MACROECONOMIC POLICY STRATEGIES IN A MONETARY UNION: SIMULATIONS WITH A DYNAMIC-GAME MODEL

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ABSTRACT

We analyze alternative strategies of monetary and fiscal policies in a monetary union model using a small macroeconomic model and by running numerical simulations in the framework of a dynamic game. Several coalitions are investigated between governments of the member countries and the common central bank. We show that only a coalition between all governments and the central bank is efficient while a fiscal union or other partial coalitions can be counterproductive.

INTRODUCTION

A series of crises shook the euro area (EA) over the last few years: the Great Recession (the financial crisis 2008–2010), the European sovereign debt crisis, the COVID-19 crisis, and the Ukraine war (energy price) crisis. The EA was particularly vulnerable during the sovereign debt crisis in view of the heterogeneity of its economies; moreover, the European Central Bank (ECB) is responsible for monetary policy for all participating countries despite the asymmetries between them. For policy makers concerned with monetary and fiscal policy for macroeconomic objectives such as economic growth, employment, price stability, and the sustainability of public finances, it is highly desirable to be given some guidance as to how they should design their policies to reach their objectives as well as possible.

In this paper, we examine the optimal design of fiscal and monetary policy in a monetary union like the EA in the presence of shocks similar to the series of crises over the last few years using numerical simulations of dynamic games between policy makers. Dynamic game theory is an appropriate tool to analyze the dynamics within a monetary union and enables us to consider the strategic interactions of heterogeneous players. Analytical solutions of dynamic games are available only in extremely restrictive circumstances; hence numerical solutions are called for. Following (Michalak et al. 2008), (Blueschke and Neck 2011), (Anastasiou et al. 2019), and (Blueschke and Neck 2018), among others, we study interactions between monetary and fiscal players for a macroeconomic model of a monetary union with three fiscal players (representing blocks of countries) and a common central bank to capture some specific asymmetries between the EA countries. Of course, the EA consists of more countries but considering interactions between all of them would be rather cumbersome without adding much to the question we investigate here. A more restrictive assumption we have to make is the requirement that coalitions between the countries remain the same over the entire horizon of the dynamic game. Our results in terms of the EA should therefore be interpreted with care.

The structure of the paper is as follows: The next section sketches the basic approach of dynamic game theory and our solution algorithm OPTGAME. The following section describes the model of the monetary union used in the analysis as well as the objective functions of the policy makers and specifies the numerical values of the parameters. It also shows the exogenous shocks and their calibration. The results of game experiments with five scenarios are presented and interpreted in the next section. In the next section, the sensitivity of the results is examined with respect to the weights of the countries in the monetary union. The last section concludes.

THE DYNAMIC GAME FRAMEWORK

Here we apply the dynamic game framework (see, e.g., (Basar and Olsder 1999), (Basar and Zaccour 2018)) in order to analyze coalition strategies between the countries in a monetary union facing different shocks. The economies under consideration are described by a dynamic system of nonlinear difference equations in state-space form:

$$x_t = f(x_{t-1}, x_t, u_t^1, \dots, u_t^N, z_t), \quad x_0 = \overline{x_0}. \qquad (1)$$

Here x_t is an $(n \times 1)$ vector of state variables and u_t^i is an $(m_i \times 1)$ vector of individual control variables of player i $(i = 1, \dots, N)$ having m_i variables at their disposal. z_t is a vector of non-controlled exogenous variables including exogenous shocks, $t = 1, \dots, T$.

The problem is formulated in the so-called dynamic tracking game form where each player minimizes an

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objective function (loss function) J_i, which is the sum over time of quadratic deviations of state and control variables from given target values (denoted by ~):

$$\min_{u_1^i,\dots,u_T^i} J^i = \min_{u_1^i,\dots,u_T^i} \sum_{t=1}^{T} L_t^i(x_t, u_t^1, \dots, u_t^N), \quad (2)$$

with

$$L_t^i(x_t, u_t^1, \dots, u_t^N) = \left[x_t - \tilde{x}_t^i\right]' \Omega_t^i \left[x_t - \tilde{x}_t^i\right] + \left[u_t - \tilde{u}_t^i\right]' \Psi_t^i \left[u_t - \tilde{u}_t^i\right]. \quad (3)$$

The game is played over a time horizon of T periods and consists of individual optimization problems for N players. The penalty matrices Ω_t^i and Ψ_t^i contain the weights of the deviations of states and controls from their desired levels in any period t and indicate the importance of each of the relevant variables for the players.

Equations (1), (2), and (3) formulate a nonlinear dynamic tracking game problem. Equilibrium solutions cannot be obtained analytically. For our simulations of the policy strategies, they will be numerically approximated using the OPTGAME algorithm. This algorithm allows us to find approximations to cooperative (Pareto optimal) and non-cooperative Markov (subgame) perfect (feedback) Nash equilibrium solutions of the game. For details of the OPTGAME algorithm, see (Blueschke et al. 2013).

The OPTGAME algorithm delivers approximations to the true solutions of the nonlinear-quadratic game under consideration. Although we have tested OPTGAME for linear-quadratic dynamic games and confirmed the (known) true solutions for this special case, the question of the quality of the approximations is an open one. Moreover, we consider only deterministic games. A fully stochastic analysis for a dynamic game like ours would be enormously complicated as our experiences with the single-decision maker (optimization) problem have shown (Blueschke et al. 2021). Finally, one may question the assumption of the finite time horizon and introduce a scrap value, which we found not to change the strategies by much, apart from the last few periods. Hence, we consider the choice of a finite period which is longer than the effects of the shocks to be the best alternative. Our study, therefore, should not be interpreted as ex-ante advice to policy makers but as ex-post evaluations of past hypothetical policies.

THE MACROECONOMIC MODEL MUMOD2

Here we follow (Blueschke and Neck 2018) and consider three fiscal players, which are calibrated in such a way so as to represent blocks of countries in the EA, namely the core block (also called country 1) with relatively solid public finances, the thrifty periphery block (called country 2) with higher initial public debt but which accords relatively high importance to fiscal objectives, and the thriftless periphery block with higher initial public debt which accords little importance to fiscal targets (country 3). This allows us to analyze different coalition scenarios in a monetary union model for the EA affected by shocks like the Great Recession 2008–2010, the European sovereign debt crisis, the COVID-19 crisis, and the Ukraine war crisis. The first two are modelled as pure demand-side shocks while the latter two also contain some supply-side elements. These shocks impact on the MUMOD2 model, a dynamic macroeconomic model of a monetary union. The governments of the three member countries of the union design their fiscal policies to optimize their own objective functions. In addition, the joint central bank optimizes a (unionwide) objective function over the same model. All four players take account of the other players' strategies, either in a noncooperative way according to the feedback Nash equilibrium solution concept or in a cooperative way by forming coalitions with each other or with subsets of the other players. The goal of the analysis is to learn about possible advantages of a more centralized design for fiscal policies in a monetary union.

The monetary union is calibrated with the data of the EA. The core block consists of EA countries with a more robust fiscal and inflation performance. The share of this block in the EA's real GDP was 60% in 2007 (pre-Great Recession). In a second step the periphery block is divided into two sub-blocks. We assume that, despite their similar initial economic situation (primarily higher public debt compared to the core block), the periphery block is not homogenous regarding its view of the importance of fiscal stability indicators. We split the periphery block into two equal parts each having a 20% share in the real GDP of the monetary union. Altogether we consider four policy makers, as shown in Table 1.

Table 1: Players in the Dynamic Game

acronym	player	calibration for euro area
C1	government of country 1	core block
C2	government of country 2	thrifty periphery block
C3	government of country 3	less thrifty periphery block
CB	common central bank	ECB

The governments decide on fiscal policy and the common central bank of the monetary union is responsible for controlling monetary policy. The central bank decides on the prime rate R_{Et}, a nominal rate of interest under its direct control. The national governments decide on real fiscal surplus (or, if negative, its fiscal deficit), g_{it} (i = 1, 2, 3), measured in relation to real GDP. The players use their control variables as instruments in order to track the desired paths of the state variables, which evolve according to the dynamic system given by the MUMOD2 model. Table 2 shows the list of state variables of that model, and its equations are given by:

$$y_{it} = \delta_i \left(\frac{\pi_{jt}+\pi_{kt}}{2} - \pi_{it}\right) - \gamma_i(r_{it} - \theta) + \rho_{ij} y_{jt} + \rho_{ik} y_{kt} - \beta_i \pi_{it} + \kappa_i y_{i,t-1} - \eta_i g_{it} + z d_{it}, \quad (4)$$

$$r_{it} = I_{it} - \pi_{it}^e, \quad (5)$$

$$I_{it} = R_{Et} - \lambda_i g_{it} + \chi_i D_{it}, \quad (6)$$

$$\pi_{it} = \pi_{it}^{e} + \xi_i y_{it} + zs_{it}, \tag{7}$$

$$\pi_{it}^{e} = \varepsilon_i \pi_{i,t-1} + (1-\varepsilon_i)\pi_{i,t-1}^{e}, \varepsilon \in [0,1], \tag{8}$$

$$y_{Et} = \sum_{i=1}^{3} \omega_i y_{it}\,,\ \sum_{i=1}^{3} \omega_i = 1, \tag{9}$$

$$\pi_{Et} = \sum_{i=1}^{3} \omega_i \pi_{it}\,,\ \sum_{i=1}^{3} \omega_i = 1, \tag{10}$$

$$D_{it} = \left(1 + BI_{i,t-1} - \pi_{i,t-1}^{e}\right) D_{i,t-1} - g_{it}, \tag{11}$$

$$BI_{it} = \frac{1}{6}\sum_{\tau=t-5}^{t} I_{it}. \tag{12}$$

Table 2: Variables of the Three-Country (i = 1,…,3) Monetary Union

Control variables	
g_{it}	real fiscal surplus of country i
R_{Et}	prime rate
Endogenous variables	
y_{it}	short-term deviations from the LR equilibrium output level
r_{it}	real interest rate in country i
I_{it}	nominal interest rate in country i
π_{it}	inflation rate in country i
π_{it}^{e}	expected inflation rate in country i
y_{Et}	weighted output in the monetary union
π_{Et}	weighted inflation rate in the monetary union
D_{it}	real government debt in country i
BI_{it}	average interest rate for government bonds in country i

The MUMOD2 model is formulated in terms of deviations from a long-run growth path. The aggregate goods market is modelled by the short-run income-expenditure equilibrium relation (4) for real output y_{it}. $\theta \in [0,1]$ is the natural real rate of output growth, assumed to be equal to the natural real rate of interest. Excess demand for goods and services depends on the domestic inflation rate relative to that in the other two countries, on the real rate of interest relative to the natural rate, on aggregate excess demand in the other two countries (exports to them), on the domestic inflation rate, and on the domestic budget surplus/deficit (through a Keynesian multiplier). Exogenous demand-side shocks can affect the domestic output via zd_{it}.

The current real rate of interest r_{it} is given by the Fisher equation (5). The nominal rate of interest I_{it} (equation (6)) is driven by the prime rate, adjusted by country-specific risk premiums $-\lambda_i$ and χ_i. The inflation rate π_{it} is determined by the expectations-augmented Phillips curve (7), in which the expected rate of inflation is based on adaptive expectations (8). Exogenous supply-side shocks (such as energy price shocks) can enter the inflation equation through zs_{it}. The real government debt D_{it} measured in relation to GDP evolves according to the government budget equation (11) and depends on the previous stock of public debt, the current budget surplus, and interest payments that depend on the interest rate on bonds BI_{it}. An average government bond maturity of six years (12) is assumed following Krause and Moyen (2016).

The average values of output and union-wide inflation in the monetary union are given by (9) and (10). The parameter ω_i in these equations expresses the weight of country (block) i in the economy of the entire monetary union as defined by its output level. The parameters of the model are calibrated for the EA and are given in Table 3.

Table 3: Parameter Values for an Asymmetric Monetary Union, i = 1,…,3

T	θ	ω_1	ω_2, ω_3	$\delta_i, \eta_i, \varepsilon_i$	ρ_{21}, ρ_{31}	$\rho_{23}, \rho_{32}, \beta_i, \gamma_i, \kappa_i, \lambda_i$	ρ_{12}, ρ_{13}	ξ_i	χ_i
30	0.03	0.6	0.2	0.5	0.375	0.25	0.125	0.1	0.0125

We consider a game with a time horizon of 30 periods, interpreted here as years. The long-run growth rate θ is assumed to be 3%. The economic weights of the players ω_i correspond to EA real GDP in 2007 for the blocks of countries with the core block having 60% weight and the two periphery blocks having 20% each.

The dynamic system as given by equations (4)–(12) describes the evolution of the state variables over time. The four players use their control variables to lead the objective state variables by minimizing their respective objective functions. They differ with respect to the set of state variables in their objective function as well as to the importance of the individual objective variables. As can be seen in equation (13), governments (i = 1, 2, 3) emphasize their national variables: inflation, output, public debt, and budget balance. In contrast, the common central bank (E, equation (14)) targets union-wide inflation, average output in the monetary union, and the prime rate.

$$J_i = \frac{1}{2}\sum_{t=1}^{T}\left(\frac{1}{1+\frac{\theta}{100}}\right)^{t} \{\alpha_{\pi i}(\pi_{it} - \widetilde{\pi_{it}})^2 + \alpha_{yi}(y_{it} - \widetilde{y_{it}})^2 + \alpha_{Di}\left(D_{it} - \widetilde{D_{it}}\right)^2 + \alpha_{gi} g_{it}^2\}, \tag{13}$$

$$J_E = \frac{1}{2}\sum_{t=1}^{T}\left(\frac{1}{1+\frac{\theta}{100}}\right)^{t} \{\alpha_{\pi E}(\pi_{Et} - \widetilde{\pi_{Et}})^2 + \alpha_{yE}(y_{Et} - \widetilde{y_{Et}})^2 + \alpha_E\left(R_{Et} - \widetilde{R_{Et}}\right)^2\}. \tag{14}$$

Table 4: Weights of the Variables in the Objective Functions

α_{yi}, α_{gi}	$\alpha_{\pi E}$	$\alpha_{yE}, \alpha_{\pi i}$	α_{D1}, α_{D2}	α_{D3}	α_{RE}
1	5	0.5	1	0.1	3

Although the governments have the same set of state variables, there is an asymmetry in the importance of the variables to the policy maker concerned as given by parameter α (see Table 4), which refers to the importance of the public debt target (α_D) in the objective function. Oriented towards fiscal stability, countries 1 and 2 attach a ten times higher weight to it than country 3 (the less thrifty periphery block). There is also a difference between governments and the common central bank: The governments put greater emphasis on (their national) output while the central bank gives a higher weight to (union-wide) inflation.

Next, the desired paths of the objective variables have to be defined. These target values are summarized in Table 5. A balanced growth path along the natural level of real GDP is targeted by all players, i.e. the short-run output gap should be zero ($\widetilde{y_{it}} = 0$). The target value for the inflation rate is set to 2%, the official objective of the ECB. Regarding the public debt target, the governments aim to fulfil the Stability and Growth Pact criterion of 60% of GDP. As the periphery blocks start from a higher initial level, they steer towards a linear decrease in public debt from 80% to 60% over the entire planning horizon. Finally, the governments prefer a balanced budget (g = 0), and the central bank aims at a prime rate of 3%. The target values and the weights given to the controls (the policy instruments of each player) also reflect the desire to avoid overly excessive fluctuations in these variables, which are not possible in the real world due to the path dependence of policies.

Table 5: Target Values for the Asymmetric Monetary Union

$\tilde{D}_{1t}$	$\tilde{D}_{2t}, \tilde{D}_{3t}$	$\tilde{\pi}_{it}$	$\tilde{\pi}_{Et}$	$\tilde{y}_{it}$	$\tilde{y}_{Et}$	$\tilde{g}_{it}$	$\tilde{R}_{Et}$
60	80 ↘60	2	2	0	0	0	3

For the cooperative Pareto scenario, the joint objective function is given by the weighted sum of the four objective functions:

$$J = \mu_1 J_1 + \mu_2 J_2 + \mu_3 J_3 + \mu_E J_E, \qquad (15)$$

where the weights are the same as those in equations (9) and (10). The Pareto solution requires the full commitment of all the players, which would have to be guaranteed by some appropriate institutional devices.

Table 6: Modelling the Great Recession and the Sovereign Debt Crisis

t	1	2	3	4	5	6	7	8	9	...
$year$	'08	'09	'10	'11	'12	'13	'14	'15	'16	...
zd_{1t}	-1	-6	-1	0	0	0	0	0	0	0
zd_{2t}	-1	-6	-1	-3	-4	-3	-1	0	0	0
zd_{3t}	-1	-6	-1	-3	-4	-3	-1	0	0	0

The MUMOD2 model can serve to analyze strategic economic interactions between the policy makers in a monetary union in the presence of exogenous shocks. We model key aspects of the Great Recession 2008–2010, the ensuing European sovereign debt crisis, the COVID-19 crisis, and the Ukraine war crisis. Following the arguments of (Kahle and Stulz 2013) we model the Great Recession as a demand shock. To do so, we add an exogenous shock on the demand side with a drop in GDP by 1% in 2008, by 6% in 2009, and by 1% in 2010. This shock affects all economies in the monetary union in a symmetric way. On the other hand, the following sovereign debt shock impacts the periphery block only. The numerical values of the shocks are given in Table 6.

In contrast to the Great Recession and the sovereign debt crisis shocks, which hit the EA mainly via the demand side, the COVID-19 shock was not just a negative demand shock. The pandemic situation interrupted existing supply chains, leading to increasing production costs, and can thus be modelled as a combined demand and supply shock. Higher prices of oil and other resources as well as higher world market prices for food had similar supply-side effects on the EA. For a discussion of the different channels of the COVID-19 shock see, e.g., (del Rio-Chanona et al. 2020). Although the pandemic is not yet completely over (early 2023), we modelled the strongest negative impact of the shock on the demand side in 2020 in accordance with world trade and EA data. The supply-side effects started to impact the economies under consideration in 2021 and, amplified by the Ukraine war, starting in 2022, are assumed to slowly decrease over the next three years and completely disappear in 2025. We interpret the Ukraine war crisis as a supply shock reinforcing and extending the supply-side elements of the COVID-19 shock. The numerical values of the COVID-19 and the Ukraine war shocks are summarized in Table 7.

Table 7: Modelling the COVID-19 Crisis and the Ukraine War Crisis

t	12	13	14	15	16	17	18	19	20	21	...
$year$	'19	'20	'21	'22	'23	'24	'25	'26	'27	'28	...
zd_{1t}	0	-5	0	0	0	0	0	0	0	0	0
zd_{2t}	0	-5	0	0	0	0	0	0	0	0	0
zd_{3t}	0	-5	0	0	0	0	0	0	0	0	0
zs_{1t}	0	0	1	9	3	2	1	0	0	0	0
zs_{2t}	0	0	1	9	3	2	1	0	0	0	0
zs_{3t}	0	0	1	9	3	2	1	0	0	0	0

BASELINE SIMULATIONS

This research aims at analyzing the effects of different coalition strategies in a monetary union in the presence of negative exogenous shocks. We consider five scenarios with different coalitions (as summarized in Table 8). In accordance with game-theory terminology, a coalition means a strictly binding agreement between two or more players to always act jointly. The members of the coalition play as one player, with a cooperative strategy inside the coalition and a weighted sum of the participants' objective functions as their joint objective function.

In the following, sc1_NF4 denotes an "everyone for themselves" scenario. This means a non-cooperative Nash game with all four players being independent, i.e. each player only cares about their own objective function (no coalition). sc2_2+3 denotes a non-cooperative Nash game with three players, where country 2 and 3 build a coalition. It means that the central bank (CB) plays against country 1 (core block) and against a coalition of countries 2 and 3 (periphery block). sc3_1+2 denotes a Nash game with three players, where the countries oriented towards fiscal stability form a coalition and play together against the central bank and country 3. sc4_FU denotes a Nash game with two players, where a coalition of all fiscal players plays against the central bank. This strategy corresponds to the creation of a fiscal union with an independent central bank. sc5_P stands for total integration of fiscal and monetary policy; this is the fully cooperative Pareto solution. We also consider the non-controlled forward simulation using the starting values of the control variables (sim), modelling fixed rules.

Table 8: Coalition Strategies when Facing Negative Exogenous Shocks

	scenario	game strategy
sc1_NF4	everyone for themselves	Nash FB with 4 players
sc2_2+3	core vs periphery: coalition of periphery countries	Nash FB with 3 players CB / C1 / (C2+C3)
sc3_1+2	thrifty vs thriftless: coalition of countries 1 & 2	Nash FB with 3 players CB / (C1+C2) / C3
sc4_FU	fiscal union: coalition of 3 countries	Nash FB with 2 players CB / (C1+C2+C3)
sc5_P	fiscal and monetary union	Pareto solution
sim	non-controlled simulation	simulation

To compare the performances of the players for different coalition scenarios, we present graphs for the control and three state variables: output and inflation rate for the entire union, and public debt. Figures 1–4 show the outcomes for the control variables of the players. Figures 5–9 present the results of the state variables.

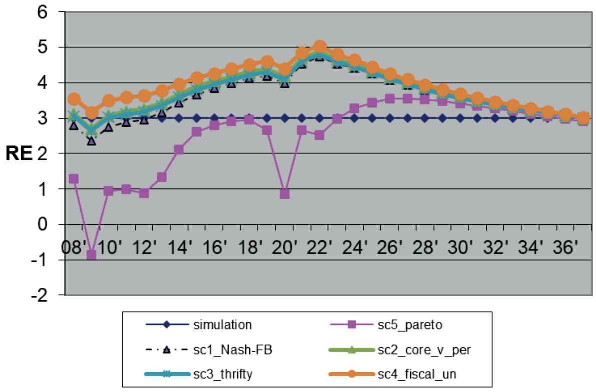

Figure 1: Control Variable Prime Rate (R_E)

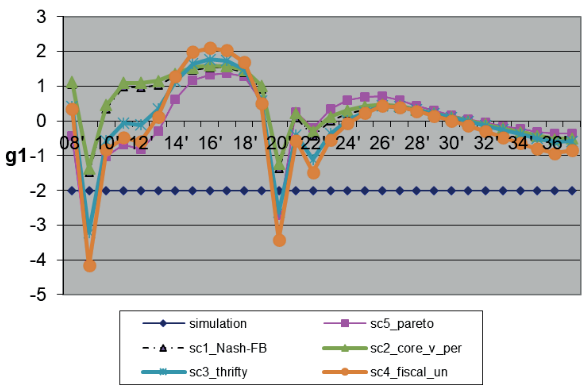

Figure 2: Control Variable Fiscal Surplus (g_1)

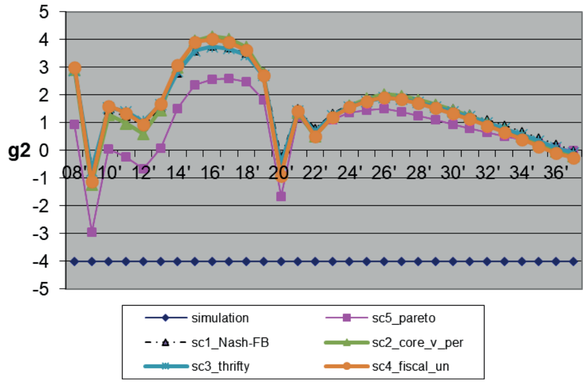

Figure 3: Control Variable Fiscal Surplus (g_2)

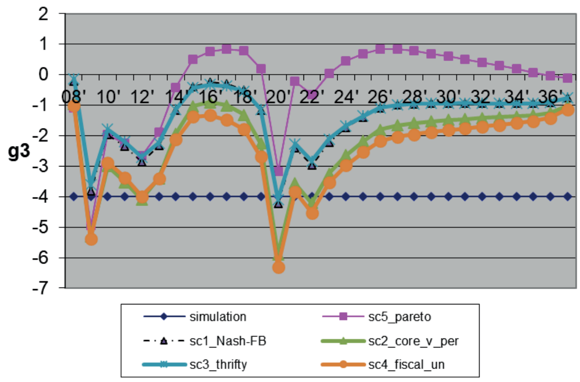

Figure 4: Control Variable Fiscal Surplus (g_3)

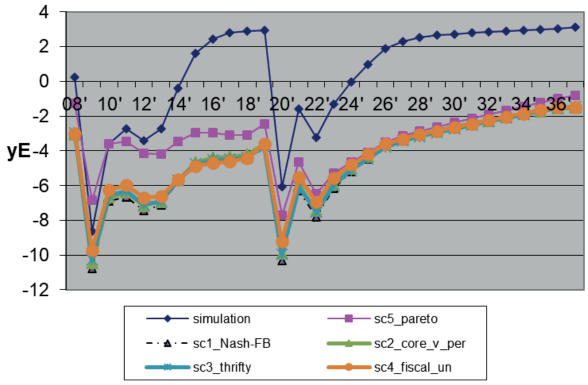

Figure 5: State Variable Union-Wide Output (y_E)

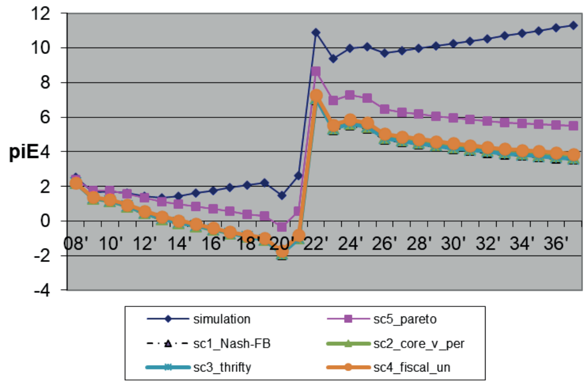

Figure 6: State Variable Union-Wide Inflation (π_E)

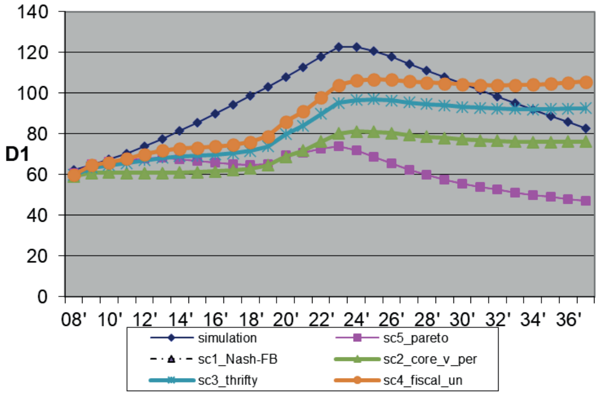

Figure 7: State Variable Public Debt (D_1)

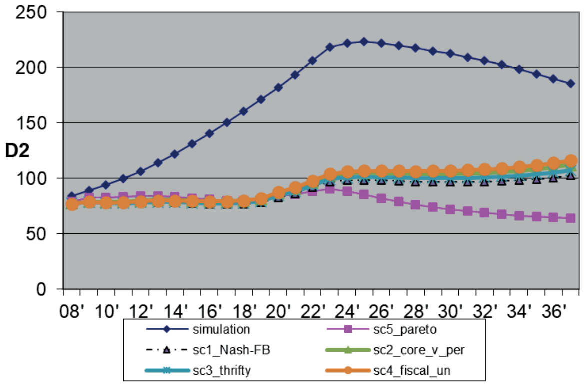

Figure 8: State Variable Public Debt (D_2)

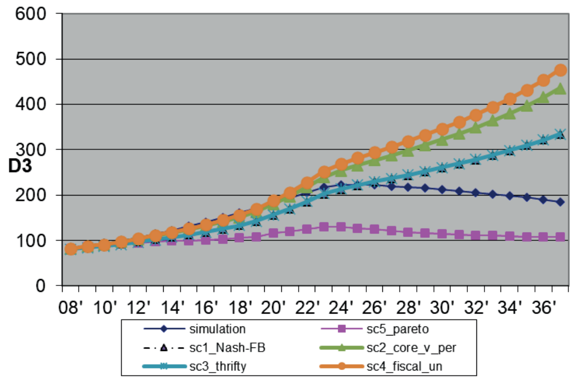

Figure 9: State Variable Public Debt (D_3)

In addition, the performance of individual players is shown by the resulting objective function values (loss functions to be minimized) in Table 9.

Table 9: Objective Function Values for the Baseline Scenarios

Strategy	CB	C1	C2	C3	sum
simulation	1545.67	397.80	1591.95	481.42	4016.84
pareto	594.83	181.60	281.18	254.74	1312.07
sc1_NF4	485.26	271.29	576.45	453.94	1786.95
sc2_2+3	490.89	269.70	585.90	485.27	1831.76
sc3_1+2	482.32	302.84	572.13	442.31	1799.60
sc4_FU	499.87	340.93	577.16	485.91	1903.87

The results can be summarized as follows; see also (Blueschke et al. 2023) for a similar exercise: The policy instruments are used in a countercyclical way during the demand shocks (Figures 1–4), which is expected given the Keynesian structure of MUMOD2 (Figures 5 and 6). The demand shocks have similar effects; the deeper COVID-19 shock requires more active monetary and fiscal interventions by all players. Monetary policy and mostly also fiscal policy return faster to their "business as usual" course, in contrast to policies actually executed by the ECB and most governments in the EA. The fiscal policies of the thrifty countries do not only return to the log-run steady state (0 here) but overshoot by producing primary surpluses after the end of the shocks to secure the sustainability of their public debt. On the other hand, neither monetary nor fiscal policy reacts to the supply-side shock in the last phase of the COVID-19 shock. Thus, even the Keynesian MUMOD2 model does not support longer expansionary phases of countercyclical policies after temporary demand shocks or any expansionary policy against a supply shock. This is a feature that agrees with results from new-classical or monetarist models.

As must be the case, the cooperative Pareto solution results in the best performance in terms of the value of the overall objective function. Table 9 and the graphs clearly show that in this simulation, the main burden of cooperation falls on the common central bank, which supports the endeavors of the governments to mollify the negative effects of the crises by running a more expansionary monetary policy than it would do without cooperating. This situation corresponds to the actual policy of the ECB in the last few years, apart from the more discretionary reaction of monetary policy our model calls for. Such an accommodating monetary policy provides an important advantage to fiscal policy makers, as already shown in (Blueschke and Neck 2018). In the cooperative Pareto solution, all countries perform much better in terms of both output and public debt than in all the other scenarios. A main advantage of cooperation is that all players under binding agreements know that no one would beggar their neighbor. The accommodation of their expansionary fiscal policies and their joint monetary policy make them more effective and allow for more expansionary actions than otherwise.

Among the two periphery countries, it is clear that country 3 runs higher fiscal deficits in all four (partially) non-cooperative scenarios due to its assumed lower preference for fiscal stability (Figure 4). This leads to non-sustainable public debt levels for the thriftless country in all scenarios other than the cooperative Pareto solution (Figure 9). Such a policy would result in the bankruptcy of this country by the end of the planning horizon. On the other hand, countries 1 and 2, which accord higher importance to fiscal stability, are able to stabilize their public debt at a sustainable level even after a prolonged period of consecutive crises (Figures 7 and 8). This indicates the necessity for a careful design of fiscal policy, especially in periphery countries, with an emphasis on the goal of government debt sustainability in order to avoid a situation leading to another European sovereign debt crisis.

Regarding the possible advantages of a more centralized fiscal policy in a monetary union, a remarkable result is the fact that the pure fiscal union scenario (sc4_FU, with all fiscal players being part of the same coalition) gives the worst solution in terms of the total objective function value. In this scenario the main burden of reducing the impact of the exogenous shocks falls on the fiscal players running very high budget deficits during the shocks. Here, the central bank does not really support the fiscal players, choosing high prime rates instead in order to fulfil its primary mandate to secure price stability. This shows that a pure fiscal union, without accommodating monetary policy, can deliver results that are worse than even the scenario without any coordination at all. This result is new and points toward the need for coordination not only between the governments but also between them and the central bank. A common finance minister for the union or some other form of a fiscal union without coordination with the monetary authorities can lead to a situation where fiscal and monetary policies counteract each other and may be highly inefficient.

If we compare the two 'small' coalition strategy scenarios (sc2_2+3 and sc3_1+2), it is clear that the country which allies itself with the country with higher government debt has to apply a more active fiscal policy than otherwise. In scenario sc2_2+3 (the coalition of periphery countries), this is true for country 2; in the case of sc3_1+2 (the coalition of core and thrifty periphery countries) it is true for country 1. Being part of a fiscal coalition allows country 3 to run higher deficits and to concentrate more on the growth side of the growth-public debt trade-off. On the contrary, if left alone, this country has to pay more attention to the public debt target. This behavior results in significantly lower public debt levels in country 3 in the scenarios where it does not cooperate (sc1_NF4 and sc3_1+2). This result raises doubts about the idea of a fiscal union as a possible solution for unsustainably high public debts in some EA countries.

SENSITIVITY ANALYSIS

In order to examine the robustness of the main results shown so far, we ran several alternative simulations. For lack of space, we describe only those which change the size of the countries concerned. This also serves to show what happens if one or more countries have a stronger or weaker position than the others. To do so, we run three alternative sets of simulations with different distributions of the weights of the countries as indicators of their relative strength or size within the union.

Simulation with weights 0.2/0.4/0.4

First, we consider the case when the core country is only half as large as either of the two periphery countries: $\omega_1 = 0.2, \omega_2 = 0.4, \omega_3 = 0.4$. The results for the fiscal policy variables and the overall losses are given in Figures 10–12 and Table 9. The results for the state variables are very similar to those presented in Figures 5 and 6 in the baseline scenarios.

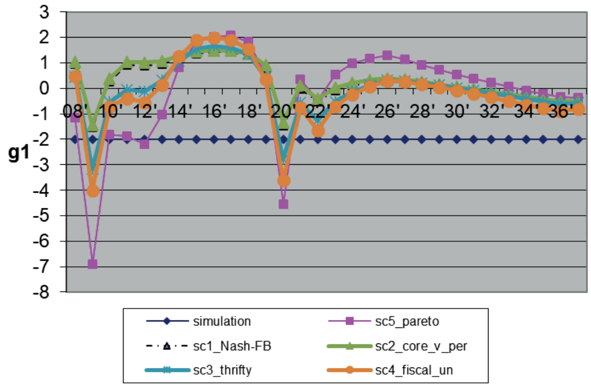

Figure 10: Control Variable Fiscal Surplus (g_1)

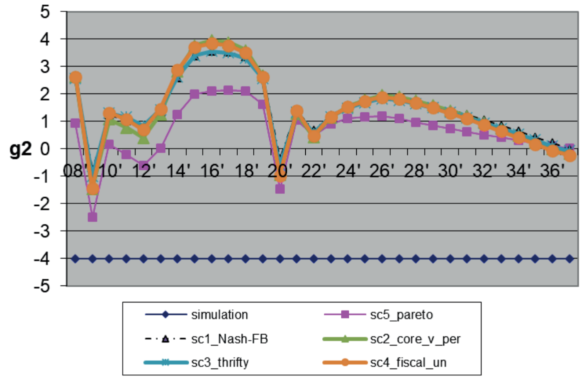

Figure 11: Control Variable Fiscal Surplus (g_2)

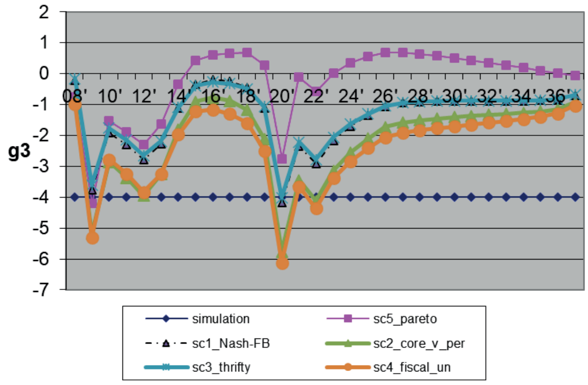

Figure 12: Control Variable Fiscal Surplus (g_3)

Table 9: Objective Function Values

Strategy	CB	C1	C2	C3	sum
simulation	1570.67	397.80	1591.95	481.42	4041.84
pareto	598.62	212.97	249.74	229.26	1290.59
Nash_sc1	493.22	254.37	532.86	421.99	1702.43
Nash_sc2	494.79	254.51	546.57	450.23	1746.10
Nash_sc3	489.96	280.05	528.04	410.34	1708.39
Nash_sc4	501.89	312.77	538.24	447.75	1800.64

Simulation with weights 0.2/0.6/0.2

Next, we consider the case where the core is again smaller than the periphery, but the thrifty periphery country is three time as large as the thriftless one. This serves to investigate whether a stronger thrifty periphery government can counteract the trend towards unsustainable public debt caused by the policies of the thriftless government. The results are shown in Figures 13–15 and in Table 10.

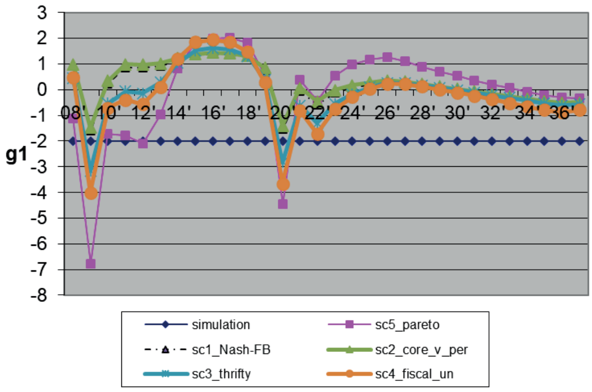

Figure 13: Control Variable Fiscal Surplus (g_1)

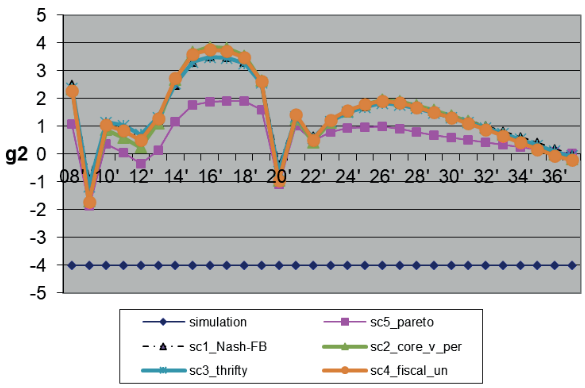

Figure 14: Control Variable Fiscal Surplus (g_2)

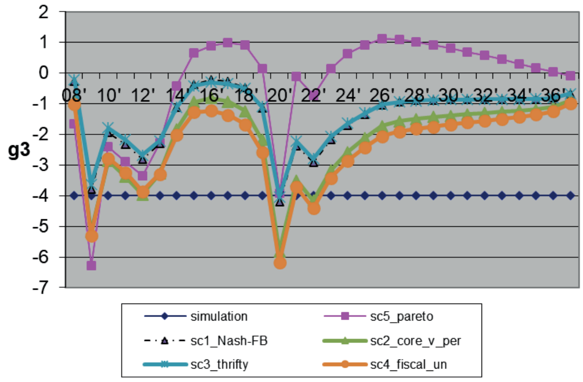

Figure 15: Control Variable Fiscal Surplus (g_3)

Table 10: Objective Function Values

Strategy	CB	C1	C2	C3	sum
simulation	1570.67	397.80	1591.95	481.42	4041.84
pareto	601.26	208.73	238.55	243.98	1292.53
Nash_sc1	494.74	247.41	515.03	409.32	1666.50
Nash_sc2	494.77	245.93	525.69	434.65	1701.05
Nash_sc3	490.54	272.08	511.70	398.46	1672.78
Nash_sc4	499.73	300.41	517.97	432.06	1750.18

Simulation with weights 0.2/0.2/0.6

Finally, we run simulations for the case where both the core and the thrifty government are small and the thriftless government is three times as large as each of the other two and is thus stronger than the thrifty governments combined. The consequences of such a constellation is of interest in view of populist tendencies in several EA countries (and elsewhere). In particular, it might be hypothesized that in such an environment the thriftless government may drive the thrifty ones into bankruptcy, too. The results are shown in Figures 16–18 and Table 11.

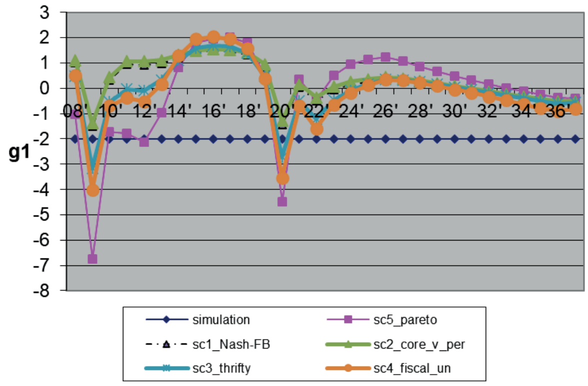

Figure 16: Control Variable Fiscal Surplus (g_1)

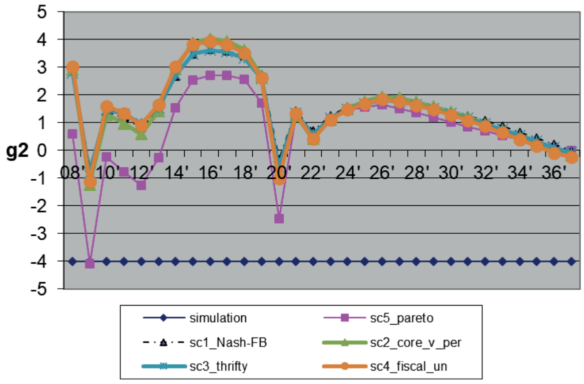

Figure 17: Control Variable Fiscal Surplus (g_2)

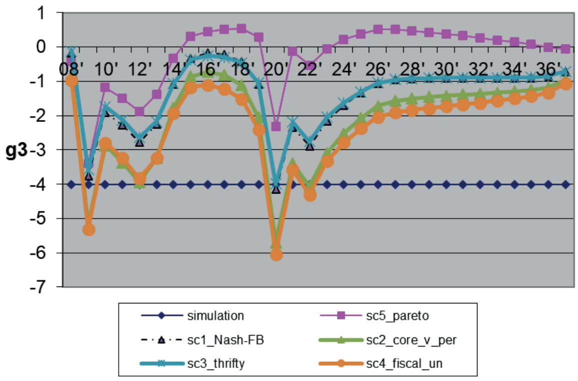

Figure 18: Control Variable Fiscal Surplus (g_3)

Table 11: Objective Function Values

Strategy	CB	C1	C2	C3	sum
simulation	1570.67	397.80	1591.95	481.42	4041.84
pareto	589.49	211.30	270.95	228.21	1299.95
Nash_sc1	491.81	261.70	551.41	435.30	1740.22
Nash_sc2	494.64	263.54	568.17	466.73	1793.08
Nash_sc3	489.33	288.39	544.99	422.81	1745.52
Nash_sc4	503.63	325.59	559.21	464.39	1852.82

The results of the three alternative simulations reveal a remarkable robustness of the strategies and the resulting development of the dynamic behavior of the state variables. The most striking feature is the ordering of the sum of the objective functions, which can be interpreted as the ordering of the different institutional arrangements modelled by the coalitions or their absence. The overall coalition of all governments with the central bank is always better than any other scenario, and the simulated scenario with fixed rules is always worst. This has to be expected due to the construction of the game. However, what is unexpected is the position of the fiscal union: Apart from the fixed-rules scenario, it always turns out to be worst. It is also interesting that the fully non-cooperative scenario always gives better results than those with partial coalitions (sc2 and sc3). The coalition scenario of the thrifty countries gives better results than the one with the coalition of the two periphery countries. The hypothesis of unsustainable public finances in countries other than the thriftless one in the weighting scheme with the strong thriftless country is not confirmed; relatively small (politically weak) thriftless governments can avoid going bankrupt even when there is a majority of thriftless governments.

CONCLUSIONS

We analyzed the dynamics in a monetary union that consists of three asymmetric fiscal players and a common central bank in the presence of exogenous shocks. The monetary union was calibrated for the euro area, starting at the pre-financial crisis level, and the shocks were modelled to imitate the negative effects of the Great Recession, the European sovereign debt crisis, the COVID-19 crisis, and the Ukraine war crisis. We calculated cooperative Pareto and non-cooperative feedback Nash equilibrium solutions for different coalition strategy scenarios. The fully cooperative (Pareto) solution gives the best results in terms of the objective function values and requires a more active monetary policy. The fiscal union coalition scenario without cooperation with the central bank gives the worst outcome of all scenarios examined. The completely non-cooperative scenario is even better than all partial coalitions. This confirms the general insight that the cooperation of policy makers may improve the outcome only if this cooperation is fully comprehensive, that is, only if taking all relevant players on board. A centralization of fiscal policies for stabilization purposes can therefore be recommended only if it is comprehensive and is also coordinated with monetary policy. These results are also confirmed by several sensitivity analyses.

The results are relevant for the institutional arrangements of the EU and the EA. Sometimes it is claimed that the introduction of a common finance minister or even a joint budget of the EA would improve the architecture of the EA due to better possibilities for coordination of national policies. Our results that this may be a double-edged sword: Only when the joint fiscal policies are coordinated with the monetary policies of the ECB, such measures would be beneficial. As for the details of the relative positions of the other scenarios considered, our results should be interpreted with caution for the EA. In order to relate them more closely to ongoing debates in the EA, the analysis would have to be augmented by a more elaborate macroeconomic model and a more sophisticated calibration of the model. A more detailed calibration of the EA, especially with a higher number of countries, would also be required and is an aim for future research.

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REFERENCES

Anastasiou, D., H. Louri, and M. Tsionas. 2019. "Nonperforming Loans in the Euro Area: Are Core–Periphery Banking Markets Fragmented*?" International Journal of Finance & Economics,* 24 (1), 97–112.

Basar, T. and G.J. Olsder. 1999. *Dynamic Noncooperative Game Theory*. 2nd ed. SIAM, Philadelphia, PA.

Basar, T. and G. Zaccour. 2018. *Handbook of Dynamic Game Theory*. Springer International Publishing, Cham.

Blueschke, D., V. Blueschke-Nikolaeva, and R. Neck. 2021. "Approximately Optimal Control of Nonlinear Dynamic Stochastic Problems with Learning: The OPTCON algorithm." *Algorithms,* 14 (6), 181.

Blueschke, D., V. Blueschke-Nikolaeva, and R. Neck. 2023. "Should Fiscal Policies be Centralized in a Monetary Union? A Dynamic Game Approach." *Central European Journal of Operations Research*, DOI: https://doi.org/10.1007/s10100-023-00846-4.

Blueschke, D. and R. Neck. 2011. ""Core" and "Periphery" in a Monetary Union: A Macroeconomic Policy Game." *International Advances in Economic Research,* 17, 334–346.

Blueschke, D. and R. Neck. 2018. "Game of Thrones: Accommodating Monetary Policies in a Monetary Union." *Games,* 9 (1), 9.

Blueschke, D., R. Neck, and D.A. Behrens. 2013. "OPTGAME3: A Dynamic Game Solver and an Economic Example". In *Advances in Dynamic Games. Theory, Applications, and Numerical Methods,* Krivan, V. and G. Zaccour (Eds.). Birkhäuser Verlag, Basel, 29–51.

del Rio-Chanona, R.M., P. Mealy, A. Pichler, F. Lafond, and J.D. Farmer. 2020. "Supply and Demand Shocks in the COVID-19 Pandemic: An Industry and Occupation Perspective." *Oxford Review of Economic Policy,* 36 (Supplement 1), S94–S137.

Kahle, K.M. and R.M. Stulz. 2013. "Access to Capital, Investment, and the Financial Crisis." *Journal of Financial Economics,* 110 (2), 280–299.

Krause, M.U. and S. Moyen. 2016. "Public Debt and Changing Inflation Targets." *American Economic Journal: Macroeconomics,* 8, 142–176.

Michalak, T., J. Engwerda, J. Plasmans, B. van Aarle, and G.D. Bartolomeo. 2008. "Models of Endogenous Coalition Formation between Fiscal and Monetary Authorities in the Presence of a Monetary Union." In *Quantitative Economic Policy*, R. Neck et al. (Eds.), Springer, Berlin, 103–136.

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