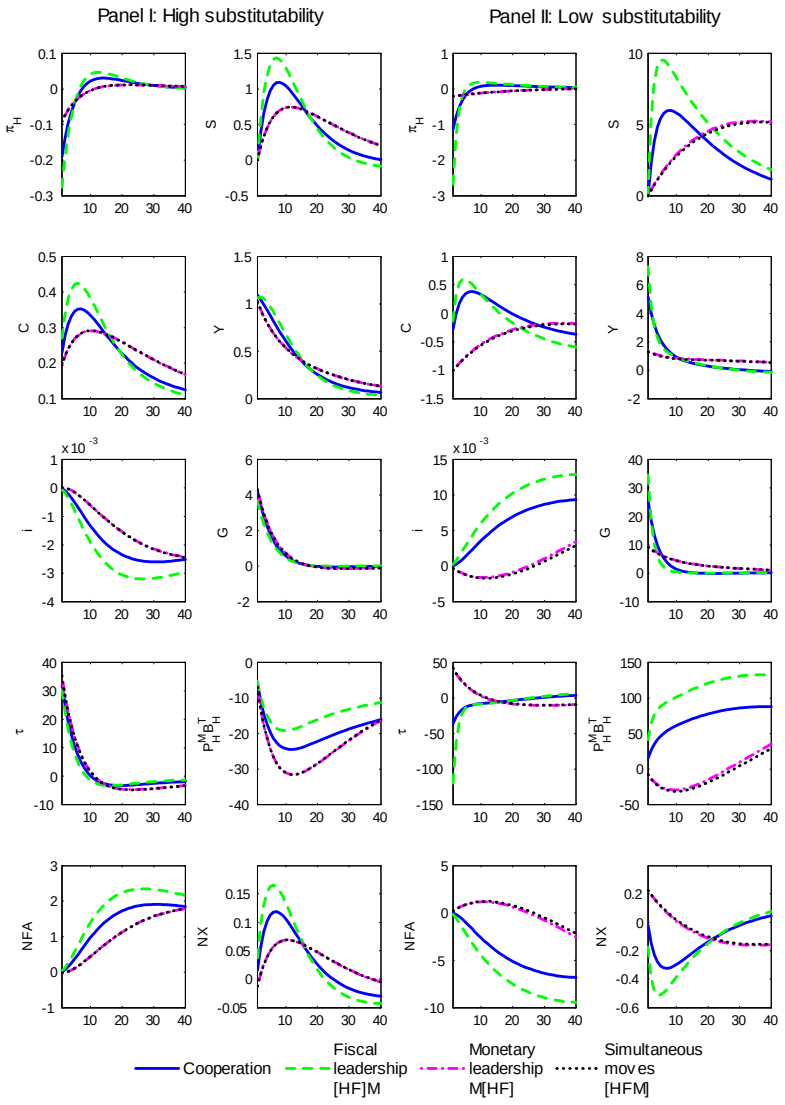

Figure 3: Impulse responses to one standard error asymmetric technology shocks in selected policy regimes

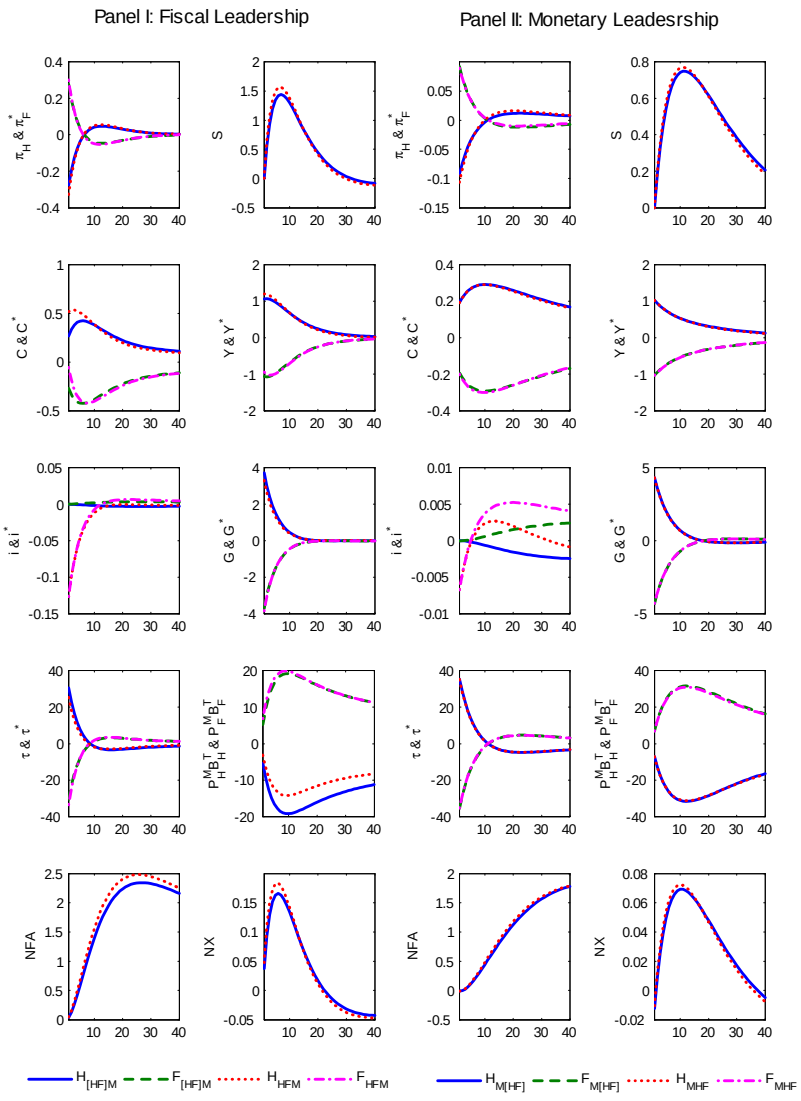

Figure 4: Noncooperative Policy Regimes, high substitutability

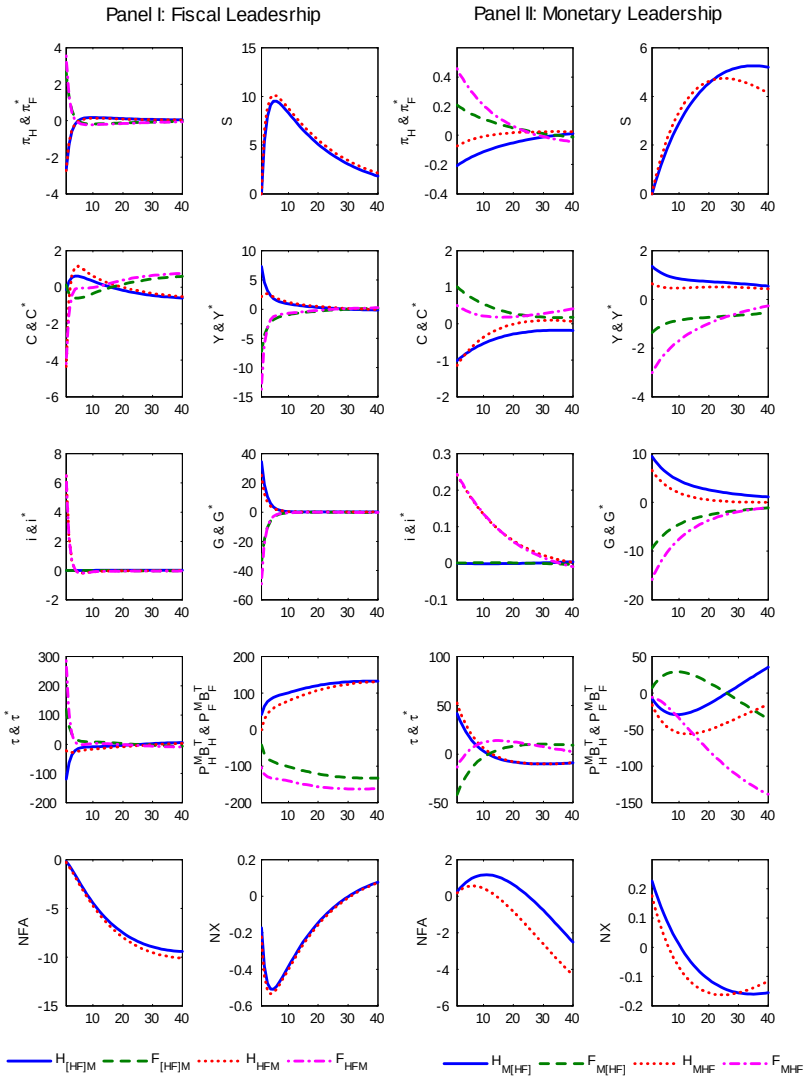

Figure 5: Noncooperative Policy Regimes, low substitutability

the excessively volatile inflation.

The symmetric monetary leadership regime M[HF] is very close to the regime of simultaneous moves, [HFM], see Panel II in Figure 3. This property is not affected by the degree of substitutability between the goods, and is mostly explained by the inability of the monetary policymaker to exploit fiscal policy in stabilization against technology shocks in all symmetric policy regimes. However, once there is unilateral fiscal leadership in regime MHF, increasing H-tax produces a small negative externality on F-inflation, because of low substitutability between goods. Therefore, not expecting a large reaction of F-fiscal authority, the leading H-fiscal authority increases the tax rate by more than in M[HF] regime in order to achieve better stabilization of H-inflation, see Panel II in Figure 5. Anticipating positive average inflation, the leading central bank increases the interest rate, which directly helps to stabilize F-inflation. As a result, H-policymaker gains, F-policymaker loses, and there is an incentive for a fiscal policymaker to take fiscal decisions earlier in the fiscal period.

4.3 Sustainable Policy Equilibria

The discussed above relative ranking of *regimes with fiscal leadership*, HFM, FHM and [HF]M produces Nash equilibrium (L_N, L_N), see Table 2. Because each fiscal policymaker would like to be an intra-period leader, as a result there is a sustainable equilibrium in which they act simultaneously and schedule the Fiscal Policy Committee meeting in the morning of the first working day in the fiscal policy period. This equilibrium is unique in case of high degree of substitutability between home and foreign goods.

With high η, despite the cooperative outcome is preferred by each of the policymakers, it is not a Nash equilibrium. Consider the leadership regime with simultaneous fiscal moves and 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 now country F and the monetary policymaker share objectives and react on averages, H and F policy responses are no longer symmetric and monetary policy ends up helping stabilization of Home country's inflation. Despite 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, see Panel I in Figure 6. 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

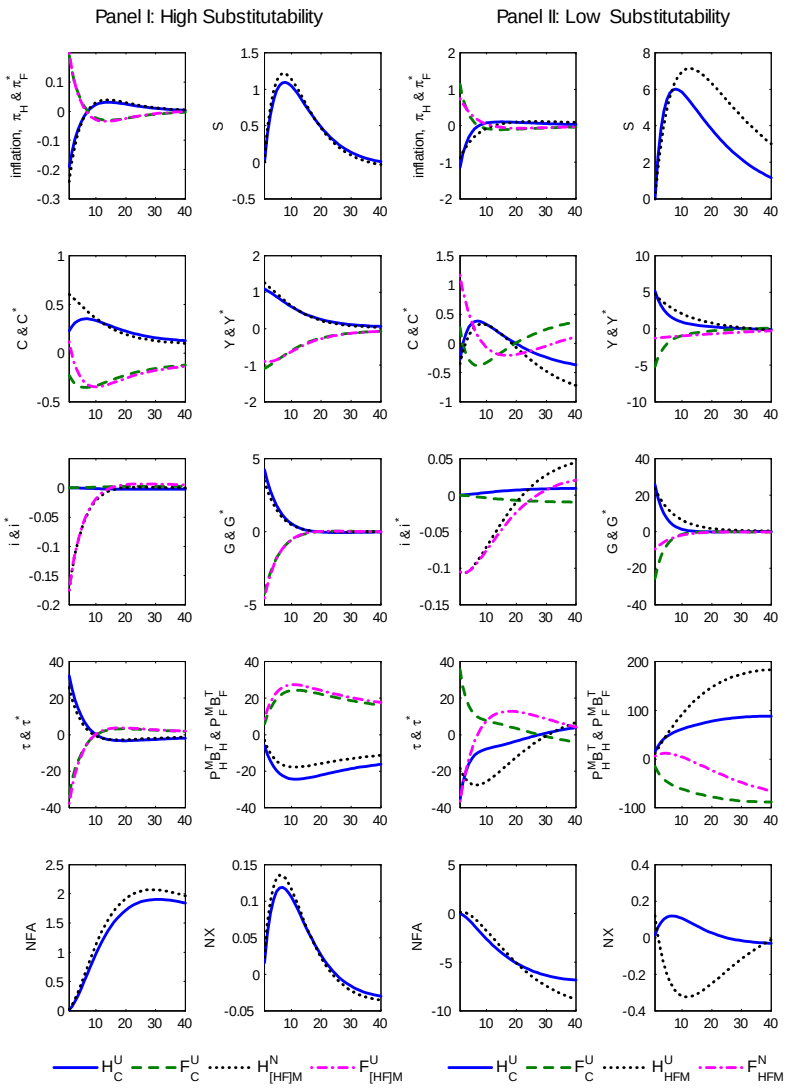

Figure 6: Sustanability of cooperative equilibrium in fiscal leadership regimes

objectives unilaterally.

This incentive of a fiscal policymaker to deviate from cooperative outcome (L_U, L_U) prevents it to become a Nash equilibrium, see Panel A1 in Table 2. Fiscal authorities have Prisoner's dilemma: despite the joint adoption of the 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 does not realize, and the non-cooperative fiscal leadership under national objectives [HF]M remains the unique Nash equilibrium.

There is Prisoner's dilemma also for *regimes with monetary leadership*, MHF, MFH and M[HF]. The cooperative outcome is preferred by both fiscal players, but each of them faces an incentive to adopt the national objective. Reactions are not-symmetric anymore and H-policymaker is helped by monetary policy. Overall, the gain attributed to each fiscal policymaker because of giving up the union-wide objective is smaller than in regimes with fiscal leadership, as the monetary policymaker cannot be manipulated, but it makes the cooperative equilibrium unsustainable.

Once we lower the degree of substitutability between home and foreign goods, there are some changes. Regimes with fiscal leadership become relatively inferior, predominantly because of very aggressive tax movements required to achieve the desired effects in case where demand cannot be easily shifted abroad, leading to substantial inflation costs. However, the unilateral fiscal leader has an advantage, and such ranking of regimes results in Nash equilibrium (L_N, L_N). This is not the only Nash equilibrium, the couple (F_N, L_U) and (L_U, F_N) arise. To understand their existence, consider cooperative equilibrium. In a cooperative equilibrium both fiscal policymakers adopt the union-wide objective and the order of moves does not matter. Suppose the cooperative equilibrium is (L_U, F_U). There is an incentive of the fiscal follower to adopt the national objective. With national objective F-policymaker lowers tax to stabilize domestic inflation, and does not reduce spending that much as under cooperation. As a result, there is a gain in inflation stabilization (although the monetary policymaker lowers interest rate to stabilize the average inflation, the reduction is not large enough to eliminate the gain) and gain in spending and output gap stabilization for F-country, see Panel II in Figure 6 The gain to F-country is substantial, so that equilibrium (F_N, L_U) is union-wide preferred to cooperation. Multiplicity of Nash equilibria implies that any of them may realize as a result of coordination failures.

In regimes with monetary leadership, Nash equilibrium (L_N, L_N) is unique. It dominates cooperation, is overall union-wide preferred and the ranking of regimes with unilateral fiscal

leadership implies that both fiscal policymakers will try to make decision earlier, coordinate on the same day at the beginning of fiscal period.

To summarize, with lower degree of substitutability between home and foreign goods cooperation is a dominated equilibrium. The best equilibria under fiscal and monetary leadership are sustainable. However, there are multiple Nash equilibria and so coordination failures may happen precluding coordination on the best equilibrium.

5 Conclusion

We demonstrate that cooperation of fiscal policymakers is unlikely to be sustainable as a Nash equilibrium. The outcome is however dependent on the degree of substitutability of home and foreign goods and the type of leadership over the monetary authority.

Under technology shocks the monetary leadership regimes only dominate fiscal leadership regimes in case of low substitutability of home and foreign goods and the need for more aggressive policies.

Under technology shocks the one fiscal policymaker's gain is another fiscal policymaker's loss so the Fiscal Fight equilibrium – in which both fiscal policymakers try to exploit leadership against each other and end up acting simultaneously – is sustainable for both monetary and fiscal leadership regimes.

If the fiscal policymakers are able to exploit the leadership over monetary policy, then they will fail to cooperate even if the cooperation is preferred by all agents. The Fiscal Fight equilibrium is unique in high substitutability of goods economy.

The need for aggressive policies with the reduction in degree if substitutability between goods makes multiple Nash fiscal leadership equilibria to arise, and creates a potential role for a supranational policy coordinator.

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