A Simple Model of a Monetary Union*

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Abstract

This paper explicitly models strategic interaction between two independent national fiscal authorities and a single central bank in a simple New Keynesian model of a monetary union. Closed analytical solutions for the policy instruments are computed for several strategic games. The analytical results depend nonlinearly on parameters of the model. Thus, impulse response graphs to various shocks are discussed. Depending on the kind of disturbance, various results can be drawn: First, intraunion spillover effects dampen or amplify the shock. Second, policy instruments do not only serve as complements, but severe conflicts on the direction of monetary and fiscal policy might arise. Third, coordinated policy does not lead to the best outcome in terms of welfare. Fourth, central banks have an incentive to be leader when setting instruments if the economies are hit by cost-push shocks, because this policy regime reduces their welfare losses, whereas governments wish either to coordinate all policies or set all instruments simultaneously.

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Introduction

With the introduction of the European Monetary Union in 1999, there has been a change of monetary and fiscal institutions. Although the primary goal of the common central bank is price stability, the Stability and Growth Pact imposes restrictions on fiscal policy that might hamper the stabilization role of fiscal policy. The literature using the consensus of the New Keynesian framework has mainly focused on the role of optimal monetary policy. There is hardly any disagreement about the role and functions of monetary policy in this consensus approach.[1] Monetary policy is ineffective in two cases: first, if the economy is in a liquidity trap and second, if a monetary union is hit by asymmetric shocks, which cancel on the union level. This implies that fiscal policy might play a more prominent role. However, one of the main weaknesses of the New Keynesian models is the absence of an explicit role for fiscal policy. This is at odds with (a) the large size of the public sector in modern economics and (b) the increasing role that governments play in attaining a solution for the financial crisis and the related Great Recession of 2008–2009.

When analyzing the role of monetary and fiscal policy in a monetary union, one has to take into account that many decision makers (decentral governments and a central bank) strategically interact when deciding on the proper implementation of their policy instruments. Previous research has mainly focused on the case of full coordination (i.e., a supranational authority sets all monetary and governmental policy instruments). However, a realistic description of the current situation is that policies are not coordinated given that actual policy reveals that instruments rather are set simultaneously. A second possible scenario is to consider the central bank as a first mover (actually setting or keeping the nominal interest rate near the zero lower bound) and governments reacting to this decision.

In this article, I establish a tractable simple model with New Keynesian properties of a two-country monetary union in order to analyze the outcome of several strategic games (benchmark scenario of full coordination, scenario of noncoordination, and the scenario of monetary leadership). I keep the model as simple as possible to achieve qualitative results: Closed, analytical solutions of monetary and fiscal policy better help to identify and understand transmission mechanisms. This is the main contribution of this article, as closed solutions are hardly computed in other articles using New Keynesian models of monetary unions. Moreover, the article moves a step further and compares the outcome of several strategic games, instead of focusing on the benchmark scenario or implementable rules.

The key findings of this paper are the following: Concerning the closed-form solutions, it is noteworthy that the analytical results in case of monetary leadership coincide with the ones for the Nash regime of noncoordination in some special parameter restrictions. Second, as in a closed economy, monetary policy focuses on aggregate shocks and faces the same trade-off between inflation rate stabilization and output gap stabilization on the union level in all regimes. However, interest rates are set differently given that the central bank takes into

[1] The main references in this field are the books by Woodford [2003] or Galí [2008].

account how aggregate fiscal policy reacts to the shocks. Third, results of the instruments and country-specific output gap and inflation rate depend on the country size in the case of the Nash game and the monetary leadership game.

Although I chose the most simplest form of equations, some of the analytical results are no longer straightforward and depend nonlinearly on parameters of the model. To visualize the results, the model is calibrated and impulse responses to the underlying shocks are plotted. It depends on the shock whether the policy regime of monetary leadership performs better than the one of a Nash game. It is noteworthy that in the benchmark scenario the aggregated loss function leads to more fluctuations in the output gap and the inflation rate than in the other two policy scenarios, but to less fluctuations in the policy instruments. Thus, losses are significant in the benchmark case, which does not lead to the best outcome in terms of welfare. Second, it depends on the shock whether intraunion spillover effects help to amplify or dampen the shock. Third, severe coordination problems between monetary and fiscal policies might arise as a result of different shocks. Whereas the central bank follows a restrictive policy in case of a symmetric or home cost-push shock, governments set their instruments in an expansionary way.
Last, there is no consensus among the policymakers on which game to play. Central banks have an incentive to be a leader when setting instruments if the economies are hit by cost-push shocks as this policy regimes reduces their welfare losses whereas governments wish either to fully coordinate all policies or set all instruments simultaneously.

The rest of the paper is organized as follows. The next section provides a short review of related literature. Then the key equations of the economic model are introduced followed by a section about the policy problem of the economy. As a next step the different policy regimes are analyzed and compared with each other, before analytical results are obtained. Finally, impulse response functions and welfare effects of the different shocks are discussed. The last section concludes.

Related Literature

Previous literature within the class of dynamic New Keynesian models on strategic interaction assumes coordination of both monetary and national fiscal policies (i.e., the existence of a supranational authority that decides how to set instruments).[2] The first contributions by Beetsma and Jensen [2004, 2005] analyze the performance of several monetary and fiscal policy rules in a two-country currency union in which all three authorities coordinate their policies in order to maximize unionwide welfare. Here, government spending serves as an active stabilization tool. In contrast, Ferrero [2009] explores a model with exogenous government spending which is financed by distortionary taxes and riskless bonds. He also determines optimal fiscal and monetary rules when policies are conducted in a coordinated fashion. Galí

[2] An overview of static models like Dixit and Lambertini [2003] can be found in Beetsma and Debrun [2004].

and Monacelli [2008] discuss the benchmark case of coordination when the monetary union consists of a continuum of small open economies. This article is extended by Forlati [2009] who analyzes the case of simultaneous decision making (Nash game). The results, compared with the baseline model when policies are coordinated, completely change. Lambertini [2008] focuses on optimal fiscal policy in a monetary union when the central bank follows an interest rate rule. In this setup, governments set labor income taxes and issue public debt to finance stochastic government spending. Kirsanova et al. [2005] consider a two-country model of a monetary union, which is close to the one of Beetsma and Jensen [2005], but they allow for some home bias in consumption and introduce inflation inertia. The latter assumption plays a crucial role for the use of fiscal policy as a stabilization tool to asymmetric shocks, given that inflation inertia is a source of instability in a monetary union. The paper investigates the case of a monetary leadership equilibrium with the two fiscal policy setting their instruments simultaneously. In a second paper, Kirsanova et al. [2007] focus on simple and potentially implementable fiscal rules within the same model. The central bank can commit to an optimal policy. Moreover, they include debt dynamics into the model. The researchers find that fiscal policy can play an important role in stabilizing the economy. Machado and Ribeiro [2010] analyze in a two-country monetary union with different country size the influence of debt policy in several strategic games. They find that country size plays a crucial role. Under noncoordination, a small country sets fiscal policy instruments more actively to stabilize debt than does a bigger country. Coordination improves welfare in all scenarios. Lambertini et al. [2007] set up a microfounded model with a different price-setting behavior of firms (than Calvo-setting). They model a central bank that is more conservative than both governments and has conflicting views on the desired targets of the output gap and the inflation rate on aggregate. The scenario of a Nash game is suboptimal in this setup. Fiscal cooperation on the horizontal dimension even worsens outcome because cooperation aggravates the time-consistency problem of fiscal policies.

A Consensus Model

In this article, the monetary union consists of two countries, the H(ome) (of size $n \in [0,1]$) and the F(oreign) country. The economic conditions of each member country of the monetary union can be described by three building blocks, an aggregate supply (or Phillips) curve, an aggregate New Keynesian demand curve in the spirit of Clarida et al. [1999], and a description of fiscal and monetary policy. The Phillips curves of both countries $j = H, F$ take the following form:[3]

$$\pi_t^j \quad = \quad \beta E_t \pi_{t+1}^j + \lambda x_t^j + \mu g_t^j + u_t^j \tag{1}$$

Inflation dynamics in both countries are driven by forward-looking elements in the form of conditional expectations of the future domestic inflation rate $E_t \pi_{t+1}^j$ for $j = H, F$, the

[3] All variables should be read as deviations from their respective values at an efficient steady state.

domestic output gap x_t^j, $j = H, F$, and a country-specific cost-push shock u_t^j, $j = H, F$. The discount rate β and the output gap coefficient λ (the slope of the Phillips curve) are both positive. Moreover, the inflation rate depends on the governmental budget deficit g_t^j, $j = H, F$, negatively, that is, $\mu < 0$, which is in line with Galí and Monacelli [2008].[4] The coefficients of the Phillips curve are equal for both countries. All assumptions are imposed to keep the model as simple as possible.

The demand side of both countries $i, j = H, F$, $i \neq j$ can be expressed with the following curves

$$x_t^j, \quad = \quad E_t x_{t+1}^j - \varphi(\bar{\imath}_t - E_t \pi_{t+1}^j) + g_t^j + \gamma \left(x_t^i - x_t^j \right) - \delta(\pi_t^j - \pi_t^i) + \varepsilon_t^j \tag{2}$$

Country-specific demand is related inversely to the real interest rate which is the difference of the nominal interest rate $\bar{\imath}$ and the expected future country-specific inflation rate. The nominal interest rate is set by the monetary policy and is the same for both countries. So, monetary policy affects output directly through the interest rate channel. Real interest rates differ as a result of possible different inflation expectations. g_t^j should be read as governmental deficits, so an increase in g_t^j is due to either an increase in governmental spending or a tax cut. Changes in domestic demand as a result of spillover effects in the monetary union are modeled by the term $\gamma(x_t^j - x_t^i)$, for country $i = H, F$, $i \neq j$. If $\gamma > 0$, an increase in the output gap abroad leads to an increase of the domestic output gap. But if $\gamma < 0$, then an increase in the demand of the neighbor country leads to a reduction of the home demand. Moreover, inflation rate differentials are included to account for intraunion competitiveness channels as in Andersen [2008] or Michalak et al. [2009]. ε_t^j, $t = H, F$, are country-specific demand shocks other than fiscal policy.
Both shocks ε_t^j and u_t^j follow $AR(1)$-processes. Microfoundations for these ad-hoc reduced-form equations can be found in the literature.

The Policy Problem

Two independent governments and an independent central bank in the monetary union are considered. Policy authorities do not set their instruments by following a rule, but rather choose their instruments optimally by minimizing an appropriate loss function. These are postulated ad hoc in this paper.

The *common monetary authority* focuses on aggregate variables of the monetary union[5] and thus includes the aggregate inflation rate π_t^W and the aggregate output gap x_t^W in the central bank's loss function. The instrument is the nominal interest rate which is the result of the

[4] This parameter plays a crucial role when examining various policy regime. The analysis of different policy games shows that the regime of full noncoordination and the one of monetary leadership coincide if $\mu = 0$.

[5] For a generic variable y, the aggregate is denoted by $y^W = ny^H + (1-n)y^F$, where n is the country size of the Home country. Additionally, with $y^R = y^F - y^H$ the relative variable is denoted.

following optimization problem

$$\min_{\bar{\iota}_t} \frac{1}{2}\left(\alpha(x_t^W)^2 + (\pi_t^W)^2\right), \tag{3}$$

where $\alpha > 0$ denotes the relative weight of inflation over output.

In contrast, both *fiscal authorities* focus on national output and are not concerned about inflation, but they include deviations of governmental budget deficits g_t^j, $j = H, F$ into their loss function as can be found in Uhlig [2003] or Andersen [2008]. Thus, they are more concerned about fiscal sustainability and economic stability. They have delegated the nominal targets to the independent monetary authority. The instrument is government deficits, g_t^j, $j = H, F$. The parameter θ weighs fiscal sustainability over stabilization.

$$\min_{g_t^j} \frac{1}{2}\left((x_t^j)^2 + \theta(g_t^j)^2\right). \tag{4}$$

Given that all three policymakers do not necessarily coordinate in setting their instruments, the timing of policy actions is relevant for the analysis. Nash, leadership, and coordinated equilibria are analyzed. A Nash equilibrium in a monetary union seems plausible, given that actual policy reveals that policy authorities hardly coordinate. Rather, they set their instruments independently of each other. However, central banks can react faster to shocks than governments who suffer from long fiscal implementation lags. Thus, a Stackelberg game with the central bank as a leader (in setting its instruments) and the two governments reacting to the monetary decision is the appropriate framework to analyze stabilization policy in this set-up. Though empirical research supports the existence of fiscal leadership regimes (Fragetta and Kirsanova [2010]), this article rather focuses on the other policy scenarios. Present policy making is more likely to be simultaneous decision making. Even the case of monetary leadership can be defended with the central bank currently setting (or keeping) its instrument near the zero lower bound. Governments move second when deciding their policies.

This article assumes that no policy authority can commit to future policy choices. Optimal policy under discretion describes best reality, because no major central bank makes any kind of binding commitment. Regarding governments even within the limits imposed by the Stability and Growth Pact, fiscal policy is conducted in a discretionary manner.

Optimal Responses of the Different Policy Scenarios

Benchmark: Joint coordination

In the benchmark of full coordination both governments and the central bank set their instruments to minimize welfare losses of the monetary union. This loss function is a weighted average of the monetary and fiscal loss functions given by equations (3) and (4). The relative weights assigned to the governmental loss functions are given by the country weights n for the loss function of the home country, respectively $(1-n)$ for the fiscal loss function of the foreign country. The instruments of the coordinated policy are the nominal interest $\bar{\iota}$, aggregated governmental deficit $g_t^W = ng_t^H + (1-n)g_t^F$, and differential governmental deficit $g_t^R = g_t^F - g_t^H$. Constraints of this optimization problems are given by the aggregate and relative demand and Phillips curves.[6] Deriving the first-order optimality conditions of the aforementioned problem and rearranging yields the following three targeting rules

$$g_t^R = -\frac{1-2\delta\mu}{\theta(1+2\gamma+2\delta\lambda)} x_t^R \tag{5}$$

$$g_t^W = -\frac{\mu}{\theta}\pi_t^W \tag{6}$$

$$x_t^W = \frac{-\lambda}{1+\alpha}\pi_t^W. \tag{7}$$

Simultaneous Decisions of all Policymakers

In this section the optimal responses for both governments and the central bank are derived, assuming that all three policymakers do not coordinate and set their instrument independently of the others. In this case, the timing of the events is as follows. Considering discretionary policy expectations of the private sector on inflation have been made beforehand; that is, expectations $E_t\pi_{t+1}^j$, $j = H, F$ are given for all policymakers. The monetary union is hit by the cost-push shocks, u_t^j, and the demand shocks, ε_t^j, $j = H, F$ at the same time. The policymakers observe these shocks. Then, they set their instruments.

The problem of the central bank is to maximize the criterion (3) with respect to the interest rate taking as given government deficits of the home and the foreign country. The results are given by the trade-off between stabilizing the aggregate inflation rate and the aggregate output gap

$$0 = \alpha x_t^W + \lambda\pi_t^W. \tag{8}$$

Optimal responses of fiscal policies are the results of optimizing (4) subject to the structural equations (2) and (1). For $j = H, F$ these are given by

$$0 = x_t^j \frac{(1+\gamma+\delta(\lambda-\mu))}{1+2\gamma+2\delta\lambda} + \theta g_t^j \qquad \Longleftrightarrow \qquad g_t^j = -\frac{1}{\theta}\frac{(1+\gamma+\delta(\lambda-\mu))}{1+2\gamma+2\delta\lambda} x_t^j. \tag{9}$$

Governments change government spending when they observe fluctuations in their own output gap. The amount by which they change it depends on the various coefficients underlying the model.

[6] Detailed calculations can be found in a technical appendix to this article which is available upon request from the author: stefanie.flotho@vwl.uni-freiburg.de

Monetary Leadership

In the policy regime of monetary leadership, by assumption the central bank first sets the nominal interest rate, then both governments react simultaneously and decide over government deficits. This game is solved by backward induction. First, considering the problem of the governments leads to the optimal responses (9). Aggregating these and inserting the result into the aggregate Phillips curve yields the new constraint which the central bank has to take into account when minimizing the monetary loss function (3). These calculations end in the following optimal response

$$0 = \alpha x_t^W + \left[\lambda - \frac{\mu}{\theta} \frac{1 + \gamma + \delta(\lambda - \mu)}{1 + 2\gamma + 2\delta\lambda} \right] \pi_t^W. \tag{10}$$

Discussion of Optimal Responses

Equations (7), (8), and (10) are the "lean-against-the wind" rules of optimal monetary policy that relate the aggregate inflation rate negatively to the aggregate output gap in all three cases, but in each case to a different extent. In the benchmark case of full coordination and the strategic interaction of fully uncoordinated policy, only the relative weight of output gap stabilization in the monetary loss function, α, and the slope of the New Keynesian Phillips curve, λ, dictate the negative relation whereas in the case of monetary leadership, the slope of the trade-off is determined by the parameters γ and δ, which depict the competitiveness channels between the two economies and the parameters μ and θ. The reason for this lies in the kind of backwards solution of the game. If the parameter μ is set to zero, then the optimal rules of the Nash and monetary leadership coincide. Moreover, if $\mu = 0$ in the benchmark scenario, aggregate government deficits should equal zero; that is, there is no role for the aggregate fiscal instrument. Monetary policy alone can stabilize the economy if it is hit by aggregated shocks that do not cancel (like asymmetric shocks). Governments coordinate to set relative government deficits to offset any fluctuations in the relative output gaps (equation (5)).

In the optimality conditions (5) and (6) of the benchmark scenario and (9) relating fiscal deficits to the output gaps, the relative weight θ of the fiscal loss function plays a role. The higher θ (i.e., the more weight is put on deviations of governmental deficits from a target), the smaller the fiscal instruments react to disturbances.

The influence of both competitiveness channels of the demand curves are ambiguous. In the coordination scenario, the parameters of price spillovers, δ, and demand spillovers, γ, do not determine the trade-off between aggregate fiscal deficits and the aggregate inflation rate and hence, via the "lean-against-the-wind" rule, the aggregate output gap. Policymakers focusing on aggregate variables and considering the monetary union as one single economy to stabilize do not analyze the influences of regional spillovers on these union wide levels. However, the parameters γ and δ determine how relative fiscal deficits are set to cope with relative output gap fluctuations (equation (5)). In case of an increase of demand spillovers γ relative fiscal

deficits increase.[7] In case of an increase of inflation spillovers δ the reaction of fiscal deficits is positive for a certain condition on the parameters.[8]
The optimal responses relating aggregate governmental deficits and the aggregate output gap (equation (9)) coincide for the Nash scenario and the monetary leadership scenario, because in the leadership scenario, the central bank takes the fiscal reaction function into account. The reactions of relative governmental deficits to a change in γ and θ are the same in direction as in the benchmark case, but they are of half the size. Moreover, if δ and γ are set to zero, then the optimality conditions – relating the relative government deficit and the relative output gap – are the same for all three games. Hence, the results for the relative inflation rate and the relative output gap are also the same for all three games.

Analytical Results

The derivation of the closed-form solutions is straightforward and follows the same procedure in all three scenarios. First, the aggregate Phillips curve and the optimality conditions relating the aggregate output gaps and inflation rates to the aggregate fiscal deficits are combined. Then, the new equation is solved forward. As a result the aggregate inflation rate and output gap – and thus, government deficits – all linearly depend on the aggregate cost-push shock.

Second, the equations of the relative Phillips curve and the relative demand curve form a system of two equations with rational expectations depending on relative government deficits.

Targeting rules relating the relative output gap to the relative governmental deficits (equations (5) in the benchmark case, the difference of equations (9) for $j = F$ and $j = H$, for the uncoordinated and the leadership scenario) are inserted into this system. Then it is solved using the method of undetermined coefficients. As a result, the relative inflation rate and the relative output gap depend linearly on the relative cost-push shock and the relative demand shock.

Third, the aggregate demand curve relates aggregate and relative variables as well as the nominal interest rate:

$$x_t^W = E_t x_{t+1}^W - \varphi(\bar{\iota}_t - E_t \pi_{t+1}^W) + g_t^W + \gamma(2n-1)x_t^R + \delta(2n-1)\pi_t^R + \varepsilon_t^W.$$

All results obtained in the first and second step are inserted into the aggregate demand curve to solve for the nominal interest rate. Thus, the monetary instrument depends on aggregate as well as relative cost-push and demand shocks.

Having the results for all aggregate and relative variables the derivation of the home and

[7] This is true if the condition holds that $\delta\mu < 1/2$ which seems to be likely when assuming negative values for μ and positive for δ. This can be determined by inspecting the partial derivative of the coefficient in (5) with respect to γ. For a more detailed discussion of the influence of all parameters refer to the aforementioned technical appendix.

[8] This condition is given by $\lambda + \mu(1 + 2\gamma) > 0$.

foreign variables follows straightforward from $y^H = y^W - (1-n)y^R$, respectively $y^F = y^W + ny^R$.

Table 1 gives an overview of some analytical results. For a complete derivation of all results see the technical appendix.

In all three scenarios, the aggregate fiscal instrument is set to accommodate the aggregate cost-push shock, but to a different extent in each game. The aggregate inflation rate and aggregate output gap react to aggregated cost-push shocks, whereas relative variables react to relative shocks. The nominal interest rate reacts to both aggregate and relative cost-push and demand shocks. If both countries are of the same size, then the nominal interest rate is set to accommodate aggregate shocks. If the shocks are asymmetric, the central bank does not react at all. As in the closed economy, monetary policy offsets aggregate demand shocks.

Simulating the Model

To visualize the dynamic behavior of the model impulse response functions to asymmetric, symmetric and home cost-push and demand shocks are depicted in this section. The values assigned to the different parameters are comparable to other simulation studies in related literature: The discount factor β is set to 0.99. Following Galí and Monacelli [2008], the interest rate elasticity of output φ is set to be equal to 0.75.[9] The slope of the Phillips curves λ is set to be equal to 0.25.[10] Moreover, μ is calibrated to equal –0.03 following Galí and Monacelli [2008]. The parameters measuring competitiveness effects in the demand equations are set to $\gamma = 0.5$ and $\delta = 0.5$, which is in line with the papers by van Aarle et al. [2004] and Michalak et al. [2009]. The monetary policy sets the relative weight in the central bank's loss function to 0.5. In contrast, governments want to stabilize output and put more weight on output stabilization ($\theta = 0.1$). Shocks are assumed to be highly persistent with a coefficient ρ^j of 0.9. At the beginning, it is assumed that both countries are of equal size ($n = 1/2$.) The parameters are summarized in table 2.

[9]Estimates for this parameter vary from 0.4 for the US (McCallum [2001]) and an average value of 0.7 for the EU, ranging from 0.4 in Portugal to 1.2 in Germany (Cecchetti et al. [2002]). The value chosen here is also in line with van Aarle et al. [2004].

[10]Usually, as shown in Galí [2008], λ is a parameter depending on the structural equations of an underlying microfounded model. Taking the standard values for a closed economy the slope of the Phillips curve can be computed to be equal to 0.0425. Taking into account a microfounded model of a small open economy of a monetary union, Galí and Monacelli [2008] compute a value of 0.3718. Other calibration of this value range from 0.1 for the US (Rotemberg and Woodford [1999]) to 0.3 (McCallum and Nelson [1999]). The value chosen in this paper is in line with Herz et al. [2006] and van Aarle et al. [2004].

Table 1: Summary of analytical results of aggregate variables

i_t	Benchmark Nash ML	$\bar{\iota}_t = \frac{1}{\varphi}\left[(a\varphi\rho_u^W + b(1-\rho_u^W) + c)u_t^W + (2n-1)(\gamma+\delta)(c_u+d_u)u_t^R + (2n-1)(\gamma+\delta)(c_\varepsilon+d_\varepsilon)\varepsilon_t^R + \varepsilon_t^W\right]$
g_t^W	Benchmark	$g_t^W = \frac{-\mu}{\theta(1-\beta\rho_u^W)+\mu^2+\frac{\lambda^2\theta}{(1+\alpha)}}\, u_t^W$
	Nash	$g_t^W = \frac{-\lambda(1+\gamma+\delta(\lambda-\mu))}{(\lambda(1+\gamma+\delta(\lambda-\mu))\mu-(1+2\gamma+2\delta\lambda)(\alpha+\lambda^2-\alpha\beta(\rho_u^W))\theta)}\, u_t^W$
	ML	$g_t^W = \frac{(1+2\gamma+2\delta\lambda)(-1-\gamma-\delta\lambda+\delta\mu)(-\lambda+\frac{(1+\gamma+\delta(\lambda-\mu))\mu}{(1+2\gamma+2\delta\lambda)\theta})\theta}{(1+\gamma+\delta(\lambda-\mu))^2\mu^2-2\lambda(1+2\gamma+2\delta\lambda)(1+\gamma+\delta(\lambda-\mu))\mu\theta+(1+2\gamma+2\delta\lambda)^2(\alpha+\lambda^2-\alpha\beta(\rho_u^W))\theta^2} u_t^W$
π_t^W	Benchmark	$\pi_t^W = \frac{(1+\alpha)\theta}{(1+\alpha)\theta(1-\beta\rho_u^W)+(1+\alpha)\mu^2+\lambda^2\theta}\, u_t^W$
	Nash	$\pi_t^W = \frac{-(\alpha(1+2\gamma+2\delta\lambda)\theta)}{(\lambda(1+\gamma+\delta(\lambda-\mu))\mu-(1+2\gamma+2\delta\lambda)(\alpha+\lambda^2-\alpha\beta(\rho_u^W))\theta)}\, u_t^W$
	ML	$\pi_t^W = \frac{\alpha(1+2\gamma+2\delta\lambda)^2\theta^2}{(1+\gamma+\delta(\lambda-\mu))^2\mu^2-2\lambda(1+2\gamma+2\delta\lambda)(1+\gamma+\delta(\lambda-\mu))\mu\theta+(1+2\gamma+2\delta\lambda)^2(\alpha+\lambda^2-\alpha\beta(\rho_u^W))\theta^2} u_t^W$
x_t^W	Benchmark	$x_t^W = \frac{-\lambda\theta}{(1+\alpha)\theta(1-\beta\rho_u^W)+(1+\alpha)\mu^2+\lambda^2\theta}\, u_t^W$
	Nash	$x_t^W = \frac{\lambda(1+2\gamma+2\delta\lambda)\theta}{\lambda(1+\gamma+\delta(\lambda-\mu))\mu-(1+2\gamma+2\delta\lambda)(\alpha+\lambda^2-\alpha\beta(\rho_u^W))\theta}\, u_t^W$
	ML	$x_t^W = \frac{(1+2\gamma+2\delta\lambda)^2(-\lambda+\frac{(1+\gamma+\delta(\lambda-\mu))\mu}{(1+2\gamma+2\delta\lambda)\theta})\theta^2}{(1+\gamma+\delta(\lambda-\mu))^2\mu^2-2\lambda(1+2\gamma+2\delta\lambda)(1+\gamma+\delta(\lambda-\mu))\mu\theta+(1+2\gamma+2\delta\lambda)^2(\alpha+\lambda^2-\alpha\beta(\rho_u^W))\theta^2} u_t^W$

Table 2: Calibration

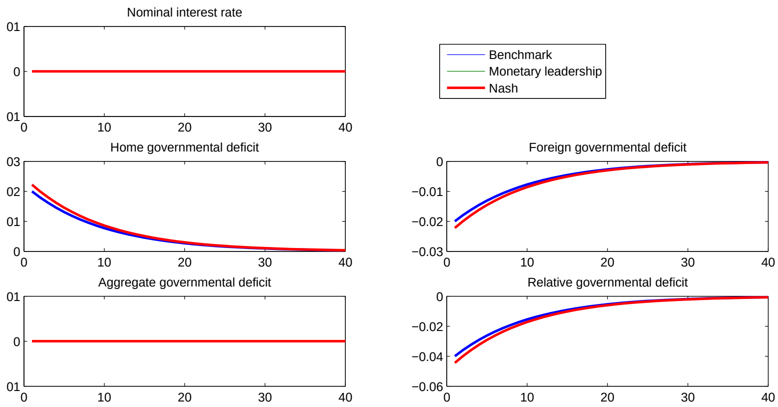
Parameter		Value
Discount factor	β	0.99
Interest rate elasticity	φ	0.75
	μ	-0.03
Slope of the Phillips curve	λ	0.25
Trade spillovers	γ	0.5
Price competitiveness	δ	0.5
Relative weight in the loss function of the central bank	α	0.5
Relative weight in the loss function of governments	θ	0.1
Home country size	n	0.5
AR term of the cost-push shock	ρ_u^j	0.9
AR term of the demand shock	ρ_ε^j	0.9

Asymmetric Shocks

Impulse response functions of the policy instruments to *asymmetric cost-push shocks* $u_t^H = -u_t^F$ are given by figure 1. As assumed both countries are of the same size ($n = 1/2$) the weighted average of both shocks is equal to zero and the relative shock is given by $u_t^R = -2u_t^H$. For the central bank the whole monetary union is not hit by any shock. So, monetary policy does not react by changing the nominal interest rate in each of the strategic games. The same results holds for aggregate governmental deficits, given that these instruments react to the weighted average of the home and foreign cost-push shocks. This implies that home and foreign governmental deficits react inversely. Although the deficit in the home country has to increase by approximately 2%, the foreign country has to decrease the deficit by the same amount. In the benchmark case of full coordination, the reaction is less than that in the other two scenarios, which coincide in this setup. To combat the recession governmental deficits increase (according to equation (9) in the uncoordinated case). This leads to a decline in the home inflation rate via the Phillips curve. The difference between the regime of monetary leadership and uncoordinated policy becomes evident when the aggregate shocks are not equal to zero.

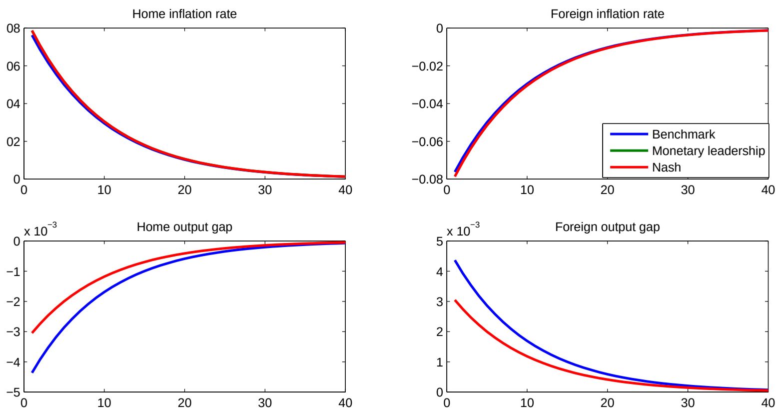
Figure 2 depicts the impulse response functions of the country-specific inflation rates and output gaps. As on aggregate, the inflation rate and the output gap do not react to the asymmetric shock the foreign variables reflect the home variables inversely. The cost-push shock in the home countries leads to a significant increase of the home inflation rate, whereas the foreign country has to cope with a severe deflation. This opposite reaction leads to high fluctuations in intraunion competitiveness with opposite effects on both countries. First, the foreign country benefits from the nominal divergence of the relative inflation rates with a boom, whereas the home country's decline of the output gap is aggravated by the decrease of the inflation differential. Second, as the real divergence is positive, the home output gap

Figure 1: Impulse responses of policy instruments to an asymmetric cost-push shock



improves whereas the neighbors have to cope with the intraunion spillovers. The gradual adjustment to the steady state of the economies is analogous in both countries because of the symmetric economic structure of both countries and the equal country size. In case of any asymmetry of the economic structures, this result changes.

Figure 2: Impulse responses of inflation rates and output gaps to an asymmetric cost-push shock

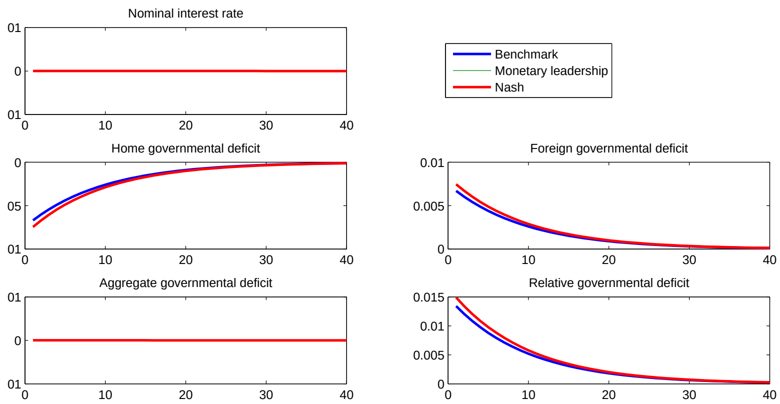


As previously mentioned, the results for the uncoordinated and the monetary leadership scenario are the same. Whereas in the benchmark case, the inflation rates react slightly less than that in the Nash scenario, the reaction of the output gaps is (slightly) higher under coordination than under noncoordination.

To conclude, in the case of an asymmetric cost-push shock fluctuations of the inflation rates and the output gaps in both countries are asymmetric. As monetary policy is restricted, governments have to offset the shock. Whereas at impact of the shock spillover effects aggravate the economic conditions in the home country intraunion competitiveness improves the output gap during the transition to the equilibrium.

When the monetary union is hit by an *asymmetric demand shock* on aggregate, the central bank does not observe any shocks, which implies that there is no reaction of the nominal interest rate, as figure 3 shows. The home demand shock increases the home output gap, whereas the foreign output gap reacts into the opposite direction. On aggregate, the output gap does not fluctuate at all as well as the union-wide inflation rate. However, the home country has to deal with an increase in the inflation rate, whereas the neighbor country faces a deflation. The governments have to offset the shock by increasing relative governmental deficit. As on aggregate, the deficit is zero, the instruments have to be inversely. However, in this case, in contrast with the asymmetric cost-push shock, the home governmental deficit has to decrease, whereas the foreign governmental deficit has to increase which is in line with the optimal fiscal responses in all three policy scenarios. The reaction is less strong than that in the case of cost-push shocks. Again, leadership and uncoordinated policy making coincide.

Figure 3: Impulse responses of policy instruments to an asymmetric demand shock



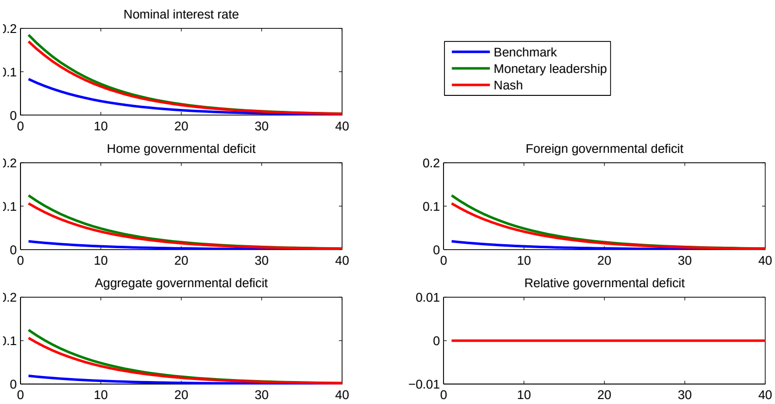
Intraunion spillover effects work in the same direction in contrast with the case of asymmetric cost-push shocks. Both the real competitiveness channel (in the form of decreasing relative output gaps) and the nominal inflation rate differential dampens the home boom. In contrast, the foreign country benefits from both competitiveness channels. The negative foreign output gap converges gradually to the steady state.[11]

[11]The figure showing the impulse response functions in this case can be found in the additional appendix.

Symmetric Shocks

This section discusses the impulse response functions in the case that the two countries are of the same size and are both hit by *symmetric cost-push shocks*, that is, $u_t^H = u_t^F = u_t^W$ and $u_t^R = 0$. As figure 4 shows, there is a reaction of the nominal interest rate in each of the three cases. Because both countries are hit by the same cost-push shock, fiscal authorities set their instruments in the same way. The symmetric cost-push shock leads to a coordination failure between monetary and fiscal policies. The central bank has to increase the interest rate in all three settings enormously with the highest reaction in the case of the monetary leadership game and the lowest in the case of full coordination. In this way, governments pursue an expansionary policy by increasing governmental deficits to cope with the recessions in their countries. However, the higher the fiscal expansion, the larger the central bank has to increase the nominal interest rate to discipline the inflationary outcomes that would result from the fiscal expansion.

Figure 4: Impulse responses of policy instruments to a symmetric cost-push shock



The dynamics of the country-specific inflation rates and output gaps after both countries are hit by symmetric shocks (see additional appendix) resemble those reactions of the variables as in the case of the closed economy. In the benchmark case of full coordination, a positive cost-push shock leads to a trade-off between the inflation rate and the output gap. The cost-push shock increases the inflation rate as a result of the Phillips curve relation directly. Indirectly, the shock increases the conditional expectations of the future interest rate through the $AR(1)$-structure of the shock. This implies a decrease in the output gap. As a result, the central bank increases the nominal interest rate. As a result of the symmetry of the shock and the country size, the reaction of all variables are identical in both countries and on aggregate. There is no effect on intraunion competitiveness in the form of the inflation rate differential and output gap differential. This result changes if the countries are not of equal size. Then there are nominal divergences in the form of intraunion competitiveness (fluctuations in (π_t^R) and real divergences (fluctuations of the relative output gap). As a result, even symmetric shocks lead to asymmetric transmissions within a monetary union. Almost the same mechanism holds in the case of simultaneous setting of all instruments. As governments increase their spending, the central bank has to react with a higher interest rate than in the benchmark case. The nominal interest rate reacts the strongest in the case of monetary leadership, because in this case, the central bank anticipates the reaction of the fiscal policy. This implies the lowest responses of the country-specific inflation rates that have to be paid with higher output gaps.

If the monetary union is hit by a *symmetric demand shock*, the results are the same as in the closed economy. The central bank can completely offset the shock by increasing the nominal interest rate without any responses of any other variable. As the analytical results of table 1 show, the aggregate demand shock just plays a significant role in the determination of the nominal interest rate. As relative demand shocks are zero and all other variables depend on cost-push shocks, the monetary instrument is the only one that reacts in this case.

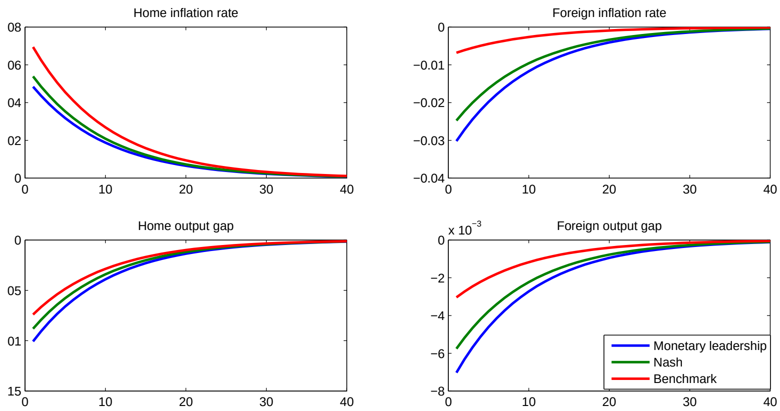
Single Shocks Just Hitting One Country

Last, in this section it is analyzed how a single shock hitting just one of the countries affects both economies of the monetary union. Figure 5 displays the impulse response functions of a *home cost-push shock*. At impact, the shock leads to an increase of the home inflation rate. As on aggregate, the central bank observes a cost-push shock and increase of the unionwide inflation rate, the nominal interest rate is increased leading to a negative output gap in both countries. However, the effect of the shock on the economic conditions of the foreign country is much less than that in the home country where the shock occurs. Spillover effects, however, transmit the shock to the foreign country. Whereas the home government has to react to the shock with high and prolonged fiscal deficits, the foreign country has to set much less deficits. In the benchmark scenario, fiscal deficits do not respond at all to the shock abroad. The foreign country benefits from improved competitiveness. Although both countries are assumed to be identical (in size and economic structure) the adjustments to the shocks in both countries are asymmetric. Fluctuations in intraunion competitiveness (relative output gaps and relative inflation rates react to the shock) can be observed.

Moreover, it is noteworthy that the response in both countries is smaller than that in the case of a symmetric cost-push shock to both countries. The foreign country gains from the competitiveness channel. In contrast, the home country benefits from a smaller recession in the neighbor country. Fiscal deficits on the aggregate are smaller, and the central bank responds with a smaller increase of the nominal interest rate to combat aggregate inflation, which rises less because the foreign country faces a deflation.

Concerning the interaction of monetary and fiscal policies, this case of asymmetric cost-push shock again leads to a coordination problem. Whereas the central bank pursues a restrictive monetary policy to combat the effects of the shock, fiscal policy is expansionary. As a result,

Figure 5: Impulse responses of inflation rates and output gaps to a home cost-push shock



both policies are (strategic) substitutes counteracting each other. This result holds for all three policy scenarios, even in the benchmark case of full coordination, although the effect, then, is less severe than that in the other two games.

The responses of the policy instruments and country-specific inflation rates and output gaps to a *home demand shock* are similar in pattern to the responses of these variables to an asymmetric demand shock with the exception that in the considered case the nominal interest rate responds to the shock. Although the shock is asymmetric, the response of both economies is symmetric. The home demand shock leads to a mild inflationary boom in the home country. In response, fiscal deficits become negative and the the central bank has to increase the nominal interest rate. Both instruments are set in a contractionary way. Through the interest rate channel, this leads to an immediate recession in the foreign country. Because both countries are assumed to be identical in size and economic structure, the response of the foreign variables is analogously in size to the one of the home variables. The extent is the same across all three policy scenarios. So, in the case of a country-specific demand shock, there is no coordination problem between the central bank and both governments. The policy instruments (both contractionary) are complements and support each other.

Welfare Effects

In this section, welfare effects of the different shocks previously discussed and the various policy regimes are computed. Table 3 gives the values for the one-period, aggregated, monetary, and fiscal loss functions as a result of the different demand shocks. It is noteworthy that for all three kind of shocks (asymmetric, symmetric, and single home demand shock), the central bank does not have any losses at all. The analytical results of table 1 show that the aggregate inflation rate and the output gap are determined by the aggregate cost-push shock in all three policy scenarios.

In case of a symmetric demand shock, there are no losses at all for all policymakers. As discussed in the section about symmetric shocks, the central bank can offset the shock completely by raising the nominal interest rate. Inflation rates and output gaps – and, as a consequence, fiscal deficits – do not respond to the shock.

In case of a single home demand shock, the losses for the home and foreign country (and as a result the aggregate losses) are the same. As the impulse responses show, the reaction is inversely in both countries but of the same magnitude. As both countries benefit from the spillover effects, in this case the losses they suffer are smaller than those ones in the case of asymmetric shocks.

Table 3: Welfare losses (one-period) as a result of various demand shocks

	Asymmetric				Symmetric				Home			
	Agg	CB	H	F	Agg	CB	H	F	Agg	CB	H	F
Benchmark	0.332	0	0.332	0.332	0	0	0	0	0.083	0	0.083	0.083
Nash	0.329	0	0.329	0.329	0	0	0	0	0.0824	0	0.0824	0.0824
ML	0.329	0	0.329	0.329	0	0	0	0	0.0824	0	0.0824	0.0824

Numbers have to be multiplied by 10^{-5}.

Comparing the results across the three policy regimes, it is remarkable that in the benchmark case of full coordination, the losses are the biggest for all three demand shocks. Although the policy instruments respond to the shocks to a lesser extent, the inflation rates and the output gaps react more in the case of coordination than in the other two policy regimes. The aggregate of all three loss functions puts too much emphasis on output gap stabilization.

Table 4 gives the values for the one-period aggregated, both governmental and the monetary loss functions of the different cost-push shocks. As the aggregated cost-push shock plays a significant role in determining the unionwide inflation rate and output gap, the central bank suffers significant losses (besides the case of asymmetric shocks).

On aggregate, the losses are the biggest in the case of the symmetric shocks followed by the scenario of the home cost-push shock. As a result of the high volatility of the aggregated inflation rate and the aggregated output gap in the policy regime of full coordination, the aggregate and monetary losses are higher than those in the other two policy regimes. For the central bank, it is best to play the leader, whereas the governments suffer the most losses in this case. For them, the coordinated policy regime leads to the best welfare results because in this scenario, governmental deficits and country-specific output gaps do not fluctuate in such an extent as they do in the other scenarios. This leads to a severe coordination problem of fiscal and monetary policies regarding the proper time to implement policy instruments.

Table 4: Welfare losses (one-period) as a result of various cost-push shocks

	Asymmetric				Symmetric				Home			
	Agg	CB	H	F	Agg	CB	H	F	Agg	CB	H	F
Bench mark	2.947	0	2.947	2.947	210	203.000	7.213	7.213	52.253	49.713	4.617	0.463
Nash	2.930	0	2.930	2.930	110	47.719	66.942	66.942	29.398	11.930	24.471	10.466
ML	2.930	0	2.930	2.930	120	23.938	92.246	92.246	29.779	5.984	32.014	15.574

Numbers have to be multiplied by 10^{-5}.

Conclusion

A simple model of a two-country monetary union based on the New Keynesian framework is set up. Three policymakers, that is, two governments and one single central bank decide over policy variables to stabilize the economy. Authorities do not coordinate their instruments; rather, they set their instruments in an uncoordinated manner or in some kind of policy regime in which one (group) of the policymakers reacts to the policy decision made by the other one before. Closed analytical solutions for all variables (specially for the policy instruments) are derived for all different strategic scenarios. Moreover, the different outcomes are evaluated by comparing welfare effects. Last, to visualize the dynamic behavior of the variables, the model is simulated and impulse response functions in the case of asymmetric and symmetric shocks are depicted.

Although the structure of the model is quite simple, analytical results are no longer straightforward in some of the strategic games (especially the regime of monetary leadership). The closed analytical results depend on the various constants of the underlying model in a nonlinear way. For some parameter restrictions, the scenarios of noncoordination and leadership coincide with the benchmark scenario.

Depending on the kind of the shock, interaction problems between fiscal and monetary policies might arise. Whereas after some kinds of shocks the central bank prefers to be restrictive governments follow an expansionary fiscal policy. Moreover, intraunion spillovers can both amplify or dampen the shock. Coordinated policy does not lead to the best outcome in terms of welfare. Policy instruments react less to the shocks in the benchmark than in the other cases, but fluctuations in the output gap and the inflation rate are greater. In the case of cost-push shocks, central banks have an incentive to be a leader when setting instruments, because this policy regimes reduces their welfare losses. However, governments wish to coordinate all policies or set all instruments simultaneously.

This setup can be extended in many ways to answer open questions. First, the model abstracts form debt dynamics, which are an important issue at present. Second, in today's economic environment, monetary policy is constrained by the zero-lower bound on the nominal interest rate. The extension of this paper's model to the environment of a binding zero-lower bound is analyzed in Flotho [2011]. Third, including time lags in the form of inflation inertia in the Phillips curve might lead to a better fit of the model to the data. The result of all of these additional assumptions is that the model gets more complicated and analytical results are, however, no longer available.

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