Strategic Interactions between Fiscal and Monetary Authorities in a Multi-Country New-Keynesian Model of a Monetary Union

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Abstract

In this paper we consider a number of key issues related to the policy coordination in a monetary union that has been recently discussed in the literature. To this end we propose a multi-country New-Keynesian model of a monetary union cast in the framework of linear quadratic differential games. Our framework can be used to simulate strategic interactions between an arbitrary number of fiscal authorities interacting in coalitions with or against the common central bank. For many parameter combinations our results confirm the findings of Beetsma et al. (2001) that for symmetric inflation and output gap shocks, fiscal coordination between all the countries is counter-productive within a monetary union. The clash between the central bank and the coalition of national governments is most intense under a symmetric inflation shocks when there is strong conflict concerning the orientation of stabilisation policies. This conflict is less pronounced under an asymmetric inflation and output gap shocks, however, still makes fiscal cooperation unattractive. We extend the existing New-Keynesian literature on policy coordination by considering not only cases of non-coordination, fiscal cooperation and the grand coalition, but also the partial cooperation arrangements between fiscal players. We show that, in many cases, partial fiscal coordination of a subgroup of fiscal players is more efficient, from the social point of view, than non-coordination. However, this regime still delivers poor results from the perspective of individual players. This occurs especially in the case of asymmetric shocks, as the countries directly affected by the shocks tend to "export" losses to the countries with whom they form a coalition. Furthermore, we show that the common objective of the grand coalition is of the upmost importance for the outcome of the stabilisation process.

JEL Code: C70, E17, E58, E61, E63.

Keywords: macroeconomic stabilisation, EMU, policy coordination, linear quadratic differential games.

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1 Introduction

The creation of the (multi-country) European Monetary Union (EMU), with a common central bank, yet independent national fiscal policies, urged the ongoing discussion about the need and the feasibility of macroeconomic policy coordination within a monetary union. Since the 'one-size-fits-all' policy of the European Central Bank (ECB) cannot address country-specific shocks, and the other stabilisation mechanisms in the euro-zone (such as labour force mobility and financial assets mobility) are limited, the general consensus is that the main burden of stabilisation should be born by fiscal policies. However, the abuse of fiscal policies can be detrimental to both financial and economic stability and may result in undesirable suboptimal outcomes. Consequently, budgetary positions in the EMU Member States are constrained (mainly by the provisions of the Stability and Growth Pact, SGP) and are monitored by the European Commission (EC). This situation gives rise to several important questions which are relevant, not only specifically to the EMU, but also to monetary unions in general:

1. Is there a need for the coordination of monetary and fiscal policies in macro-economic stabilisation?
2. Do different types of shocks call for different forms of cooperation?
3. Can cooperation in a monetary union be counter-productive and if so, under which conditions?
4. Will fiscal constraints like SGP hamper stabilisation?
5. How does SGP influence possible cooperation agreements between fiscal or fiscal and monetary authorities?

The literature on monetary unions is vast and some of the above issues have already been extensively discussed. This paper extends this literature by presenting and analysing a multi-country New-Keynesian (NK) model of a monetary union which is cast in the framework of open-loop linear quadratic differential games (LQDGs) including multi-player strategic elements. To the best of our knowledge, it is the first model in the New(-Keynesian) Open Economy Macroeconomics (NOEM) spirit to feature strategic elements between more than three players. Essentially, the starting point of the NK approach is the explicit derivation of macroeconomic relationships from underlying microeconomic foundations. This principle is largely shared with New Classical macroeconomics, although the former includes a great deal of imperfections in the goods and labor markets. Recently, NK macroeconomics has constituted the core of the macroeconomic paradigm world-wide, with a great deal of research effort directed towards the issue of optimal monetary policy. However, until now, relatively little attention has been paid to the interactions between fiscal and monetary policies when stabilising an economy after a shock; something that is especially important in the EMU context.[1] The strength of our NK model is its multi-player (monetary union countries and the central bank) strategic dimension, which allows us to address all the above research questions in one study. Throughout this paper, we show that non-trivial conclusions can be drawn from analysing fiscal cooperation between only a subgroup of countries in a monetary union. The remainder of this subsection summarises the main findings of our research.

Studies analysing the desirability of policy coordination in a monetary union provide mixed results. On the one hand, many authors support the classic result of the Optimal Currency Area (OCA) that policy coordination is desirable in case of symmetric shocks. For instance, Buti and Sapir (1998) argue that coordination of fiscal policies should be implemented to tackle large symmetric shocks. However, on the other hand, there are a number of studies that demonstrate that policy coordination can provide inferior levels of welfare. Notably, in a two-country model of a monetary union, Beetsma *et al.* (2001) find fiscal cooperation to be counter-productive as a result of the elevated conflict with the central bank. We discuss this issue in the framework of a dynamic multi-country NK model of a monetary union, in which multiple-fiscal authorities and the central bank enter into various coordination arrangements in order to play in coalitions against each other in the LQDG framework. Our approach adds new dimensions to that of Beetsma *et al.* (2001). First of all, the model has much richer NK specification. Secondly, in our approach, strategic interactions become dynamic. Furthermore, a multi-country model enables us to study various intermediate coordination regimes between fiscal players (partial fiscal cooperation). Finally, we consider cooperation between the central bank and multiple fiscal players (*i.e.* the grand coalition) in the same manner in which other recent but only two-country NK studies have done.[2]

[1] See the next section for a selection of papers that analyse this issue in the spirit of NOEMs.
[2] See next section for a short literature review on policy coordination in a monetary union.

Our findings support those of Beetsma *et al.* (2001), illustrating that, for symmetric inflation and output gap shocks, fiscal coordination between all the countries is counter-productive within a monetary union. Signs and magnitude of spillovers from policies of fiscal and monetary authorities are pivotal to our analysis. The first ones are positive, *i.e.* expansionary fiscal stance in a member state of a monetary union increases output gap in other countries. Conversely, the second ones are negative, *i.e.* a (real) interest rate has a negative impact on output gaps. Additionally, it is assumed that the use of both policies or deviation from the rules that both authorities previously agreed to abide by, is increasingly costly. In such a setting, positive fiscal spillovers create strong incentives for non-cooperating governments to free-ride on each others' stabilisation efforts. Usually free-riding is considered to be detrimental for economic efficiency. However, in both Beetsma *et al.* (2001) and our analysis, free-riding proves to be the key factor making certain regimes more profitable than others. More specifically, free-riding of fiscal players reduces their stabilisation effort which, in turn, diminishes the conflict with the central bank. Consequently, everybody is better off, especially in the case of an inflation shock where the potential for conflict is the greatest. In contrast, full fiscal coordination rules out free-riding and increases governments' activism. This brings about results in direct opposition to those expected by the governments, since the central bank replies to increased fiscal activism with much firmer monetary policy, meaning that everybody ends up worse off.

The clash between the central bank and the coalition of national governments is most intense under symmetric inflation shocks when there is strong conflict concerning the orientation of stabilisation policies. In this context, Beetsma *et al.* (2001) argue that cooperation between fiscal authorities in a monetary union might become profitable when the asymmetry of shocks increases. The rationale behind this argument is that, in such a situation, the central bank has fewer incentives to enter into a conflict with a coalition of governments because the average price increase is smaller. In connection to this, when the asymmetry is stronger, the average deviation of inflation will be more moderate and there will potentially be less discord between authorities.[3] The results of our model confirm, in many cases, the above position of Beetsma *et al.* (2001). However, it should be noted that, in this context, a strong distinction between inflation and the output gap shocks exists.

Under an asymmetric inflation shock there is a noticeable reduction in the control effort of all the players caused by the restrained reaction of the central bank. However, it is still not enough to make fiscal cooperation profitable. In other words, an asymmetry of a price shock, indeed, makes the conflict between all cooperating governments and the central bank less pronounced, yet does not make such a regime beneficial w.r.t. non-cooperation.

In contrast, the conflict between authorities is generally much less pronounced under both symmetric and asymmetric output gap shocks. This means that the relative difference between symmetric and asymmetric shocks is much smaller than in the case of an inflation shock. This is caused by the fact that, under an output gap shock, there is no conflict between policy-makers regarding the general orientation of stabilisation policies. Instead, both authorities focus on suppressing output gap, albeit that, for the central bank, this is mainly due to the intention of suppressing inflation. In spite of having the same policy orientation, there remains conflict regarding the exact policy stance in the first few periods after the shock. The disagreement concerns the initial periods in the aftermath of a shock, which turn out to be crucial in determining the future shape of output gap and inflation dynamics. Consequently, all the players are much more active in the non-cooperative regime under an output gap shock, than in the same regime under an inflation shock. Put more simply, since there is much more to gain, players engage more in stabilisation policies. As a result of this, the free-riding effect that is so exposed under a symmetric inflation shock is not visible under a symmetric output gap shock. Under an asymmetric output gap shock, fiscal cooperation becomes profitable for the country affected by the shock w.r.t. non-cooperative regimes.

We extend the existing NK literature on policy coordination in a monetary union by considering not only cases of non-coordination, fiscal cooperation and the grand coalition, but also partial cooperation arrangements between fiscal players. We show that, in many cases, partial fiscal coordination of a subgroup of fiscal players is more efficient, from the social point of view, than non-coordination. In other words, coordination of fiscal policies is likely to be counter-productive when the coordinating group of countries is large enough, thus increasing the conflict with the central bank. However, when countries cooperate in smaller groups, their policies are not completely symmetric, therefore there is less likely to be conflict with the central bank, since this only targets union averages.

[3] Note that in the extreme case of an asymmetric shock, i.e. when two countries in a (symmetric) monetary union are hit by a completely anti-symmetric shock (one shock is exactly opposite to the other), both output gap and inflation deviations will also be in direct oposition. Consequently, the central bank will not react when the average inflation and output gap remain the same. An example of such an analysis can be found in Plasmans *et al.* (2006).

As far as the social welfare is concerned, the grand coalition usually outperforms all the other arrangements. In this context, it is interesting to study whether such a regime is feasible. From the individual countries' perspective, the grand coalition seems barely possible because, in many cases, national governments incur higher losses when playing together with the central bank than when playing non-cooperatively. An effective solution to this problem would be a fiscal federation similar to the US or at least an effective transfer system. Unfortunately, due to various political reasons, it is doubtful that either of these will be possible in the near future. Similarly, although, from the social point of view, partial fiscal cooperation regimes are, in general, superior to full fiscal cooperation or non-cooperation, they usually deliver poor results from the perspective of individual players. This occurs especially in the case of asymmetric shocks, as the countries directly affected by the shocks tend to "export" losses to the countries with whom they form a coalition. Furthermore, we show that the common objective of the grand coalition is of utmost importance for the outcome of the stabilisation process. If the distribution of bargaining power in the grand coalition does not coincide with socially optimal preferences, this regime may turn out to be counter-productive w.r.t. a fiscal coalition, thus an effective institutional design of cooperation between the governments and the central bank, ought to take into account the fact that the central bank is outnumbered in any monetary union.

With our model, we perform extensive parameter sensitivity checks in several directions, *i.e.*, among others, w.r.t.: (i) structural parameters, (ii) policy rule parameters; (iii) preference parameters towards output gap and inflation (which is related to policy delegation analysis) and (iv) preference parameters towards fiscal debt (which is related to the analysis of SGP stringency).

The remainder of the paper is organised as follows. The next section gives a brief overview of the literature on cyclical stabilisation in a monetary union and related issues. Section 3 outlines the model of a monetary union whereas Section 4, following Beetsma *et al.* (2001), introduces an alternative concept of a social loss. Section 5 presents results of numerical simulations and discussion. The last section concludes and proposes directions of future research. An appendix containing sensitivity analysis, the derivation of the reduced form of the model and the initial condition is available on-line at www.ua.ac.be/tomasz.michalak.[4]

2 Policy coordination in a monetary union

The inability of the common monetary policy to tackle country-specific shocks is generally considered to be the single and most important macroeconomic cost of monetary unification. As Beetsma *et al.* (2001) point out, the size of this cost depends on other mechanisms which may be helpful in adjusting to idiosyncratic shocks.[5] Unfortunately, factor markets (especially the labour market) are relatively immobile in Europe and capital flows are limited (Buti, 2001a). Consequently, these two basic mobility mechanisms, which play an important role in the US economy, are rather dysfunctional in the EMU case.[6] This means that, the stabilisation burden in the case of country specific shocks should be placed on other policies. One such policy is the federal tax-transfer system; another mechanism that is vital to the US state-specific adjustments (see von Hagen, 1999 and Melitz and Zumer, 1998). Also, in the EU framework, tax-transfers already take place, however, in spite of public perception, the amounts of funds transferred are limited and are related to the long-term economic development, rather than to short and medium term conditions. A deeper tax-system integration, which may be able to address idiosyncratic shocks, seems to be politically implausible in the EMU, at least in the near future.[7] In the light of this, the national fiscal policy is considered to be the most important instrument left to policymakers.[8] In theory, this policy might be able to circumvent the problem of country specific shocks in the euro-zone. However, whether the incurred cost of stabilisation *via* national fiscal policies in a (relatively) integrated economic environment like the EMU is lower than the benefits,

[4] http://www.ua.ac.be/download.aspx?c=tomasz.michalak&n=42902&ct=43348&e=169681

[5] It should also be noted that from the macroeconomic perspective the real cost of accessing a monetary union is reflected by the shadow cost of the abandonment of an own monetary policy so that it cannot be used as an adjustment tool in the case of an idiosyncratic shock. In other words, the cost of entering the union depends, to a large extent, on the effectiveness of the national central bank to tackle idiosyncratic shocks. It is especially important in the environment of closely integrated economies, like the EU, and in the case of small countries, such as Belgium.

[6] See, for instance, Pierdzioch (2004) who presents a dynamic general equilibrium two-country optimizing sticky-price model to analyze the consequences of international financial market integration for the propagation of asymmetric productivity shocks in the EMU.

[7] The issue of fiscal transfers within the EMU has been studied by a number of authors such as van Aarle *et al.* (2004), Kletzer and von Hagen (2000) or Evers (2006). The latter considers direct transfers among private sectors and indirect transfers among national fiscal authorities showing relative efficiency of such solutions.

[8] Already Kenen (1969) emphasized the possible role which fiscal policies might play in a monetary union as potential chock-adjustment mechanisms.

remains to be answered, especially since spillovers from national fiscal policies may be counteractive w.r.t. each other and lead to suboptimal outcomes. Another closely related problem is the response of a common monetary authority which will react to national fiscal policies. Such a reaction can be counteractive as the objectives of fiscal and monetary policies tend to be dissimilar. All of these issues warrant a discussion on the profitability and feasibility of policy coordination in a monetary union.

Aside from certain institutional issues, such as the effectiveness of enforcing the cooperation agreement, profitability of any coordination arrangement depends on the nature of the shock, *i.e.* whether it is symmetric or asymmetric, inflation or output gap, *etc.* In the case of symmetric shocks, policy coordination was traditionally considered to be beneficial because it internalised externalities emerging from individual policies (as recently argued by Uhlig, 2003 and Plasmans *et al.,* 2006a). In particular, the usual argument in favour of international policy coordination is based on direct positive demand spillovers. In contrast to this, more recent micro-founded models of the EMU tend to conclude in favour of negative fiscal spillovers by emphasising the adverse terms-of-trade effects of balanced-budget foreign fiscal expansion on the domestic economy. For example, should governments perceive negative spillovers from other countries, they would reconsider a non-cooperative ("beggar-thy-neighbour") policy in response to bad economic shocks and would agree on a more restrictive stance in all countries.[9] Conversely, should governments perceive positive spillovers, coordination should eliminate free-riding behaviour of individual countries and promote a more expansionary policy in response to some economic shocks. Evidently, incentives for fiscal policy coordination in a monetary union are directly linked to the sizes and signs of the spillovers resulting from national fiscal policies. Fiscal spillovers are crucial, since they ultimately determine whether coordination should lead to a more expansionary or a more restrictive fiscal stance in the member states.

Other arguments in favour of coordination are that (see *e.g.* Hughes Hallett and Ma, 1986): (i) it restores policy effectiveness; (ii) speeds up an economy's response to policy actions; and (iii) enables to exploit comparative policy advantages.

In contrast to the above traditional arguments, more recent works question the profitability of policy coordination. The seminal paper of Beetsma *et al.* (2001) shows that policy coordination in a monetary union can be counter-productive in the case of a symmetric shock, which as Buti (2001a) notes, '*turns conventional wisdom on its head*'.[10] Their model emphasises the conflict between governments and the central bank which share the stabilisation burden.[11] According to their argument, the coordination of budgetary stance between countries in the union makes fiscal policy more effective, thus governments are more willing to accept changes in their deficits. In other words, cooperation increases the use of fiscal policies. This, in turn, has important consequences on the behaviour of the CB, which, generally has objectives different from those of fiscal policymakers. More specifically, in the case of a negative demand shock, both fiscal and monetary authorities are interested in stabilising output, which, from the central bank's point of view, is a means of stabilising inflation. Since cooperating fiscal authorities are eager to bear more stabilisation burden, the (non-cooperating) central bank free-rides on their efforts and does not loosen monetary policy as much as when governments do not collude. In contrast, supply shocks make output and inflation move in opposite directions. The stronger fiscal response encouraged by cooperation exacerbates the conflict between price and output stability and, therefore, between monetary and fiscal authorities. As a result of this, the central bank is more restrictive when governments cooperate, compared to when governments participate in the non-cooperative regime. In other words, for both types of shocks, fiscal coordination may turn out to be counter-productive, albeit for different reasons. Following the same rationale, Beetsma *et al.* (2001) argue that fiscal cooperation may be beneficial in the case of a country-specific shock. The free-riding of (or the conflict with) the central bank can largely be avoided as the monetary authority is interested in aggregate inflation (and possibly, to some extent, an aggregate output). In this respect, the reaction of the monetary authority to idiosyncratic shock is limited.

Lombardo and Sutherland (2004) confirm some findings of Beetsma *et al.* (2001) by showing, in a

[9] One country attempts to improve its output-inflation trade-off by running a "beggar-thy-neighbour" policy. This is followed by the reaction of another country(-ies) and the resulting non-cooperative outcome is a deflationary bias with all countries worse off with regard to a cooperative situation in which each country takes care of domestic inflation without attempting to affect the exchange rate (Cooper, 1985).

[10] It should be noted that prior to Beetsma *et al.* (2001), it has been observed in empirical studies (see e.g. Neck *et al.,* 1999) that coordination does not necessarily lead to superior results as a result of either time-inconsistency and/or coalition formation of the fiscal policymakers against the monetary authority (see also next footnote). Furthemore, Beetsma and Bovenberg (1998) show that fiscal coordination may a negative influence on a tax and public spending discipline, *i.e.* they may reduce the positive effects of monetary unification.

[11] Rogoff (1985) already stated that there is a potential for a negative impact of coordination among a subset of actors (in this case the two fiscal authorities, leaving out the common centra bank).

micro-founded model, that fiscal coordination is advantageous when country-specific shocks are negatively correlated. This study also suggests that the best results are delivered by an appropriate mix of both fiscal and monetary instruments.

Other works defend the view of desirability of policy coordination. Von Hagen and Mundschenk (2003) argue that, in the long run, there is little need for coordination, however, in the short term, there are substantial gains from fiscal cooperation. Furthermore, if the central bank also pursues a goal of output stabilisation, the grand coalition of all the authorities together is advisable. Buti *et al.* (2001b), Engwerda *et al.* (2002), Beetsma and Jensen (2004) and Kirsanova *et al.* (2007) also support the active role of fiscal policy in stabilisation.

Cavallari and Di Gioacchino (2004), in the framework of a two-country static model, show that coordination of fiscal policies can only reduce output and inflation volatility w.r.t. the non-cooperative regime in the case of a demand shock, and that it can be potentially counter-productive otherwise. This adverse effect of union-wide coordinated fiscal measures can be circumvented by "global coordination", *i.e.* grand coalition. In more complex micro-founded general equilibrium models, Galí and Monacelli (2005b) and Beetsma and Jensen (2004, 2005) also consider the case for fiscal and monetary policies' coordination. Specifically, Beetsma and Jensen (2005) extend the framework developed by Benigno (2001) and develop an NK two-country monetary union model whereby national fiscal authorities pursue active stabilisation policies using public spending. Their model reveals that the relative advantage of using fiscal stabilisation policy is unchanged when the correlation of the supply shocks decreases. However, from a welfare point of view, the use of fiscal policy for the purpose of stabilisation appears to be of relevance. Beetsma and Jensen (2005) argue that the governments should be active in situations in which a restriction on fiscal policy in order to equalise this policy with its natural level leads to welfare losses being equivalent to a permanent reduction in consumption of the order from 0.5 to 1 percentage point. A similar view is shared by Galí and Monacelli (2005b) who argue in favour of active fiscal policies.

In addition to cooperative scenarios, Forlati (2007) focuses on a non-cooperative regime showing that, in such a situation, the central bank does not stabilise the average monetary union inflation as it has to accommodate the distortions caused by non-cooperative national governments. At the same time, the non-existence of an agreement between countries calls for an active fiscal stance, even in case of symmetric shocks.

In addition, there are a number of more empirically oriented studies concerning issues related to policy coordination in a monetary union. Westaway (2003) shows that discretionary policy can be much more beneficial than Taylor type fiscal rules. Weyerstrass *et al.* (2006) present an extensive empirical study of policy coordination in the EMU in the context of fiscal spillovers and they strongly advocate the case for fiscal cooperation. Semmler and Zhang (2004) focus on fiscal policies and show that the non-Ricardian fiscal policy has been pursued in France and Germany in the first years of the EMU. Moreover, they find that fiscal and monetary policies in France and Germany have been counteractive and do not accommodate to each other (in the years *prior* to 1999). Using VAR analysis, Giuliodori and Beetsma (2005) explore the trade spillover effects caused by fiscal policies in Europe and conclude that monetary unification in Europe had caused a "slight strenghtening on average of the cross-country spillovers from a fiscal expansion". This indicates that policy coordination might be increasingly beneficial in the euro-zone.

Most of the initial works (like the static model of Beetsma *et al.*, 2001) were tractable enough to deliver analytical solutions. However, the much more complex dynamic general equilibrium modelling with a higher number of cooperation arrangements require resorting to numerical methods. These were used in Beetsma and Jensen (2004, 2005), van Aarle *et al.* (2002a, 2002b) and Plasmans *et al.* (2006a), among others, and will also be applied in this paper.

3 A multi-country NKOEM model of a monetary union

During recent years the theoretical and empirical research in NK macroeconomics has been extended steadily and produced a whole new series of results and insights about the workings of the macroeconomy. Essentially, the starting point of the NK approach is the explicit derivation of macroeconomic relationships from underlying microeconomic foundations. This principle is shared with New Classical macroeconomics, although the former includes a great deal of imperfections in the goods and labour markets. The NK approach now constitutes the core of the macroeconomic paradigm world-wide.

Our modelling objective is to cast the New-Keynesian model of a monetary union in the LQDG framework in order to analyse strategic interactions between a comparatively large number of players. By definition, LQDGs concern continuous-time models but, unfortunately, the vast majority of NK/NOEM models were constructed in the discrete-time framework. Notable exceptions are Buiter (2004), Linnemann (2002), Benhabib *et al.* (2001), Kirsanova *et al.* (2006). However, with the exception of the last one, all these are single economy models, thus would obviously require extensions to allow them to be applied to a monetary union setting.[12] In line with this, our strategy will be to transform a discrete-time NK model of a monetary union into its continuous-time counterpart. This methodology is also convenient from the point of view of model parametrisation as most of the empirical studies useful for calibration purposes, concern discrete-time models. The second important modelling issue is the computational complexity of a LQDG, which grows with the number of dynamic equations of the model and/or the number of players. Having this in mind, we aim to describe every country in a monetary union in a manner as concise as possible. In fact, as explained in Svensson (1997) and Ball (1999), short-term macrodynamics can be analysed using a relatively simple system consisting of an AD curve showing the evolution of the output gap driven by the real interest rate (see *e.g.* Woodford, 2003), and a Phillips curve describing the dynamics of inflation. Despite its relative simplicity, such models have been widely used to understand the basic mechanisms of macroeconomic policies. Consequently, our multi-country monetary union model will consist of as many AD equations as countries, as many Phillips curves as countries, and a number of real exchange rate relationships.

Due to space constraints, we will refrain from deriving the NK model of a monetary union from micro-foundations. Instead, we will refer to results from various studies in the literature. Let fiscal and monetary players from a set N be divided in two groups: n countries i ($i \in F$) and one central bank b ($b = B$, with $N = F \cup B$). Following, among others, Lindé *et al.* (2004), aggregate demand (AD) equations are:[13]

$$\begin{aligned} y_{i,t} = {} & \kappa_{i,y} E_t y_{i,t+1} + (1-\kappa_{i,y})\, y_{i,t-1} - \gamma_i \left(i_{U,t} - E\pi_{i,t+1}\right) + \eta_i f_{i,t} \\ & + \sum_{j \in F/i} \rho_{ij} \left[-\kappa_{i,y} E_t y_{j,t+1} + y_{j,t} - (1-\kappa_{i,y})\, y_{j,t-1}\right] \\ & + \sum_{j \in F/i} \delta_{ij} \left[-\kappa_{i,y} E_t s_{ij,t+1} + s_{ij,t} - (1-\kappa_{i,y})\, s_{ij,t-1}\right] + v^y_{i,t}, \end{aligned} \tag{1}$$

where E_t is an expectation operator at time t; $y_{i,t}$, $p_{j,t}$, $\pi_{i,t}$, $f_{i,t}$, $s_{ij,t} := p_{j,t} - p_{i,t}$ denote output gap, price level, inflation, fiscal policy in country i and real exchange rate (competitiveness) between countries i and j, respectively, whereas $i_{U,t}$ denotes union-wide common nominal interest rate. All parameters are non-negative. The current output gap in country i depends positively on the expected output gap, the past output gap, real interest rate, government's fiscal deficit, dynamics of other countries' output gaps and competitiveness, defined as a difference of respective price levels. Finally, $v^y_{i,t}$ is an independent, exogenous, stationary, zero mean AR(1) shock with damping parameter $0 < \psi_{i,y} < 1$, *i.e.* $v^y_{i,t} = \psi_{i,y} v^y_{i,t-1} + \epsilon^y_{i,t}$, where $\epsilon^y_{i,t}$ is an independently and identically distributed (*i.i.d.*) error term. This functional form of the AD equation may be obtained from a linearised model of optimisation behavior on the part of consumers, in particular, from the resulting Euler equation, in which consumption is replaced with output gap, as shown, for instance, in Lindé *et al.* (2004). Interia term $(1-\kappa_{i,y})\, y_{i,t-1}$ reflects so-called "habit formation" in consumption (see for example Smets and Wouters, 2002 or Plasmans *et al.,* 2006b), which measures the sluggishness of households in changing their choices over time. Foreign output gap and competitiveness elements in (1) reflect the economic linkages between countries. In particular, the first one is a trade channel, where, intuitively, higher foreign output gaps contribute to higher domestic output gaps as a result of increased import. Similarly, domestic export increases when a foreign price level becomes higher than the domestic one. The forward-looking and backward-looking dynamics of foreign output gap and competitiveness spillovers result from habit formation in consumption and have a similar form as the dynamics of domestic output gaps in the AD equations.[14] From the strategic point of view, the AD equation delivers an intuitive argument in favour of monetary and fiscal policy coordination. Basically, both authorities actually target the same variable (i.e. output gap) in (1), thus coordination seems to be a natural choice. As Lambertini and Rovelli (2003) rightly note:

[12] There are two countries in the model developed by Kirsanova et al. (2006) but this particular framework becomes computationally difficult when we add another, third country.

[13] By F/i we denote the set of all countries except for country i.

[14] In this respect, we refer to Lindé *et al.* (2004) who develop a small open economy model which features habit formation resulting in the reported dynamics of international economic linkages in the AD curve (see eq. 2.24 in Lindé *et al.* 2004), imperfect financial integration, and gradual exchange rate pass-through. As imperfect financial integration and gradual exchange rate pass-through are irrelevant in the model of a (closed) monetary union with a common interest rate, we will put them aside. Consequently, the Lindé *et al.* (2004) model can be boiled down to five main equations: (i) aggregate demand/IS curve, (ii) an aggregate supply curve, (iii) monetary, and (iv) fiscal policy rules; and (v) competitiveness relationships.

”*This is of immediate concern for both policymakers, no matter whether they consider aggregate demand (or the output gap) as an argument in their objective function (as will be generally the case for fiscal authorities) or only as an intermediate variable in the policy-transmission mechanism (as would be the exclusive concern of inflation nutter-type central banker)*”.

The second set of equations in our model are New-Keynesian Phillips curves, which relate inflation to cyclical activity. In the New-Keynesian model, these are derived from optimising firms' price-setting decisions subject to constraints on the frequency of price adjustment. We assume Phillips curves of the form:

$$\pi_{i,t} = \beta_i \left[\kappa_{i,\pi} E_t \pi_{i,t+1} + (1-\kappa_{i,\pi})\,\pi_{i,t-1}\right] + \xi_i \left(y_{i,t} + \sum_{j \in F/i} \varsigma_{ij} s_{j,t} \right) + v^{\pi}_{i,t}, \tag{2}$$

where we follow various studies in the literature allowing for some degree of price inertia for $0 < \kappa_{i,\pi} < 1$.[15] In case $\kappa_{i,\pi} = 1$ equation (2) becomes the pure forward-looking NK Phillips Curve employed, for instance, in Clarida *et al.* (1999) or Chapter 3 of Woodford (2003). In contrast, when $\kappa_{i,\pi} = 0$ the pure backward-looking aggregate supply equation emerges (the, so called, ”accelerationists” Phillips-Curve) which is studied, for instance, in Kirsanova *et al.* (2005).[16] The exact form of our Phillips curve with foreign price spillover was derived by Lindé *et al.* (2004, see eq. 2.47). Inflation shock $v^{\pi}_{i,t}$ in (2) is an independent, exogenous, stationary, zero mean AR(1) shock defined analogically to $v^{y}_{i,t}$ with dumping parameter $\psi_{i,\pi}$ and error term ϵ^{π}_{i}. In the context of our model, these shocks should be interpreted as cost-push shocks (for instance, oil shocks in the 1970s), whereas the shocks in output equations (1), $v^{y}_{i,t}$, should be interpreted as demand shocks, for instance, changes in consumer preferences, *etc.*[17].

For n countries there are as many as $n\,(n-1)$ competitiveness relationships s_{ij}, however, as shown in the on-line Appendix, it is possible to rewrite all of them only in terms of $s_{1j,t} := p_{j,t} - p_{1,t}$ where $j \in F/1$:

$$s_{1j,t+1} = s_{1j,t} + \pi_{j,t+1} - \pi_{1,t+1}, \tag{3}$$

which are only $n-1$ dynamic equations.

In his seminal work, Taylor (1995) demonstrated that actual US monetary policy could be described by a simple rule that relates the real interest rate to inflation and to output gap. This relationship became known as the (monetary) Taylor rule. In the monetary union case, the Taylor rule of the central bank might be written in the form:

$$i_{U,t} = \theta^{U}_{\pi} \pi_{U,t} + \theta^{U}_{y} y_{U,t}, \tag{4}$$

where $\pi_{U,t} := \sum_{i=1}^{n} \omega_i \pi_{i,t}$ is the average union inflation and $y_{U,t} := \sum_{i=1}^{n} \omega_i y_{i,t}$ is the average union output gap with parameter ω_i indicating the relative weight of country i in a monetary union ($\sum\limits_{i=1}^{n} \omega_i = 1$).[18] The first term in the Taylor rule shows that the central bank responds to the rise in average inflation with a more restrictive monetary policy in order to weaken demand across the union. This, in turn, should hinder the growth in inflation. The second term shows that the real interest rate is also raised if output rises as this indicates a future inflation acceleration.

Taylor (2000) also points out that fiscal policy can be approximated by a policy rule (for further discussion see van Aarle *et al.*, 2004). The fiscal Taylor rule can be written as:

$$f_{i,t} = \theta^{i}_{\pi} \pi_{i,t} + \theta^{i}_{y} y_{t}. \tag{5}$$

In this paper we extend the above definition of both rules so that:

[15] See, among others Fuhrer and Moore (1995), Section 4 model of Gali and Getler (1999), Chapter 3, Section 3.2 model of Woodford (2003), Lindé *et al.* (2004, where two backward-looking lags are allowed), Evans and McGough (2005), or Plasmans *et al.* (2006b).

[16] More on this type of the Phillips Curve can be found in Friedman (1968) and Mortensen (1970). For a recent discussion of different types of a Phillips curve see Ólafsson (2006).

[17] The shock $v^{y}_{i,t}$ should not to be interpreted as a (positive) technological shock as it leads to increased and not decreased inflation.

[18] For a similar formulation of the monetary policy rule in a model of a monetary union see van Aarle *et al.* (2004).

$$\tilde{\imath}_{U,t} = i_{U,t} + \hat{\imath}_{U,t} = \theta_\pi^U \pi_{U,t} + \theta_y^U y_{U,t} + \hat{\imath}_{U,t}, \text{ and} \tag{6}$$

$$\tilde{f}_{i,t} = f_{i,t} + \hat{f}_{i,t} = \theta_\pi^i \pi_{i,t} + \theta_y^i y_t + \hat{f}_{i,t}, \tag{7}$$

where $\hat{f}_{i,t}$ and $\hat{\imath}_{U,t}$ are control variables of the players in the LQDG and denote deviations of the fiscal deficit and nominal common interest rate from (4) and (5), respectively. In particular, as Taylor (2000) argues, a simple fiscal rule can be used to explain most fluctuations in fiscal deficits. The starting point of his analysis is the division of the fiscal deficit into a cyclical component and a structural component. The first part can be interpreted as the systematic response of fiscal policy to output fluctuations (the so-called automatic stabilisers); the second part contains structural and discretionary components of fiscal policy. In our case, the standard Taylor fiscal rule $\theta_\pi^i \pi_{i,t} + \theta_y^i y_t$ is to be interpreted as an automatic stabiliser, whereas $\hat{f}_{i,t}$ is a discretionary component. For the monetary Taylor rule $\hat{\imath}_{U,t}$ is the discretional component of the central bank's policy.

The interpretation of the above policy rules in our setting is closely related to the assumptions of the LQDG. In particular, we assume the so-called *open-loop information structure*, which means that (i) every player knows at time $t \in [0, \infty)$ just the initial state, and the model structure; and (ii) the set of admissible control actions are functions of time, where time runs from zero to infinity. This scenario can be interpreted as the players simultaneously determining their actions and submiting them to some authority who then enforces these plans as binding commitments.[19] Thus, this follows the same procedure of the policies under commitment as assumed in, for instance, Beetsma and Jensen (2005) in the case of optimal commitment policy. In reality, optimal commitment policies are difficult to enforce and maintain as players usually have incentives to unilaterally deviate from initially agreed strategies. Instead, it is argued that, although policy rules also require commitment, it is easier to control whether they are followed, especially when their structure is simple and deviations can easily be detected.[20] Our setting contains features of both approaches as we consider commitment to optimal deviations from the pre-set policy rules. This might be interpreted as a situation where both fiscal and monetary authorities announce to the public that they follow certain policy rules. However, facing the shock they agree to deviate from pre-announced rules and stick to this commitment throughout the stabilisation process. The cost of the deviations from the rule is, thus, the loss of public/financial markets' confidence. The further this deviation goes, the more noticeable and risky it becomes, therefore the quadratic form of the loss function is especially appealing in this case. There is still an unanswered question related to the commitment, as according to the open-loop information structure, the participating parties are not able to react to each other's policies once the stabilisation period has started. Such reactions are plausible due to usual free-riding incentives of individual players. Thus, alternatively, it could be assumed that the planned deviations from the rules are made public. On the one hand, fiscal and monetary authorities are "punished" by deviating from the policy rules as embodied in the quadratic loss function. On the other hand, the public supervision guarantees, to some extent, that commitments are obeyed, thus facilitating the open-loop information structure. Naturally, the *closed-loop* assumption, where players may discretionally change their policies during the stabilisation process, would be more preferable. However, at present, there are no algorithms available to solve a multi-player case of the closed-loop LQDG.[21] Thus, more analytically and computationally tractable open-loop LQDGs are an interesting benchmark to ascertain how much parties can gain by playing various (albeit pre-committed) strategies.

In order to reduce the number of equations, it is convenient to substitute $i_{U,t}$ and $f_{i,t}$ in (1) with (4) and (5). The resulting system consists of n AD curves (1), n Philips curves (2), and $n-1$ competitiveness equations, which, together with shock AR processes, constitute a hybrid (forward- and backward-looking) Stochastic NK Model (SNKM henceforth) of a closed monetary union. All the necessary steps to cast this model into the LQDG framework are described in the on-line Appendix (Subsection A5.1).

In order to complete the construction of the LQDG, we propose the following fiscal players' objectives:

$$\min_{\hat{f}_i(t)} J_i(t_0) = \min_{\hat{f}(t)} \frac{1}{2} \int_{t_0}^{\infty} \{\alpha_i \pi_i^2(t) + \beta_i y_i^2(t) + \chi_i \hat{f}_i^2(t)\} e^{-\theta(t-t_0)} dt, \tag{8}$$

[19] For more details on the LQDG see Engwerda (2005).

[20] As Beetsma and Jensen (2005, footnote 4) note, Svensson (2003) strongly disagrees with this view, arguing that "*optimizing behaviour implying targeting rules (essentially the first-order conditions resulting from optimization) is more transparent.*"

[21] An analysis about the interaction of monetary and fiscal policies with a feedback information structure may be found in van Aarle *et al.* (2001), however, only for a model with 2 players.

for $i = 1, 2, \ldots, n$, where α_i, β_i, χ_i indicate fiscal players' relative preferences concerning deviations of national inflation rates, output gap and fiscal deficit.[22] The common central bank's objective function is defined in a similar way as:

$$\min_{\hat{i}} \; J_{CB}(t_0) = \min_{\hat{i}} \; \frac{1}{2} \int_{t_0}^{\infty} \{\alpha_{CB}\pi_U^2(t) + \beta_{CB}y_U^2(t) + \chi_{CB}\hat{i}^2(t)\} e^{-\theta(t-t_0)} dt, \tag{9}$$

where α_U and β_U indicate the central bank's relative preferences concerning deviations of inflation, output gap and interest rate in the MU as a whole.

Finally, a notion of cooperation should be more formally defined in our LQDG framework. Lambertini and Rovelli (2003, p.1) list the following forms of coordination between macroeconomic policymakers: (1) exchange of information; (2) mutual acknowledgment of the existence and probable behaviour of the other policy makers; (3) joint-policy making (full cooperation, *i.e.* collusion); and (4) agreement on a sequence of moves between the two authorities. In our framework, a cooperation between any group of players encompasses all the above elements and means that all players involved in a coalition minimise the joint loss, which is defined as the weighted sum of individual losses. A disjoint and exhaustive division of all the players in the game into coalitions will be called a *coalition structure* (and abbreviated Π).

Apart from the open-loop information structure discussed above, there are two additional crucial assumptions related to the LQDG considered in this paper:[23]

1. We consider an *infinite planning horizon*; however, the future is discounted with a non-zero parameter θ every period. We assume that the matrix pairs $(\tilde{A} - \frac{1}{2}\theta I, \tilde{B}_i)$, where $\tilde{B}_i$ is a submatrix of $\tilde{B}$ concerning control instruments of player i, are stabilizable. This formalises the assumption that, in principle, each player is able to stabilise the system on his own, taking into account his discounting perception; and

2. It might happen that our LQDG has *more than one open-loop Nash equilibrium.* Unfortunately, neither control theory nor economic theory gives a clear-cut answer as to which equilibrium would be chosen in such a case. Obviously, *Pareto*-dominated equilibria can be disregarded; however, there is no other similar objective criterion, which could be justified in the environment of self-oriented players. In such a situation, we assume that the equilibrium is chosen following the (standard) social optimum criterion, *i.e.* the equilibrium characterised by the lowest sum of losses is searched for.[24]

4 Social loss

Usually, it is assumed that the entire union's loss is represented by the total sum of monetary and fiscal authorities' losses:

$$J_U(t_0, \Pi) := \sum_{j \in F} J_i(t_0) + J_{CB}(t_0), \tag{10}$$

where $J_i(t_0)$ and $J_{CB}(t_0)$ are defined by loss functions (8) and (9), respectively, and Π is a cooperation regime in which the combined loss is computed. Whereas the above definition seems to be plausible for a two-country model, it is not appealing in more complex settings. Since, in a general formulation of our model, there are n countries in the union and only one central bank, the relative importance of monetary instrument in $J_U(t_0, \Pi)$ gets smaller with increasing n. It is rather difficult to see the rationale behind it as the relative cost related to the interest rate volatility should be irrelevant of the size of the union.[25] To circumvent the above concerns, we follow the approach of Beetsma *et al.* (2001) and propose our own MU loss function of the form:

[22] Since the seminal works of Kydland and Prescott (1977) and Barro and Gordon (1983), the quadratic loss functions are commonly used in the literature on strategic behaviour of fiscal and monetary authorities. See also Schellekens and Chadha (1999) for a more recent analysis supporting the quadratic form of the loss function.

[23] For more details see Engwerda (2005).

[24] The social optimum can be defined in various ways. For isntance, in the next section we propose a new definition of a social optimum for a monetary union case. For the other example see Beetsma *et al.* (2001).

[25] Formula (10) applied to the 50-State US and to the 13-Member State EMU would show that (*ceteris paribus*) the relative importance of interest rate volatility for the American economy is much lower than for the Euro-zone.

CS	Long notation	Acronym	Description
Π_1	$[C1\|C2\|C3\|CB]$ or [1|2|3|4]	N	non-cooperative regime
Π_2	$[C1, C2, C3, CB]$ or [1234]	C	the grand coalition
Π_3	$[C1, C2, C3\|CB]$ or [123|4]	F	full fiscal cooperation
Π_4	$[C1, C2\|C3\|CB]$ or [12|3|4]	P (*or* 4)	partial fiscal cooperation
Π_5	$[C1, C3\|C2\|CB]$ or [13|2|4]	P (*or* 5)	partial fiscal cooperation
Π_6	$[C1\|C2C3\|CB]$ or [1|23|4]	P (*or* 6)	partial fiscal cooperation

Table 1: List of considered coalition structures

$$J_U^*(t_0, \Pi) := \frac{1}{2}\int_{t_0}^{\infty} \sum_{i=1}^{n} \omega_i \left(\alpha_U \hat{\pi}_i^2(t) + \beta_U \hat{y}_i^2(t) + \chi_{f,U} \widehat{\hat{f}}_i^2(t)\right) + \chi_{r,U} \widehat{i_U}^2(t) e^{-\theta(t-t_0)} dt, \tag{11}$$

where α_U, β_U, $\chi_{f,U}$ and $\chi_{r,U}$ are preference parameters of the society concerning deviations of inflation, output gap and both types of control instruments. Averages of variables' squares instead of squares of variables' averages guarantee that negative deviations of inflations and output gaps do not cancel out with positive ones. Furthermore, taking into account the average value of fiscal control instruments across an MU guarantees that volatility of interest rate is well represented in the loss (as it corresponds to its actual relative importance in a single economy).

Whether $J_U^*(t_0, \Pi)$ is smaller, equal or greater than $J_U(t_0, \Pi)$ depends largely on the preference parameters in loss functions (8-9) and (11). In a basic case when all these preferences coincide, *i.e.* $\alpha_i = \alpha_{CB} = \alpha_U$, $\beta_i = \beta_{CB} = \beta_U$ and $\chi_i = \chi_{CB} = \chi_{f,U} = \chi_{r,U}$, it is trivial to show that the (more) conventional social loss $J_U(t_0, \Pi)$ will always be higher than $J_U^*(t_0, \Pi)$ irrelevant of $\hat{\pi}_i$, $\hat{y}_i$, $\widehat{\hat{f}}_i$ and $\widehat{i_U}$ adjustment paths. Otherwise, the result of this comparison is case dependent. In particular, it may vary with the type of the shock considered. The formula in (11) is similar to the one proposed by Beetsma *et al.* (2001); however, we extended the definition of cross monetary union loss with the deviation of the interest rate, as this is an important factor influencing the welfare of the representative citizen in each country.

Such coalition structures for which $J_U^*(t_0, \Pi)$ is the lowest will be called social optima and will be denoted by Π^{*SOP}. Similarly, those regimes that are characterised by the conventional lowest loss $J_U(t_0, \Pi)$ will be denoted by Π^{SOP}. It is straightforward to show that, in the LQDG framework considered in this paper, a coalition composed of all the players in the game (*i.e.* the grand coalition) always belongs to a set of social optima Π^{SOP} (for more details on this issue see Plasmans *et al.* 2006a, Chapter 2). However, as the definition of $J_U^*(t_0, \Pi)$ is not necessarily based on the same players' preferences as those used in the optimisation process, the grand coalition does not necessarily belong to Π^{*SOP}. This will be evident from various numerical simulations presented in the subsequent section.

5 Numerical simulations

For clarity and space concerns we will focus our simulations on the three-country application of the model from Section 3. This number is sufficient to consider partial cooperation between fiscal authorities but still small enough to be computationally tractable. Furthermore, throughout this article we assume that cooperation between the central bank and only a subgroup of countries is not allowed, which yields 6 feasible coalition structures listed in Table 1. $C1$, $C2$ and $C3$ and CB denote governments within the union and the central bank, respectively.

5.1 Parametrisation

Table 2 lists all the parameters of the benchmark model. In the baseline scenario (denoted sc_1), countries are assumed to be symmetric with respect to all 7 structural parameters.

The parameters listed in Table 2 are comparable to other simulation studies, in particular, van Aarle *et al.* (2004), Batini and Haldane (1999) and Leith and Wren-Lewis (2001). When calibrating the IS equation with both backward- and forward-looking behaviour for the UK, they assumed $\kappa_{i,y}$ equal to 0.8 and 0.9,

Structural parameters:				
$\kappa_{i,\pi/y} = 2/3$	$\gamma_i = 0.5$	$\eta_i = 0.75$	$\rho_{ij} = 0.5$	$\delta_{ij} = 0.25$
$\beta = 0.99$	$\zeta_i = 0.06$	$\varsigma_{ij} = 0.5$		
Policy rules parameters:				
$\theta_y^i = -0.5$	$\theta_\pi^i = 0$	$\theta_y^U = 0.5$	$\theta_\pi^U = 1.5$	
Preference parameters:				
$\alpha_i = 0.02$	$\beta_i = \alpha_i/5$	$\chi_i = 0.1$	$\alpha_U = 0.02$	$\beta_U = 0.02$
$\alpha_{CB,i} = \beta_{CB,i}/5$	$\beta_{CB,i} = 0.02$	$\chi_{CB,i} = 0.1$	$\chi_{f,U} = \chi_{r,U} = 0.1$	

Table 2: Baseline parameters ($i, j \in \{1, 2, 3\}, i \neq j$)

respectively, which are plausible values for quarterly data. For an average EMU economy we set this value to be 2/3 in the benchmark model, however, we will pay special attention to this parameter in our sensitivity analysis. McCallum (2001), for the US case, suggests that for the interest rate elasticity of output in the IS curve (γ_i in our model), a value of 0.4 is more appropriate than Rotemberg and Woodford's (1999) value of 0.6 or McCallum and Nelson's (1999) value of 0.2. However, Cecchetti *et al.* (2002) estimates its average value to be 0.7 in the EU. In our case it is assumed that $\gamma_i = 0.5$ which is the value in between the above studies and, for example, corresponds to the parametrisation of Batini and Haldane (1999). In the sensitivity analysis both lower and higher values of this parameter will be considered.

The fiscal multiplier (η_i) measures the impact of changes in fiscal deficit on output gap and is estimated by the European Commission (2001, 2002) in the framework of the Commission's QUEST model and the OECD's Interlink model. The first simulations suggest an average value of 0.6 (± 0.1) in the EU countries while second ones yield values of 0.6 in France, 0.9 in Italy, 1.0 in Germany and the UK, and 1.3 in the US. The difference is to be attributed to the forward-looking nature of the first model. Having these values in mind, we assume η_i to be equal to 0.75. Parameters ρ_{ij} measure the elasticity of domestic import w.r.t. foreign output gap and is estimated to equal on average to 0.4 for the EU countries (Equipe MIMOSA, 1996) and *ca.* 0.35 for Sweden by Lindé *et al.* (2004). We follow van Aarle *et al.* (2004) and assume the value of 0.5, which implies relative high trade integration of the economies in a monetary union. This regards also the competitiveness parameter δ_{ij} that is set to 0.25.

There is no consensus in the literature regarding inflation persistence in the Phillips-curve. It is generally recognised that backward-looking element plays an important role in this equation, but various empirical studies deliver different estimates of $\kappa_{i,\pi}$. Whereas Gali and Gertler (1999) and Benigno and Lopez-Salido (2002) find a predominantly forward-looking specification of the Phillips curve ($\kappa_{i,\pi}$ around 0.7 for Germany, 0.64 for France, 0.4 for Italy, etc.), Mehra (2004) finds a predominantly backward-looking specification ($\kappa_{i,\pi}$ around 0.1). Furthermore, Mankiw (2001) argues that stylised empirical facts are inconsistent with the predominantly forward-looking Phillips Curve. In the benchmark we assume the same value of $\kappa_{i,\pi}$ as $\kappa_{i,y}$ *i.e.* 0.66 but we will consider different specifications later. The elasticity of inflation w.r.t. the output gap is an important parameter of the Philips Curve as it ultimately determines short-run adjustment between inflation and output gap. McCallum and Nelson (1999) and Galí and Monacelli (2005a) assume this value to be 0.3, Batini and Haldane (1999), 0.2, Leith and Wren-Lewis (2001) for the UK and Rotemberg and Woodford (1999) for the US set this value to be 0.1, where as Beetsma and Jensen (2005) choose the value of 0.04. Furthermore, Lindé *et al.* (2004) estimates it to be at most 0.0158 for the Swedish economy. Again, we choose the value in between the above values setting $\zeta_i = 0.06$, however, it will be one of the main parameters on which we are going to focus our sensitivity check. Gagnon and Ihrig (2002) estimate the import price pass-through parameter ($\zeta_i \times \varsigma_{ij}$ in our model) to be between 0.05 and 0.23 for most OECD countries. On the other hand, Lindé *et al.* (2004) estimates this value for a Swedish economy to be smaller than 0.003. We calibrate this value to be 0.03, *i.e.* $\varsigma_{ij} = 0.5$.

Structural model parameters are assumed to be symmetric, however, policymakers' preferences are not. The central bank's preferences differ from those of the (identical) national governments. As it is common in the literature (see, for instance, Beetsma and Bovenberg, 1998, Dixit and Lambertini, 2001, Uhlig, 2003 or Engwerda *et al.,* 2002), we assume that the central bank puts a larger weight on inflation stabilisation than on output-gap stabilisation. In contrast, fiscal players are more concerned with output-gap stabilisation than with inflation stabilisation. Moreover, as laid down in the Maastricht Treaty, the central bank's objectives concern aggregate output and inflation in the MU while the fiscal players are only concerned about own output and inflation. Parameter β_U is often regarded as a (counter proportional) measure of the central bank independence and it is argued, that a fully independent central bank should be concerned only about inflation, *i.e.* $\beta_{CB} = 0$.[26] In the benchmark we do not take such a restrictive position and we assume that the central bank is 5 times more concerned about inflation than about an output gap, however, β_{CB} is still positive. Fiscal authorities, in turn, are 5 times more concerned about output gap than about inflation. Thus, calibrated preferences appear to be the most appropriate in our model as they guarantee that no variable is overrepresented in the total loss of any player.[27] For the social loss function $J_U^*(t_0)$, it is assumed that society should be concerned about the output gap as much as the government is, whereas it should be concerned about inflation as much as the central bank is. Hence, $\alpha_U = \alpha_{CB} = 5\alpha_i$ and $\beta_U = \beta_i = 5\beta_{CB}$. The preference parameters of control instruments are set the same as in loss functions (8-9), *i.e.* $\chi_i = \chi_{CB} = \chi_{f,U} = \chi_{r,U}$.

As far as both policy rules are concerned, for the monetary rule, we assume the parametrisation originally proposed by Taylor (1993a, 1993b) for the US, *i.e.*: $\theta_\pi^U = 1.5$ and $\theta_y^U = 0.5$. For the fiscal policy rule, we assume that $\theta_y^i = -0.5$, which is the value found for the sensitivity of the fiscal deficit in relation to the cyclical variation by the European Commission (2001) for the Euro-area. It is used, for instance, in the simulations of Aarle *et al.* (2004). Furthermore, $\theta_\pi^i = 0$. The value of a discount factor $\theta = 0.01$ in the loss functions (8-9) is coherent with the assumed structural discount parameter $\beta = 0.99$, which implies a 1% (steady-state) real rate of return on a quarterly basis. Finally, in the benchmark, we assume symmetric bargaining power in every coalition, *i.e.* $\tau_{C1/C2/C3} = \tau_{CB} = \frac{1}{4}$ in the grand coalition, $\tau_{C1/C2/C3} = \frac{1}{3}$ in the fiscal coalition under F, and $\tau_{C1} = \tau_{C2} = \frac{1}{2}$, $\tau_{C1} = \tau_{C3} = \frac{1}{2}$, and $\tau_{C2} = \tau_{C3} = \frac{1}{2}$ in regimes 4, 5, and 6, respectively.

Numerical simulations are performed using numerical toolbox to solve the N-player affine LQ open-loop differential games presented in Engwerda *et al.* (2008).

5.2 Inflation shocks

The first four rows of Table 3 contain the (optimal) welfare losses in the various coalitional arrangements for the symmetric benchmark scenario and the common inflation shock, $v_{0S}^\pi := \left[v_{1,0}^\pi,\ v_{2,0}^\pi,\ v_{3,0}^\pi\right]^T = [1,1,1]^T$.[28] The next two rows show social losses J_U and J_U^* whereas, in the rest of the table, a decomposition of players' losses into constituting elements is presented.[29] Reporting inflation, output gap and instrument shares in the the total loss aims to provide additional intuition for our results.

As mentioned before, the grand coalition C is always a standard social optimum Π^{SOP} in the LQDG framework. In this particular case this regime constitutes also social optimum as in Π^{*SOP}. For every coalition structure, $J_U^*(t_0)$ is approximately two times smaller than $J_U(t_0)$ which is caused by the following two reasons: (i) $J_U^*(t_0)$ contains only averages of inflation, output gap and fiscal debt deviations whereas $J_U(t_0)$ is composed of nominal values; (ii) $J_U(t_0)$ includes additionally the loss of the central bank from output and inflation. For some combinations of preference parameters it could be theoretically possible to obtain $J_U^*(t_0) > J_U(t_0)$ but this condition would hold only in an extreme case.

In general, the structural symmetry of the model, the symmetry of fiscal players' preferences and the shocks make all the fiscal players' losses to be the same in the N, C and F regimes. Naturally, this symmetry is broken up under partial fiscal cooperation. The decomposition of losses shows that in nominal terms squared inflation deviation over time is about 5 times higher than squared output gap deviation over time. That is why inflation deviation contributes to the total fiscal loss as much as output gap deviation, even though fiscal players care 5 times less about inflation than about output gap. This observation validates our choice of benchmark weights in the loss functions.[30]

Regarding the form of the AD curve and the comment of Lambertini and Rovelli (2003), quoted in Subsection 2, that both types of authorities target the same variable, it is interesting to note that, in our dynamic setting, there is no straightforward relationship between changes in total volatility of output and changes in total volatility of inflation. Intuitively, we would expect that, since the volatility of inflation is directly linked with volatility of output gap *via* the Phillips Curve just as the volatility of output gap is

[26] This opinion was also expressed by Lars Svensson at the conference "Inflation Targeting, Central Bank Independence and Transparency", 15-16 June 2007, Trinity College, Camridge.

[27] This issue will be discussed further in this section.

[28] All (optimal) losses are multiplied by the factor 10^3.

[29] For instance, $C1$'s loss $\frac{1}{2}\int_{t_0}^{\infty}\{\alpha_i\hat{\pi}_i^2(t) + \beta_i\hat{y}_i^2(t) + \chi_i\hat{f}_i^2(t)\}e^{-\theta(t-t_0)}dt$ reported in the top of Table 3 is decomposed into $\frac{1}{2}\int_{t_0}^{\infty}\{\alpha_i\hat{\pi}_i^2(t)\}e^{-\theta(t-t_0)}dt$, $\frac{1}{2}\int_{t_0}^{\infty}\{\beta_i\hat{y}_i^2(t)\}e^{-\theta(t-t_0)}dt$ and $\frac{1}{2}\int_{t_0}^{\infty}\{\chi_i\hat{f}_i^2(t)\}e^{-\theta(t-t_0)}dt$ in the lower part of the table.

[30] More conventional preferences in which fiscal authorities care only two times as much about output gap as about inflation will be studied later on in this paper.

(sc_1, v_{0S}^{π})	N	C	F	[12|3|4]	[13|2|4]	[1|23|4]
$C1$	2.1948	2.1211	9.3016	2.5328	2.5328	1.7296
$C2$	2.1948	2.1211	9.3016	2.5328	1.7296	2.5328
$C3$	2.1948	2.1211	9.3016	1.7296	2.5328	2.5328
CB	6.2456	5.3308	21.843	5.6049	5.6049	5.6049
$J_U(t_0)$	12.830	11.694	49.748	12.400	12.400	12.400
$J_U^*(t_0)$	7.1445	6.3675	29.934	6.6853	6.6853	6.6853
$\alpha_{F,C1}\hat{\pi}_{C1}^2$	1.0782	0.8725	0.9979	0.9605	0.9605	0.9792
$\beta_{F,C1}\hat{y}_{C1}^2$	1.0880	1.0596	1.0612	1.3182	1.3182	0.7167
$\chi_{F,C1}\widehat{\hat{f}^2}_{C1}$	0.0285	0.1890	7.2424	0.2541	0.2541	0.0336
$\alpha_{F,C2}\hat{\pi}_{C2}^2$	1.0782	0.8725	0.9979	0.9605	0.9792	0.9605
$\beta_{F,C2}\hat{y}_{C2}^2$	1.0880	1.0596	1.0612	1.3182	0.7167	1.3182
$\chi_{F,C2}\widehat{\hat{f}^2}_{C2}$	0.0285	0.1890	7.2424	0.2541	0.0336	0.2541
$\alpha_{F,C3}\hat{\pi}_{C3}^2$	1.0782	0.8725	0.9979	0.9792	0.9605	0.9605
$\beta_{F,C3}\hat{y}_{C3}^2$	1.0880	1.0596	1.0612	0.7167	1.3182	1.3182
$\chi_{F,C3}\widehat{\hat{f}^2}_{C3}$	0.0285	0.1890	7.2424	0.0336	0.2541	0.2541
$\alpha_{CB}\hat{\pi}_{CB}^2$	5.3912	4.3627	4.9896	4.8337	4.8337	4.8337
$\beta_{CB}\hat{y}_{CB}^2$	0.2176	0.2119	0.2122	0.2181	0.2181	0.2181
$\chi_{CB}\widehat{\hat{i}_U^2}$	0.6367	0.7561	16.641	0.5530	0.5530	0.5530

Table 3: Optimal losses for symmetric inflation shock, baseline parametrisation

linked to the volatility of inflation in the AD curve, the relationship between changes in the total loss of both variables should be one-directional. In other words, diminished inflation volatility would be related to either diminished or increased output gap volatility only. However, in our relatively rich dynamic setting, diminished (total) inflation volatility can be associated both with decreased (total) volatility of output gap (*e.g.* $\beta_{F,C1}\hat{y}_{C1}^2$ and $\alpha_{F,C1}\hat{\pi}_{C1}^2$ in F vs. N) and with increased (total) volatility of output gap (*e.g.* $\beta_{F,C1}\hat{y}_{C1}^2$ and $\alpha_{F,C1}\hat{\pi}_{C1}^2$ in [12|3|4] vs. N). Thus, it is clear that complex patterns of economic conditions can emerge in our model, which emphasises the need for an accurate policy regime.

The dynamics of all relevant variables in regimes N, C and F is compared in Figure 1. Symmetric supply side (positive) inflation shocks cause output gap to decline which urges expansionary fiscal policies in all countries. In contrast, the central bank reacts to positive inflation by increasing interest rates. Thus, there is an obvious policy conflict between fiscal and monetary authorities. From decomposed losses in Table 3 we see that in the non-cooperative regime N there is a strong free-riding effect compared to the grand coalition regime C, which results from the positive fiscal spillovers characterising our setting.[31] When authorities do not cooperate, each of them tries to free-ride on the others' stabilisation efforts. The same phenomenon occurs in Beetsma *et al.* (2001) as their model also features positive fiscal spillovers. Consequently, all the authorities do not stabilise economy strongly enough and the output gap and inflation deviations under regime N are comparatively high. This results, for instance, in the following total loss for fiscal players from output gap and inflation deviations: 1.0880 and 1.0782, respectively. In contrast, under regime C, fiscal players: (i) do not try to free-ride on each other and (ii) take into account positive spillovers from other fiscal policies. Accordingly, they pursue a more active fiscal policy which is associated with the increased fiscal stabilisation cost from 0.0285 to 0.1890 and diminished losses from output gap and inflation deviations (1.0596 and 0.8725 respectively). The attitude of the central bank is crucial at this point. As under a symmetric inflation shock, there is clearly a policy conflict between fiscal and monetary authorities, increased fiscal activity should urge the central bank to more restrictive monetary policy than under the non-cooperative regime N. However, in the grand coalition all players, including the central bank, cooperate, and, secondly, the objective of every player is different than under non-cooperation as all of them aim to minimise the joint loss function which is a weighted sum of individual losses. Thus, in our benchmark, where all players have an equal weight in every coalition, the central bank's objective function (9) counts only for a quarter of the common loss function in

[31] The term "free-riding" refers here to taking advantage of others' stabilisation policies during the stabilisation game (*i.e.* from time t_0, when the shock occurs, onwards). However, this term will be also used in the context of individual players breaking-up coalitional arrangements (with the same objective to take advantage of others' cooperative stabilisation policies but themselves playing non-cooperatively and constraining own costly policies).

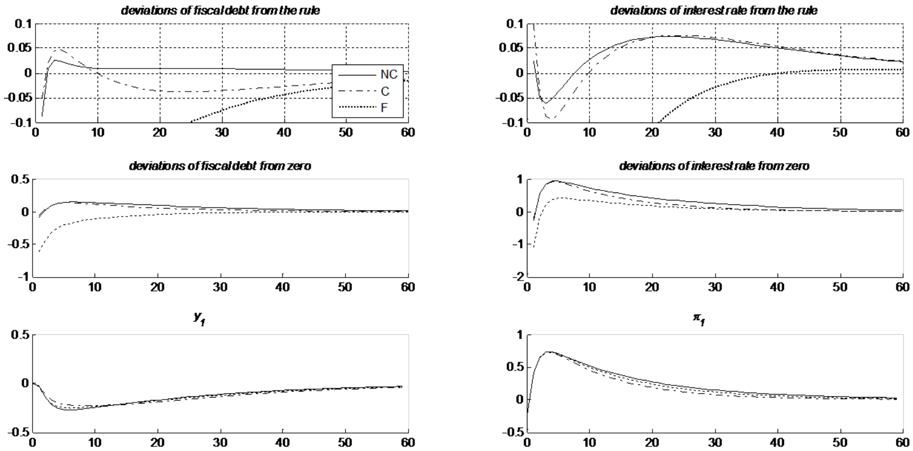

Figure 1: Benchmark model, v_{0S}^{π}, comparison of regimes N, C and F.

regime C. Consequently, this function is "biased" towards fiscal preferences. Interestingly, under regime C these are fiscal players which find it profitable to change their policies so that there is no conflict between authorities about the direction of the stabilisation policies. Deviations of fiscal debts and the interest rate from the rules is shown in the upper part of Figure 1. Under regime N both authorities deviate positively from the rules, which is counter-active as fiscal debt influences output gap in the opposite way to (nominal and real) interest rates. In contrast, when fiscal and monetary authorities cooperate, fiscal authorities deviate positively from the rule until period 10 and negatively since then. The sign of the central bank's deviations is exactly opposite; hence, both control instruments influence the output gap always in the same direction. In addition to the consent on policy direction, the lack of free-riding makes all the policies more active. All in all, cooperation makes the grand coalition the most attractive regime from the social point of view.

As far as now we have analysed our results mainly from the social perspective. However, even the regime which is the most desirable from the social point of view, can be very difficult to attain in the self-oriented environment. This is, for instance, the case for the grand coalition in Table 3. In a self-oriented myopic environment it could be very difficult to enforce this form of coordination, because every fiscal player has an incentive to unilaterally deviate from C.[32] For instance, $C1$ prefers [1|23|4] to C, thus, would break up the grand coalition, with hope that $C2$ and $C3$ maintain cooperation. In other words, there are strong free-riding incentives in the case of symmetric inflation shock to deviate from full cooperation. On the other hand, if the assumption of myopic behaviour is waived regime C is more likely to be stable, as it is clear that no partial fiscal cooperation is sustainable as any fiscal player involved in coalition would prefer to break it and play in the non-cooperative regime N.

The situation is completely different under regime F, where the central bank does not cooperate with the coalition of all fiscal authorities. As before, coordination of policies among governments eliminates the free-riding and alleviates the use of fiscal instruments. However, it is clear from the decomposed losses in Table 3 that it exacerbates the conflict with the central bank as the loss from control effort is much higher in this regime both for governments and for the central bank. The policies are counter-active (see the upper part of Figure 1) and the payoff for an increased control action is limited to only a little lower inflation and output gap deviations, which, by far, cannot make up for the increased loss. As a consequence, full fiscal coordination is worse than both cooperative and non-cooperative regimes. This latter result is exactly in line with the conclusions of Beetsma *et al.* (2001).[33] The difference between the results of both analyses is in the direction of the policies. In our model, when all fiscal players decide to cooperate, the central bank pursues more expansionary monetary policies than the assumed Taylor rule, whereas, the fiscal authorities pursue a more restrictive fiscal policy than the assumed fiscal rule. The direction of policies is, therefore, opposite to Beetsma *et al.* (2001), where supply shocks lead to more restrictive monetary policy *vs.* further reaching fiscal expansion.[34] However, in both studies a regime in which fiscal players cooperate against the central

[32]Deviations from a coalition are related to the coalition formation theory concept of internal stability (see Plasmans *et al.*, 2006a, for further details).

[33]Note that Beetsma *et al.* (2001) do not consider coordination in a grand coalition.

[34]It might be argued that the above high cost of stabilisation is caused by the specific choice of policy rules which is so far

τ^r	4/5	2/3	1/2	1/4	1/8	1/11
$C1/C2/C3$	5.2284	3.5100	2.6245	2.1211	1.9996	1.9349
CB	3.3077	3.9074	4.5186	5.3308	5.8425	6.3451
$J_U(t_0)$	18.9931	14.4376	12.3922	**11.6944**	11.8416	12.1499
$J_U^*(t_0)$	7.6804	6.4859	**6.1297**	6.3675	6.7652	7.2276
$\alpha_{F,C1}\hat{\pi}^2_{C1}$	0.5900	0.6982	0.7945	0.8725	0.8665	0.8426
$\beta_{F,C1}\hat{y}^2_{C1}$	1.3289	1.1666	1.0942	1.0596	1.0519	1.0490
$\chi_{F,C1}\widehat{\hat{f}^2}_{C1}$	3.3095	1.6451	0.7357	0.1890	0.0812	0.0432
$\alpha_{CB}\hat{\pi}^2_{CB}$	2.9500	3.4913	3.9728	4.3627	4.3329	4.2131
$\beta_{CB}\hat{y}^2_{CB}$	0.2657	0.2333	0.2188	0.2119	0.2103	0.2098
$\chi_{CB}\widehat{\hat{i}}^2_U$	0.0919	0.1827	0.3269	0.7561	1.2992	1.9222

Table 4: Optimal losses for symmetric inflation shock, different relative bargaining powers of the central bank

bank is counter-productive.

The ordering of social preferences over the regimes in Table 3 is $C \overset{J_U/J_U^*}{\succ} P \overset{J_U/J_U^*}{\succ} N \overset{J_U/J_U^*}{\succ} F$, *i.e.* cooperation in the grand coalition or in a partial fiscal coalition is better than playing alone. The analysis of P regimes follows similar lines as the discussion of the grand coalition case. Starting from the non-cooperation, the creation of partial fiscal coalition eliminates free-riding incentives between two governments involved in cooperation which increases their activity. For example, when [12|3|4] is created, $\chi_{F,C1}\widehat{\hat{f}^2}_{C1}$ and $\chi_{F,C1}\widehat{\hat{f}^2}_{C2}$ increase symmetrically from 0.0285 to 0.2541. This increase is higher than the increase for the grand coalition, thus, it cannot be justified only by the diminished free-riding incentives. At the same time $\chi_{F,C1}\widehat{\hat{f}^2}_{C3}$ also increases (from 0.0285 to 0.0336), instead of decreasing.[35] Both the above results are to be explained by the more constrained activity of the central bank, which is caused by the asymmetry of output gap and inflation in this regime that makes union-wide averages less volatile and, therefore, not affecting the loss of a monetary authority to such an extent as before. In other words, the central bank is able to free-ride even more than in regime N and this, in turn, increases the use of control instrument in both fiscal players involved in a coalition and playing non-cooperatively.

In the above discussion, we have touched upon a very important issue of relative bargaining power between fiscal authorities and the central bank in the grand coalition. As the weight of the central bank's loss in the sum of losses is only 25% under symmetric bargaining power, the common objective is biased towards preferences of fiscal policymakers in the benchmark. However, these preferences, are rather different than social loss which is at the very centre of our interests (see Table 2). Thus, it is interesting to look for alternative bargaining power schemes in regime C. Let $\tau^r := \frac{\tau_{CB}}{\tau_{C1}+\tau_{C2}+\tau_{C3}+\tau_{CB}}$ be the relative weight of the central bank with respect to the whole grand coalition. Table 4 presents decomposition of losses for different values of τ^r under regime C.[36] For $\tau^r = \frac{4}{5}$ the central bank is the most and for $\tau^r = \frac{1}{11}$ the least powerful whereas the intermediate regimes are in between. The more powerful the central bank in the grand coalition is, the more the common objective is biased towards inflation stabilisation. This is reflected by diminishing loss from the inflation deviation over time. At the same time, the output gap becomes less important; thus, its volatility increases for higher values of the central bank's bargaining power, and *vice versa*. Similar conclusions can be drawn for control instruments in Table 4. For high values of τ^r interest rate volatility is very expensive w.r.t. volatility of the fiscal debt, which urges governments to take over stabilisation efforts. For low values of τ^r the situation is reversed and the central bank bares most of the stabilisation burden. That is why the loss from fiscal debt volatility over time grows with the central bank's bargaining power and loss from the interest rate volatility over time diminishes, and *vice versa*.

away from optimum that players are forced to deviate much. In other words, it might be argued that θ_π^M should be closer to 1 and θ_π^i closer to 0. However, in other regimes, even in the fully non-cooperative regime, players are able to choose paths of stabilisation instruments close to assumed policy rules. This clearly overlures such an objection. Futhermore, the results reported in Table 3 were checked also for other parametrisations of policy rules such as: ($\theta_\pi^M = 1.5$; $\theta_\pi^i = 0$); ($\theta_\pi^M = 1$; $\theta_\pi^i = -0.5$); ($\theta_\pi^M = 1.25$; $\theta_\pi^i = 0$); or ($\theta_\pi^M = 1$; $\theta_\pi^i = 0$) and produce similar results (under all the above assumptions).

[35] The decrease in $C3$ control effort would be expected as the cooperation between $C1$ and $C2$, by increasing their activism, gives even more incentives to free-ride.

[36] Losses of countries $C2$ and $C3$ are not reported since they are symmetric to $C1$.

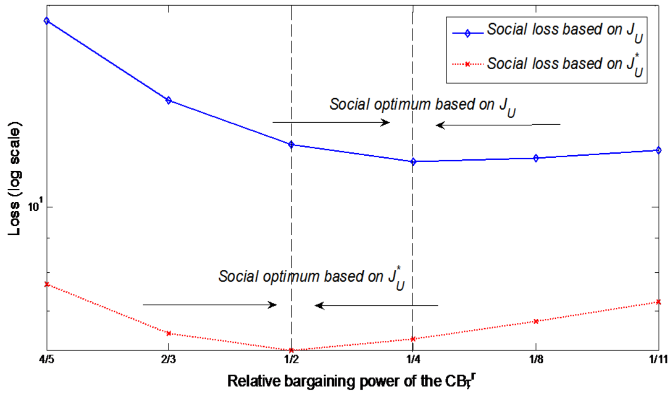

Figure 2: Social loss for different bargaining powers of the CB

Figure 2 draws social loss based on J_U and J_U^* from Table 4 against relative bargaining power of the central bank. It transpires that the lowest social loss based on J_U is obtained for the standard symmetric bargaining weights used in the benchmark simulations (*i.e.* $\tau^r = \frac{1}{4}$ as in Table 3). It is caused by the fact that, in this case, social loss J_U which is a simple sum of $J_{F,1}$, $J_{F,2}$, $J_{F,3}$ and J_{CB} directly corresponds to the common objective of the grand coalition which is $\frac{1}{4}(J_{F,1} + J_{F,2} + J_{F,3} + J_{CB})$ or $\frac{1}{4}J_U$. The optimal social loss based on J_U^* is not obtained for $\tau^r = \frac{1}{4}$ as it is based on different preferences than individual authorities' loss functions. Values of α_U, β_U, $\chi_{f,U}$ and $\chi_{r,U}$ assumed in the benchmark put the same weight to output gap as well as inflation stabilisation and make the interest rate deviations as costly as fiscal deficits ones. Clearly, it does not correspond to the common loss of the grand coalition (denoted J_C) for $\tau^r = \frac{1}{4}$ as 3 fiscal players pay much more attention to output gap than to inflation and all three fiscal debts combined are more important than interest rate. However, when $\tau^r = \frac{1}{2}$, the central bank becomes as important as all the fiscal players combined and the relative weight of inflation w.r.t. output gap in the common loss of the grand coalition becomes one. In other words, it corresponds now to α_U/β_U. Also the relative importance of control instruments corresponds to $\chi_{f,U}/\chi_{r,U}$. The only inconsistency between social loss based on J_U^* and J_C is the relative weight of control instruments to other variables. This is caused by the fact, that individual losses of monetary and fiscal authorities have non-zero preferences about both output gaps and inflation deviations, which produces different sum than J_U^*. However, this discrepancy between J_U^* and J_C in our case does not influence the outcome in our benchmark and the optimal J_U^* is found for $\tau^r = \frac{1}{2}$.[37]

The above analysis of different bargaining powers of the central bank underlines the importance of correct institutional design of cooperation between fiscal and monetary players. It should be kept in mind that the central bank is outnumbered in any monetary union (as it consists of at least 2 countries, by definition) as, for instance, in the multi-country EMU. Thus, the coordination arrangements should be structured in such a way that the individual losses of fiscal and monetary authorities are transformed to a common loss which is representative for a union (for example, the social loss based on J_U^* proposed in this paper). This would require higher bargaining weight of the central bank than the symmetric one, to alleviate the relative importance of inflation and interest rate deviations in the common loss.

Table 5 is constructed in the similar manner to Table 3 and presents (optimal) welfare losses for the asymmetric (country-specific) inflation shock, $v_{0S}^{\pi} := [v_{1,0}^{\pi}, v_{2,0}^{\pi}, v_{3,0}^{\pi}]^T = [1, 0, 0]^T$. Clearly, not all fiscal losses are now symmetric, as shock directly hits the first country only and other member-states of a monetary union have to deal with its indirect consequences. However, in general, it can be said that the pattern of losses in Table 5 is quite similar to 3: again the ordering of social preference over regimes is $C \overset{J_U/J_U^*}{\succ} P \overset{J_U/J_U^*}{\succ} N \overset{J_U/J_U^*}{\succ} F$; full fiscal cooperation is the worst regime for everybody; the grand coalition performs reasonably well but myopic fiscal players would have an incentive to break up this regime; partial fiscal coordination is not sustainable as players involved in cooperation would prefer the non-cooperative regime. Finally, it should be noted that cooperation of a country which is not affected directly by the shock with a country which

[37] Both properties were numerically checked for $\left(\tau^r \rightarrow \frac{1}{2}^{(-)} \text{ and } \tau^r \rightarrow \frac{1}{2}^{(+)}\right)$ and $\left(\tau^r \rightarrow \frac{1}{4}^{(-)} \text{ and } \tau^r \rightarrow \frac{1}{4}^{(+)}\right)$, respectively. For $\tau^r = \frac{1}{2}$ social loss based on J_U^* reaches local minimum, where as, when social loss is based on J_U its local minimum is reached for $\tau^r = \frac{1}{4}$.

(sc_1, v^{π}_{0S})	N	C	F	[12|3|4]	[13|2|4]	[1|23|4]
$C1$	0.3409	0.3245	1.0848	0.3921	0.3921	0.2807
$C2$	0.2369	0.2329	1.0495	0.3006	0.1763	0.2896
$C3$	0.2369	0.2329	1.0495	0.1763	0.3006	0.2896
CB	0.6939	0.5923	2.4270	0.6024	0.6024	0.6084
$J_U(t_0)$	1.5092	1.3827	5.6109	1.4715	1.4715	1.4684
$J^*_U(t_0)$	0.8483	0.7618	3.3804	0.7898	0.7898	0.7932
$\alpha_{F,C1}\widehat{\pi}^2_{C1}$	0.1659	0.1461	0.1584	0.1509	0.1509	0.1541
$\beta_{F,C1}\widehat{y}^2_{C1}$	0.1681	0.1679	0.1607	0.2183	0.2183	0.1100
$\chi_{F,C1}\widehat{\hat{f}^2}_{C1}$	0.0069	0.0104	0.7656	0.0228	0.0228	0.0165
$\alpha_{F,C2}\widehat{\pi}^2_{C2}$	0.1067	0.0823	0.0970	0.0896	0.0924	0.0899
$\beta_{F,C2}\widehat{y}^2_{C2}$	0.1266	0.1215	0.1253	0.1573	0.0760	0.1512
$\chi_{F,C2}\widehat{\hat{f}^2}_{C2}$	0.0035	0.0291	0.8270	0.0536	0.0078	0.0483
$\alpha_{F,C3}\widehat{\pi}^2_{C3}$	0.1067	0.0823	0.0970	0.0924	0.0896	0.0899
$\beta_{F,C3}\widehat{y}^2_{C3}$	0.1266	0.1215	0.1253	0.0760	0.1573	0.1512
$\chi_{F,C3}\widehat{\hat{f}^2}_{C3}$	0.0035	0.0291	0.8270	0.0078	0.0536	0.0483
$\alpha_{CB}\widehat{\pi}^2_{CB}$	0.5990	0.4847	0.5544	0.5220	0.5220	0.5230
$\beta_{CB}\widehat{y}^2_{CB}$	0.0241	0.0235	0.0235	0.0242	0.0242	0.0242
$\chi_{CB}\widehat{\hat{\imath}^2_U}$	0.0707	0.0840	1.8490	0.0561	0.0561	0.0612

Table 5: Optimal losses for asymmetric inflation shock, baseline parametrisation

is affected (regimes [12 |3| 4] or [13|2|4]) is very unprofitable for both of them but especially for the former one. Furthermore, also cooperation of both countries which are not affected directly by the shock (regime [1|23|4]) is also not profitable when compared to non-cooperation. Consequently, any form of partial fiscal cooperation when the correlation of shocks gets smaller seems to be unsustainable in the case of a symmetric inflation shock.

Losses in this case are smaller as for the symmetric inflation shock because there is a different reaction of the common monetary policy and national fiscal policies in countries not affected by the shock. This happens because the central bank targets average inflation which in the case of an asymmetric shock is clearly much smaller than in case of a symmetric one (see Figure 3). Also, the national fiscal policies of $C2$ and $C3$ react more moderately since these countries are only affected by cross border-spillovers and the restrained reaction of the common monetary policy.

The above findings, in general, correspond to the main arguments of Beetsma *et al.* (2001). Indeed, the clash between authorities is diminished under an asymmetric inflation shock because many effects cancel each other and policymakers have less incentives to excaberate the dispute. However, in our model, the extent of the conflict is still so substantial, that the excessive use of control instruments make the regime of fiscal cooperation, by far, unprofitable.

5.3 Output shocks

Table 6 contains the welfare losses for the symmetric benchmark scenario and the common output gap shock: $v^y_{0S} := [v^y_{1,0},\ v^y_{2,0},\ v^y_{3,0}]^T = [1, 1, 1]^T$.[38] This type of a shock causes union-wide increase in inflation, which is tackled by all authorities with restrictive stabilisation policies (fiscal deficits are negative whereas interest rate positive and above inflation). Since targeting excessive output gap is the only way to control inflation, there is, in principle, no conflict between the governments and the central bank about policy orientation. However, as we will show in our analysis there is still a conflict between both types of policymakers regarding the priorities of stabilisation. The authorities struggle over the dynamics of the output gap and inflation adjustment which is visible mainly in the initial periods in the aftermath of the shock, as they, to a large extent, determine the whole adjustment path and, consequently, players' losses. Such an effect could not be seen in the static model of Beetsma *et al.* (2001) which confirms that our dynamic analysis is an interesting extension of the literature.

[38] All (optimal) losses are multiplied by the factor 10^4.

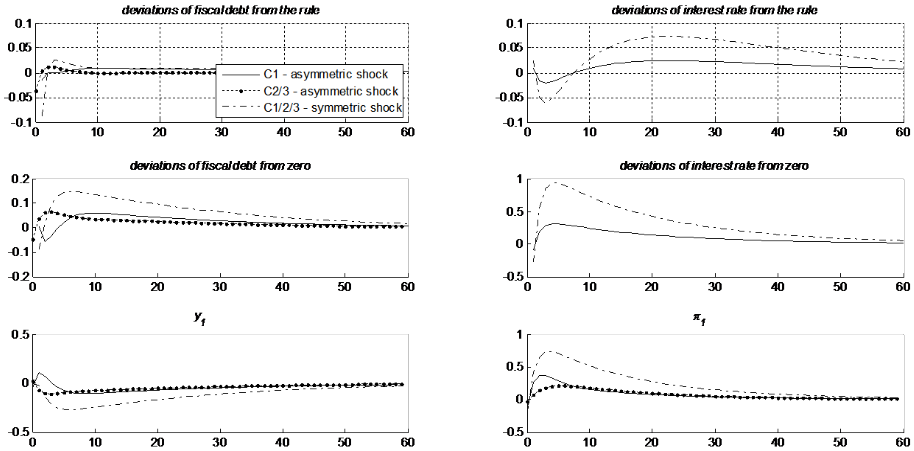

Figure 3: Benchmark model, v^{π}_{0S} vs. v^{π}_{0A}, regime N

The first observation from Table 6 is that in regime N players do not free-ride when compared to regime C. To gain more intuition behind it the dynamics of relevant variables are shown in Figure 4. In contrast to Figure 1, the deviation of control instruments from the rules is much smaller under C than under N. Clearly, the nature of the output gap shock is different then the nature of the inflation shock. Both control policies have, in general, the same direction, but, in our complex dynamic setting, there is an ongoing conflict between authorities concerning the detailed path along which output gap should be stabilised. To investigate deeper this issue we depicted in Figure 4 two situations. In the first one the central bank sticks to the Taylor rule whereas in the second one fiscal authorities stick to their rules. By comparing both scenarios we see what one type of the authority would do if the other one did not use its control instrument. It is obvious that the first few periods are crucial for the speed of the output gap and inflation convergence. Both fiscal and monetary authorities target an IS curve but governments are primarily interested in the lowest deviation of output gap, whereas, for the central bank, the output gap is mainly a tool used to suppress inflation. Thus, fiscal players' policy is designed in such a way that output gap reaches its peak relatively early and then, for a number of periods, converges to the equilibrium quicker than it would be preferred by the central bank. Only after a while, when the deviation of output gap gets much closer to zero, the situation changes. In other words, for a price of higher output gap instability in the latter periods fiscal players gain lower output gap instability in the aftermath of the shock. Clearly, taking a non-zero discounting factor in the governments' objectives into account, such a strategy is optimal for fiscal players. In contrast, the central bank, which, in general deviates from the rule upwards, *i.e.* conducts even more restrictive monetary policy than Taylor rule, at the moment when output gap surpasses its peak changes to less restrictive policy (negative deviation from the rule). Such a move makes output gap deviation to be more persistent initially and then more steeply converging to the equilibrium. In turn, steeper convergence of output gap leads to quicker convergence of inflation which the central bank is mostly interested in.

The above conflict about initial periods of output gap and inflation stabilisation is the reason for a players' behaviour visible in Figure 4. Whereas in the grand coalition case, stabilisation policies are perfectly complementary and operating in exactly the same direction, under N in the neighborhood of period $t = 10$ they have opposite signs and offset each other. This leads to excessive losses from control instruments under regime N w.r.t. C in Table 6 compared to Table 3.

Overall, it can be said that in the case of a symmetric output gap shock fiscal players try to free-ride on other fiscal players policies but, clearly, they are conflicted with the central bank which increases their losses compared to non-cooperation. The free-riding of fiscal players on each other under N is beneficial for the same reason as before. When they join up a full fiscal coalition (*i.e.* create regime F), they have no more incentives to free-ride and increase their activity which exacerbates the conflict with the central bank. However, this conflict is much less pronounced in Table 6 than in Table 3 (fiscal control effort for v^{π}_{0S} grows from 0.0285 to 7.2424 whereas for v^{y}_{0S} from 0.0246 to 0.0980).

The other difference between symmetric inflation and output gap shocks is that, in the case of the latter, being outside partial fiscal cooperation is not profitable any more. In other words, all the losses of fiscal players in the partial fiscal cooperation regime are higher than in the grand coalition as well as the non-

(sc_1, v_{0S}^y)	N	C	F	[12|3|4]	[13|2|4]	[1|23|4]	N^F	F^F
$C1$	0.3061	0.2852	0.3753	0.3092	0.3092	0.3094	0.2829	0.2827
$C2$	0.3061	0.2852	0.3753	0.3092	0.3094	0.3092	0.2829	0.2827
$C3$	0.3061	0.2852	0.3753	0.3094	0.3092	0.3092	0.2829	0.2827
CB	0.4977	0.5196	0.7901	0.4896	0.4896	0.4896	0.6000	0.6083
$J_U(t_0)$	1.4162	1.3755	1.9161	1.4174	1.4174	1.4174	1.4490	1.4564
$J_U^*(t_0)$	0.6805	0.6776	1.0319	0.6764	0.6764	0.6764	0.7364	0.7428
$\alpha_{F,C1}\hat{\pi}_{C1}^2$	0.0838	0.0898	0.0976	0.0827	0.0827	0.0826	0.1133	0.1150
$\beta_{F,C1}\hat{y}_{C1}^2$	0.1975	0.1871	0.1796	0.1992	0.1992	0.1985	0.1679	0.1665
$\chi_{F,C1}\widehat{\hat{f}^2}_{C1}$	0.0247	0.0082	0.0980	0.0272	0.0272	0.0281	0.0017	0.0011
$\alpha_{F,C2}\hat{\pi}_{C2}^2$	0.0838	0.0898	0.0976	0.0827	0.0826	0.0827	0.1133	0.1150
$\beta_{F,C2}\hat{y}_{C2}^2$	0.1975	0.1871	0.1796	0.1992	0.1985	0.1992	0.1679	0.1665
$\chi_{F,C2}\widehat{\hat{f}^2}_{C2}$	0.0247	0.0082	0.0980	0.0272	0.0281	0.0272	0.0017	0.0011
$\alpha_{F,C3}\hat{\pi}_{C3}^2$	0.0838	0.0898	0.0976	0.0826	0.0827	0.0827	0.1133	0.1150
$\beta_{F,C3}\hat{y}_{C3}^2$	0.1975	0.1871	0.1796	0.1985	0.1992	0.1992	0.1679	0.1665
$\chi_{F,C3}\widehat{\hat{f}^2}_{C3}$	0.0247	0.0082	0.0980	0.0281	0.0272	0.0272	0.0017	0.0011
$\alpha_{CB}\hat{\pi}_{CB}^2$	0.4193	0.4493	0.4880	0.4135	0.4135	0.4135	0.5665	0.5750
$\beta_{CB}\hat{y}_{CB}^2$	0.0395	0.0374	0.0359	0.0398	0.0398	0.0398	0.0335	0.0333
$\chi_{CB}\widehat{\hat{i}_U^2}$	0.0388	0.0328	0.2661	0.0362	0.0362	0.0362	0	0

Table 6: Optimal losses for symmetric output gap shock, baseline parametrisation

cooperative regime. Thus, in the case of output shock, fiscal players do not have free-riding incentives to deviate from regime C. In contrast, now the central bank would opt out as C is the second worst solution out of all for the monetary authority. Under a myopic behavioural assumption (Nash conjecture), such a deviation would not be exercised as the central bank, considering only immediate consequences of its decision, would not like to end up in F. However, if this assumption is waived, it is clear that fiscal players would break up F to end up in much more preferred N. Consequently, conversely to the inflation shocks case, the grand coalition under symmetric output shock is not sustainable when myopic assumption about players behaviour is waived and it is the central bank, and not the fiscal authorities, which has an incentive to deviate from this cooperation arrangement.

As far as the social loss is concerned, the preference ordering over regimes changes substantially in the case of symmetric output shock. In spite of the fact that partial fiscal cooperation is inferior for fiscal players w.r.t. non-cooperation or the grand coalition, the social loss in these regimes is the lowest. The grand coalition is still preferred over N and N over F, thus the full preference ordering is as follows: $P \overset{J_U/J_U^*}{\succ} C \overset{J_U/J_U^*}{\succ} N \overset{J_U/J_U^*}{\succ} F$. However, it should be noted that differences in social losses between all the regimes are substantially smaller than in the case of inflation shocks. In particular, under v_{0S}^{π}, ratios $\frac{J_U^*(C)}{J_U^*(N)}$ and $\frac{J_U^*(P)}{J_U^*(N)}$ equal to 89.12% and 93.57%, respectively. This means that there are 10.88% and 6.03% welfare gains from coordination in grand/partial fiscal coalitions. In contrast, under v_{0S}^{y}, ratios $\frac{J_U^*(C)}{J_U^*(N)}$ and $\frac{J_U^*(P)}{J_U^*(N)}$ equal to 99.57% and 99.40%, respectively. Obviously, welfare gains are much smaller in the latter case. So small differences between social loss in different regimes suggest that the preference ordering over regimes N, C and P stemming from Table 6 might be relatively easily changed under alternative set of parameters. This will be one of the issues studied in the sensitivity analysis section.

Finally, Table 7 contains welfare losses for the asymmetric (country specific) output shock which, similarly to the asymmetric inflation shock, hits only the first country, *i.e.* $v_{0S}^{\pi} := [v_{1,0}^{\pi}, v_{2,0}^{\pi}, v_{3,0}^{\pi}]^T = [1, 0, 0]^T$.

The asymmetry of shock leads to asymmetry in fiscal policy stance. Countries $C2$ and $C3$, which are only indirectly affected by the shock, do not pursue a fiscal policy too actively (*i.e.* they try to free-ride on others' stabilisation effort as before). In contrast, $C1$ which potential losses are the highest, is forced to more keen reaction to the shock. This, in turn, makes the situation more asymmetric for the central bank and increases his control effort w.r.t. the grand coalition.

There are two important differences between the pattern of losses in Table 7 and previous cases. First of all, the preference ordering changes to $C \overset{J_U/J_U^*}{\succ} N \overset{J_U/J_U^*}{\succ} P \overset{J_U/J_U^*}{\succ} F$, *i.e.* from the social point of view non-

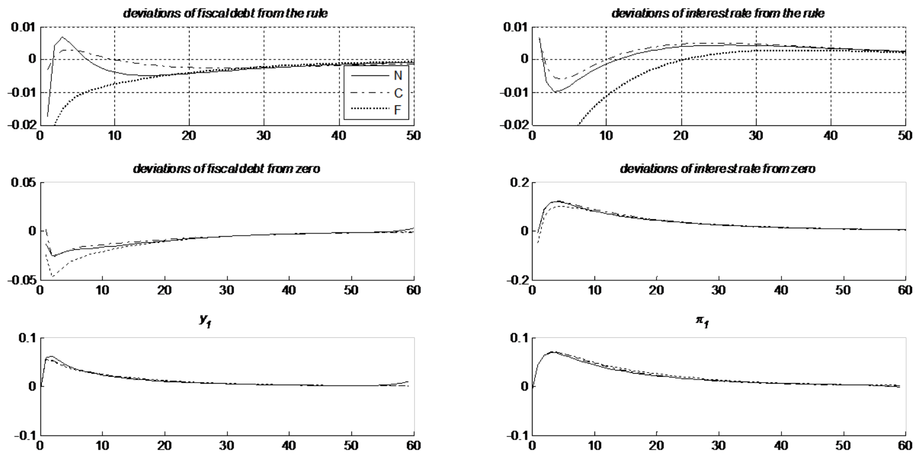

Figure 4: Symmetric output gap shock, regimes N, C and F

cooperative regime becomes more attractive than partial fiscal cooperation. Secondly, full fiscal cooperation is still the worst regime from the social perspective, however, in contrast to other shocks, it is not ultimately the worst regime for all individual players. In particular, the country which is directly affected by the asymmetric output gap shock prefers F to any form of non-cooperation, namely N and [1|23|4]. Of course, the full fiscal coalition is not sustainable as this is the worst choice for all the other players, but the differences between losses in regime F and other regimes are, by far, less pronounced compared to the inflation shock cases. Thus, it can be said that in the case of asymmetric output shock the conflict between fiscal and monetary players is much less distinct. Also, similarly to the symmetric shock case, the differences between social loss (in terms of $J_U^*(t_0)$) are relatively smaller when compared to the asymmetric inflation shock. Under v_{0A}^{π}, ratios $\frac{J_U^*(C)}{J_U^*(N)}$, $\frac{J_U^*(4,5)}{J_U^*(N)}$ and $\frac{J_U^*(6)}{J_U^*(N)}$ equal to 89.80%, 93.10% and 93.50%, respectively. In contrast, under v_{0A}^{y}, ratios $\frac{J_U^*(C)}{J_U^*(N)}$, $\frac{J_U^*(4,5)}{J_U^*(N)}$ and $\frac{J_U^*(6)}{J_U^*(N)}$ are 99.20%, 101.36% and 102.32%; hence, relatively, there is much less to gain from coordination in the latter case and preference ordering over regimes N, C and P might be sensitive to parametrisation.

The above results confirm to large extent findings of Beetsma *et al.* (2001) which claim that fiscal cooperation is likely to be profitable when the asymmetry of shocks increases. Such a situation emerges in our model for the asymmetric output shock, albeit regime F is not profitable from the social point of view. However, the conflict between fiscal and monetary authorities is substantially less pronounced than in other cases analysed before, especially involving inflation shocks.

5.4 Sensitivity analysis

Thus far, we have studied a number of cases characterised by different forms of coordination. It is interesting to perform sensitivity analyses of the model in order to identify which results (possibly) prevail and which parameters contribute mostly to particular outcomes. Some elements of a sensitivity analysis have been already present in the discussion above. In particular, we have inquired what happens to the social loss when alternative weights of the central bank in the grand coalitions are assumed. Additionally, we performed sensitivity analysis in three other dimensions:

1. Similarly to Beetsma *et al.* (2001) or Beetsma and Jensen (2005) we vary one structural parameter of the model at a time, assuming that it has either a *high* or a *low* value. Additionally, we perform not only one but a number (usually 4 or 5) of simulations in the neighbourhood of each high and low value;

2. Furthermore, we study various combinations of preference parameters in the loss functions of players. In particular, different ratios of preferences towards output gap and inflation are considered;

3. In the next step, the sensitivity analysis of governments' preferences is performed. A particular attention will be paid to the government preference parameter χ_i which different values can be interpreted as levels of the SGP stringency.

(sc_1, v^y_{0A})	N	C	F	[12|3|4]	[13|2|4]	[1|23|4]
$C1$	0.7392	0.7158	0.7245	0.7174	0.7174	0.7656
$C2$	0.0481	0.0514	0.0621	0.0580	0.0558	0.0491
$C3$	0.0481	0.0514	0.0621	0.0558	0.0580	0.0491
CB	0.0553	0.0577	0.0877	0.0607	0.0607	0.0514
$J_U(t_0)$	0.8881	0.8765	0.9366	0.8920	0.8920	0.9153
$J^*_U(t_0)$	0.3235	0.3209	0.3602	0.3279	0.3279	0.3310
$\alpha_{F,C1}\hat{\pi}^2_{C1}$	0.0147	0.0153	0.0160	0.0155	0.0155	0.0143
$\beta_{F,C1}\hat{y}^2_{C1}$	0.6496	0.6400	0.6347	0.6579	0.6579	0.7062
$\chi_{F,C1}\widehat{\hat{f}^2}_{C1}$	0.0748	0.0604	0.0736	0.0438	0.0438	0.0451
$\alpha_{F,C2}\hat{\pi}^2_{C2}$	0.0082	0.0089	0.0098	0.0091	0.0087	0.0068
$\beta_{F,C2}\hat{y}^2_{C2}$	0.0344	0.0353	0.0367	0.0323	0.0444	0.0380
$\chi_{F,C2}\widehat{\hat{f}^2}_{C2}$	0.0054	0.0072	0.0155	0.0164	0.0026	0.0042
$\alpha_{F,C3}\hat{\pi}^2_{C3}$	0.0082	0.0089	0.0098	0.0087	0.0091	0.0068
$\beta_{F,C3}\hat{y}^2_{C3}$	0.0344	0.0353	0.0367	0.0444	0.0323	0.0380
$\chi_{F,C3}\widehat{\hat{f}^2}_{C3}$	0.0054	0.0072	0.0155	0.0026	0.0164	0.0042
$\alpha_{CB}\hat{\pi}^2_{CB}$	0.0465	0.0499	0.0542	0.0503	0.0503	0.0411
$\beta_{CB}\hat{y}^2_{CB}$	0.0043	0.0041	0.0039	0.0041	0.0041	0.0047
$\chi_{CB}\widehat{\hat{i}^2_U}$	0.0043	0.0036	0.0295	0.0062	0.0062	0.0056

Table 7: Optimal losses for asymmetric output gap shock, benchmark parametrisation

The detailed description of the obtained results is available in the on-line appendix (Sections A1-A4). The structural parameter sensitivity check reveals that the degree of output gap backward-lookingness is the key parameter, which can either magnify or diminish the conflict between fiscal and monetary authorities. Counter-intuitively, it turns out that cooperation can be more effective when the economies are relatively more backward-looking. Backward-lookingness makes economies more rigid and therefore more difficult to control which, in turn, should lead to increased control effort. This is the main factor inducing conflict with the CB in the benchmark and resulting in higher losses in the full fiscal cooperation regime. However, when a certain threshold is triggered, the players realise that there is no point in setting off each other's policies as their influence on the economy becomes too limited. Consequently, they all decide to refrain from excessive actions and instead of colliding their policies, governments try to free-ride on the central bank's control effort and *vice versa*. Interestingly, this is not the case under the non-cooperative regime. Instead, in this type of regime, conflict between authorities increases together with the backward-lookingness of the output gap. Consequently, when the rigidity of the output gap becomes high enough, non-cooperation starts to become inferior w.r.t. fiscal cooperation. In other words, the situation is the exact reversal of that of the baseline analysis. In the benchmark case, characterised by high forward-lookingness, free-riding diminishes the conflict between fiscal and monetary authorities under non-coordination. However, under fiscal coordination, the struggle between governments and the CB increases everybody's loss. When high backward-lookingness is assumed, the conflict is exaggerated under non-cooperation, whereas under fiscal cooperation, authorities try to free-ride on each others' policies.

The second factor which heavily influences the results of our benchmark analysis is the relative conflict between preferences of fiscal and monetary authorities. The more governments exclusively focus on output gap stabilisation and the more CBs focus on inflation stabilisation, the more pronounced the conflict between them becomes. Consequently, the counter-profitable effects of full fiscal cooperation are even greater. On the other hand, when the preferences of both types of players are more alike, there is less reason for confict and fiscal cooperation becomes, from the social point of view, beneficial. More specifically, full fiscal cooperation initially becomes beneficial w.r.t. the non-cooperative regime, before subsequently becoming more beneficial w.r.t. partial fiscal cooperation regime and finally, more beneficial w.r.t. the grand coalition. This last effect is counter-intuitive as, by definition, the grand coalition always minimises the sum of the losses of all the players in the LQDGs. However, in our analysis we mainly refer to our own definition of the social loss in which, as has been mentioned previously, the cost of interest rate deviation from the rule is properly weighted to correspond to the one-country case. Consequently, our social optimum does not necessarily agree with the grand coalition. In fact, when the loss functions of governments and central banks become very alike, social loss obtained under fiscal cooperation tends to be smaller than under the grand coalition. This is caused by the fact that, in the simple sum of players losses, the weight of the control instrument of a monetary authority is relatively small w.r.t. fiscal debts of individual governments. This creates an incentive to use it more extensively. If the importance of interest rate is appropriately rescaled in the social loss, the grand coalition is no longer the most profitable regime.

Using numerical simulations, we study the way in which various combinations of policy rules' parameters influence output gap and inflation volatility. We also determine which of such combinations are likely to result in a(n) (near) optimal outcome from the social point of view. In the non-cooperative regime, and under a symmetric inflation shock, the proximity of the social optimum is reached for the combination of rules in which the central bank follows the standard Taylor rule, yet there is no automatic fiscal stabiliser to output. However, we show that if players in a monetary union were able to unilaterally choose their rules, the social optimum combination would not be sustainable. This is because the monetary authority has incentives to increase its automatic reaction to inflation and, at the same time, the government has incentives to increase its reaction to output gap. When these things occur simultaneously, the economies end up in a position that is suboptimal, not only from the social point of view, but also from the perspective of the individual.

Finally, we study various scenarios characterised by different levels of the SGP stringency and show that it is the third factor that is pivotal to the benchmark results. The increased SGP stringency reduces the incentives for fiscal players to use control instruments. Therefore, in situations where high social losses were driven by the conflict between authorities (notably full fiscal cooperation regime), this firmer stance is beneficial to the union-wide economic interest. However, in situations where free-riding is present (notably non-cooperative regime under benchmark parametrisation), increased SGP stringency may lead to more extensive free-riding of governments, since controlling the economy becomes much more costly. This, in turn, forces the CB to intervene and increases social loss of the union. In other words, the stringent SGP has both positive and negative effects in the context of this paper and is able to render unprofitable full fiscal cooperation regime profitable w.r.t. non-cooperation.

6 Conclusions

In this paper we considered a number of important issues concerning the policy coordination in the monetary union which have recently been discussed in the literature. In relation to this, we proposed a (stylised) Multi-Country New-Keynesian Monetary Union Model cast in the framework of linear quadratic differential games which can be used to simulate strategic interactions between an arbitrary number of fiscal authorities who interact in coalitions either in cooperation with or against the common central bank. In the above setting, we studied various coordination arrangements, including partial fiscal cooperation between only a subgroup of countries, which, to the best of our knowledge, had not previously been considered in the literature.

Our results, follow those of Beetsma *et al.* (2001) but in a much richer dynamic setting. Whereas free-riding in economics and social sciences is usually associated with inefficiency and losses, in our model, for many parameter combinations, fiscal cooperation between all countries in a monetary union turns out to be counter-productive as a result of exacerbated conflict with the central bank. Thus, the non-cooperative regime, in which policy-makers free-ride on each others' stabilisation efforts, is more profitable. The relative performance of fiscal cooperation is worst in the case of a symmetric inflation shock. When the shock is asymmetric, the response of the central bank to an average inflation in the union is more moderate, as are the losses of all the authorities.

In contrast to inflation shocks, under an output gap shock, there is no conflict between policy-makers regarding the general orientation of stabilisation policies. Both for fiscal and monetary authorities, it is of paramount importance to suppress output gap deviation. For the central bank, in particular, this is a method of tackling inflation instability. All in all, the relative difference between non-cooperative regime and fiscal coordination, as well as, symmetric and asymmetric shocks is much smaller than in the case of inflation shock.

In addition to the above results, in our multi-country framework, we were able to study intermediate regimes, in which only a subgroup of the fiscal players cooperate. Such a solution turns out to be interesting, especially from the common perspective. When a unity of governments is broken and they no longer optimize the common objective function, then the free-riding element is back into play and the ultimate choice of optimal policies is much less intense. Nevertheless, such regimes can be difficult to sustain, as they lead to a deteriorated position of some individual countries.

Furthermore, we discussed the effectiveness of the grand coalition, *i.e.* cooperation between all fiscal authorities and the monetary authority. Although this regime is profitable from the social point of view, it seems unlikely that it could be sustained without the creation of a central control or an effective transfer system. Since the situation is caused by the fact that individual countries are often worse off in the grand coalition than if they were in the non-cooperative regime, these countries are not willing to accept such a regime without compensation.

We also showed that the design of a common objective function for the grand coalition is of the utmost importance for the outcome of the stabilisation process. If a relative power of the central bank is too weak, then monetary control instrument is likely to be overused. This is because nominal interest rate affecting all the countries is, after all, much easier (cheaper) to use than national fiscal deficits.

Finally, we performed an extensive sensitivity check of our results and determined three variables that are pivotal to the results we obtained for the benchmark of our model: (i) the degree of forward-lookingness in the union's economies; (ii) the preference conflict between fiscal and monetary authorities; and (iii) the SGP stringency. The last analysis reveals the most interesting finding as long as the issue of fiscal cooperation is concerned. Since, the main source of the relative inefficiency of full fiscal cooperation is an increased conflict with the central bank due to more intensive use of a control instrument. Higher levels of SGP stringency mean that the use of fiscal debt becomes less and less attractive. This, in turn, removes the reason for conflict between two types of authorities.

The following policy conclusions stem from the above results. In general, the grand coalition is the most effective regime, however, only if the design of a cooperative arrangement takes into account a specific nature of a central bank and its policy instruments. However, this regime is difficult to implement due to various problems. In particular, the very nature of such a coalition jeopardizes the idea of the independent central bank. On the other hand, under special circumstances, like present financial crises that spreads to other sectors of global economy, we already witness various forms of cooperation between the ECB and the EMU Member States as well as EU Member States. However, in general, both de jure and de facto state of the affairs in the EMU can be described best by the non-cooperative regime. Since the grand coalition is rather out of question in the long term, inter-governmental coordination appears to be another interesting alternative. With respect to this, our results show that obligatory fiscal coordination between all the countries within the union can be counter-productive and that smaller coalitions of countries should be considered. This corresponds to the findings of the literature on voluntary environmental agreements that suggest that local solutions are more stable than centralised approach as for instance the Kyoto Protocol. Similarly, partial fiscal cooperation can be an interesting option as far as macroeconomic policy coordination is concerned. However, if (possibly multiple) partial agreements are not feasible for political reasons, then full fiscal coordination can be considered again in conjunction with the increased stringency of the SGP. The SGP should contain an increase in fiscal activity induced by cooperation.

Our analysis can be extended in several important directions. Although we considered both symmetric and asymmetric shocks in our analysis, we assumed full symmetry of monetary union member states. Following on from this, it would be beneficial to carry out an analysis of an asymmetric model, in terms of both the economies structures and the players preferences. Furthermore, since our results suggest that more attention should be devoted to partial forms of cooperation between the governments of a monetary union, we would like to extend our analysis to (at least) a four-country case, where two non-trivial fiscal coalitions may coexist in one single coalition structure. Finally, it could be interesting to consider how the results obtained in this paper are altered by the introduction of a federal fiscal transfer system in a monetary union.[39]

[39] An example of such an analysis (albeit only in a two-country setting) can be found in Plasmans *et al.* (2006), Chapter 3.

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