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Sovereign debt crisis, fiscal consolidation, and active central bankers in a monetary union*

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Abstract. In this paper we examine global financial instability and its impact on the sovereign debts of peripheral countries in a stylized model of the European Economic and Monetary Union (EMU), where centralized and national policy authorities strategically interact. We show that active expansionary monetary policies might operate as indirect risk-sharing mechanisms that improve EMU stability and the welfare of (a part of the) member states. The European Central Bank (ECB) partially internalizes the fact that the monetary union's stability is a public good by reallocating a part of the cost of stabilizing the EMU from the periphery to the core countries. In this respect, unconventional monetary policies such as 'quantitative easing' are more effective than traditional monetary policies centered on ***ex-post*** interest rate adjustments. The rationale of our findings is that unconventional monetary policies decrease the cost of fiscal interventions in the peripheral countries and incentivize the consolidation of their public balance sheets; these same unconventional policies produce positive externalities but also come at a cost for central countries.

Keywords: core-periphery models, stability in a monetary union, risk sharing, monetary union institutions, unconventional policies.

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1. Introduction

The financial turmoil of 2007-2009 proved to be a strong element of instability for an incomplete economic union such as the European Economic and Monetary Union (EMU). This instability became evident through the difficulties of the European banking sector, the vicious circle between the sovereign debt crisis and the crisis of the banking sector (the so-called doom-loop), and the limited effectiveness of conventional monetary policies due to lower-bound interest rates. At different peaks of EMU instability, the union was on the brink of a breakdown. Throughout the last few years, a lively economic and political debate has been developing to address a number of these issues.

Our paper aims to contribute to the debate at a theoretical level, analyzing the coordination problems between centralized monetary policies and national fiscal policies in a monetary union such as the EMU. It points out that ECB 'quantitative easing' (QE) operates as an indirect but effective risk-sharing mechanism between the 'core' and the 'periphery' of the euro area. QE can decrease instability and the related union breakup probability, which are associated with sovereign debt shocks in the EMU periphery. The rationale of this finding is that QE policies reduce the cost of fiscal adjustment in the periphery and incentivize debt consolidation plans. We aim to explore the properties of QE as an indirect risk-sharing mechanism, its feasibility, and the associated welfare effects for the core and the periphery of the EMU in comparison with more conventional monetary policies.

A large part of the literature on the EMU's monetary policy is focused on the possibility that the European Central Bank (ECB) is forced to prevent a sovereign debt default due to the inadequacy or ineffectiveness of national fiscal policies. This literature adds that the ECB intervention in the event of an otherwise unavoidable bankruptcy leads to a 'moral hazard' problem, since national governments are incentivized to take excessive risk in their sovereign debt policies.[1] Although this issue is important, our paper bypasses it to focus on a different and more original matter: the effects of the global financial turmoil on sovereign debts and stability of the euro area. Hence, in the following model debt shocks are not induced by the irresponsible conduct of national fiscal policy authorities; conversely, the latter operate in a benevolent way to stabilize the government debt under a trade-off between financial stability and economic recovery.[2]

We build a stylized asymmetric core-periphery representation of the EMU, where three policymakers strategically interact: a single central bank and two national fiscal authorities that belong – respectively – to a representative core member state and a representative peripheral member state. We assume that the stability of the monetary union is a public good,[3] which can be undermined by idiosyncratic sovereign debt shocks. Specifically, we consider a shock hitting the peripheral country and generating an excess deviation of its government debt from a given threshold. Cooperative equilibria are unfeasible in the EMU due to the lack of a fiscal union. Hence, our model assumes that policymakers interact in a non-cooperative way so that they are

[1] The debate is illustrated in, for example, Beetsma and Giuliodori (2010). See also Section 2 of our paper.

[2] Our model compares the welfare results derived from the management of this trade-off, but it does not account for strategic default and domino effects. The latter issues are largely investigated in a different strand of literature (see Aguiar and Gopinath, 2006; Arellano, 2008; Yue, 2010; Chatterjee and Eyigungor, 2012; Arellano and Ramanarayanan, 2012; Mendoza and Yue, 2012; Canofari ***et al***., 2015, 2017; Eijffinger ***et al***., 2018).

[3] See Beetsma and Giuliodori (2010); and Groll and Monacelli (2019) for further arguments.

unable to internalize all the policy externalities implied by the public good nature of the monetary union's stability. In other words, the outcomes of their interaction are suboptimal. However, different non-cooperative solutions can imply different degrees of suboptimality.

In our model, we are interested in analyzing how different monetary policy responses to the effects of a given sovereign debt shock in the peripheral country can lead to specific interactions between policy authorities, and thus to different outcomes. We explore three monetary policy regimes:

1. The central bank maintains a passive role even after a sovereign debt crisis hits the peripheral country; this means that, in the case here labelled as 'no intervention regime', the central bank limits itself to guaranteeing the equality between its policy interest rate and the level of the 'natural' interest rate.
2. The central bank intervenes (***ex-post***) to stabilize prices by modifying its policy interest rate; hence, in this regime, here labelled as traditional or conventional, the central bank's action occurs only after the sovereign debt shock is observed and only if the consequent national fiscal policies are unable to set the average inflation rate of the monetary union at its equilibrium level.
3. The central bank is (***ex-ante***) committed not only to stabilizing prices but also to avoiding the instability of the monetary union; hence, in this regime, here roughly assimilated to the 'quantitative easing' process (QE), the central bank credibly announces that its monetary policy will accommodate the peripheral country's effort to consolidate the domestic public debt hit by the sovereign debt shock.

Our aim is to show that, under reasonable conditions, monetary regimes sub 2 and 3 provide some indirect risk-sharing mechanisms between the peripheral and the core countries. However, QE is more effective than the conventional monetary response in the sense that its implementation improves the stability of the monetary union and the welfare of (at least one of) the two member-states. The announced QE distributes some of the cost of stabilizing the monetary union from the periphery to the core; moreover, it partially internalizes the public good nature of monetary union stabilization. In fact, QE facilitates stabilizing adjustments in the area, since the central bank rightly expects the peripheral country to react to the announced monetary expansions with more fiscal consolidation. We can thus maintain that this non-cooperative interaction imperfectly mimics a cooperative solution; however, improving the feasibility of such a solution and strengthening its cooperative flavor require coordination between the fiscal authority in the core country and the ECB.

Our model is part of a large strand of literature on risk-sharing mechanisms and their design in currency areas.[4] Several works compare different forms of sharing the government debt risk in the EMU. One of the main results is that the effects of risk-sharing mechanisms are very sensitive to their specific designs.

[4] Pioneering studies include, among others: Melitz and Vori (1993), Wildasin (1996), Persson and Tabellini (1996a and 1996b), Asdrubali ***et al***. (1996), Lockwood (1999), Mélitz and Zumer (1999 and 2002), von Hagen (2000), and Alfonso and Furceri (2008). These studies focus on risk sharing through the balance of a national government or on explicit mechanisms of fiscal equalization. The European policy debate on the same topic paralleled the first steps in the European monetary integration during the 1970s and 1980s (cf. European Commission, 1977 and 1989).

By comparing the empirical performance of different risk-sharing mechanisms in a monetary union, Furceri and Zdzienicka (2015) find that a supranational fiscal stabilization mechanism financed by a relatively small contribution could fully insure member states against severe, persistent and unanticipated downturns. Beetsma and Mavromatis (2014) refer to a small country in the same setting. They show that the government of this country will find it advantageous to reduce its debt (and thus raise the union's welfare) only if a suitably chosen and limited guarantee is introduced. They add that the union's welfare could further improve if the guarantee was made conditional to national policy actions. Therefore, Beetsma and Mavromatis (2014) support the introduction of eurobonds under the condition that the latter do not offer a full and unconditional guarantee to the small country. The maximum guaranteed should balance the ***ex-ante*** and ***ex-post*** incentives of the small country to leave its government debt without any control.

Favero and Missale (2012) examine the potential role of the eurobonds to solve crises in the EMU from an empirical perspective. The two authors use a Global VAR to test the main determinants of sovereign spreads during the recent crises. They conclude that, if properly designed, eurobonds could contribute to mitigating these crises by protecting the member states of the euro area against contagion. However, Issing (2009), CESifo (2011), and Corsetti ***et al***. (2011) express critical remarks towards eurobonds. Their different views depend on the weight assigned to ***ex-ante*** vs. ***ex-post*** incentives. For instance, referring to the well-known moral hazard mechanism, Issing (2009) argues that eurobonds would be too costly for taxpayers in the least indebted EMU countries and would represent just a placebo for the most indebted ones. Along the above lines, a recent strand of contributions has proposed the introduction of risk-absorber assets that do not have a direct risk-sharing impact but can perform a stabilizing role in a monetary union (cf. Brunnermeier ***et al.***, 2016; Brunnermeier ***et al.***, 2017; Zettelmeyer and Leandro 2018; Giudice ***et al.*** 2019). Even if the quoted papers assume different approaches, their common ground is represented by the introduction of a safe asset possibly issued by a centralized European institution.

From a fresh perspective stimulated by recent events, our paper also contributes to the traditional, general debate on the macroeconomic costs and benefits of monetary unification and its institutions. In this vein, the paper complements the recent literature on endogenous default and domino/contagion effects already mentioned in this section, as well as other theoretical models exploring the dynamics of the eurozone crisis (e.g., Aguiar ***et al***., 2015; Corsetti ***et al***., 2014; Corsetti and Dedola, 2016; and Broner ***et al***., 2014).[5]

The rest of the paper is organized as follows. Section 2 briefly discusses the actual European policy response to the financial and sovereign debt crises. Section 3 illustrates the analytical setup of our two-country monetary union model. Section 4 introduces the policy regimes and sketches their implications for monetary policy. Section 5 illustrates the monetary regimes in details in order to show how an active central bank introduces different indirect risk-sharing mechanisms; this Section also provides some suggestions on the viability and the welfare impact of these mechanisms. Finally, Section 6 concludes.

[5] Aguiar and Amador (2014) use a benchmark limited-commitment model to explore key issues in the economics of sovereign debt: default and renegotiation; self-fulfilling debt crises; incomplete markets and their quantitative implications. Hence, they contribute to highlighting the debt default issues.

2. Actual policies during the international and European crises

For the construction of the euro area (1992), the members of the European Union (EU) agreed on the need of imposing common constraints to prevent free riding among national fiscal authorities and the related instability in the monetary union. The Stability and Growth Pact (SGP) was the centralized tool aimed at imposing this fiscal discipline (cf. Buti ***et al.***, 1998; Beetsma and Uhlig, 1999). It is well known that the evolution of the SGP in the first decade of the new century was bumpy (cf., e.g., Schuknecht ***et al.***, 2011). In any case, until the peak of the European crises (2011-2012), this centralized mechanism was sufficient to confine the sovereign default of an EMU member state to an extreme event in the negative tail of the distribution function; whereas, after the bail-in of a large part of the private holders of Greek debt (March 2012) and the dramatic increase in the probability of Greece's temporary exit (July 2015), sovereign default was no longer seen as a 'black swan' in the EMU. This dramatic change highlighted that fiscal coordination among EMU member states was, at the same time, too rigid and too fragile to absorb the impact of external symmetric and asymmetric shocks coming with the European crises.

The last statement specifically applies to EMU peripheral member states characterized by structural macroeconomic disequilibria, such as an excess of government debt and/or of negative imbalances in their current account. The disequilibria inside the euro area remained manageable until the international crisis caused the collapse of the international financial markets, a 'sudden stop' in financial capital transfers from core to periphery and a sharp increase of the sovereign debt yields. The new phenomena implied that the stability of the entire euro area was at risk. The consequent European crisis necessitated the introduction of new macroeconomic stabilization tools and risk-sharing mechanisms. However, to avoid moral hazard problems, core countries exerted growing pressure to counterbalance these initiatives by means of a tougher enforcement of centralized fiscal rules and the activation of risk-reduction mechanisms at the national level. The opposition between risk sharing and risk reduction led to a stalemate in the euro area characterized by the recourse to more market discipline and decentralized responsibility at the national level. The dominance of market discipline increased EMU instability and sparked a recession which threatened the survival of the euro area (2011-2013). Monetary policy played a crucial role in these critical situations.

The consequences of the international crisis on the European one, the long recession in the euro area, and the specific problems of the EMU's peripheral member states stimulated a long debate in the policy arena on at least two issues: the reforms required to overcome the main weaknesses in the institutional design of the euro area; the limits of the ECB's monetary policy and its interaction with decentralized fiscal policies. Recently, the first issue has inspired a theoretical framework aimed at avoiding the useless opposition between risk sharing and risk reduction.[6] Here we are not interested in analyzing the possible evolution in EU governance. We focus instead on the second issue, that is, the actual impacts of a centralized monetary policy on national fiscal policies.

The recent crises questioned the effectiveness of orthodox monetary policies, which had become fashionable in the wake of the Great Moderation and were centered on the control of short-term interest rates. Since 2008 the ECB's and other central banks' efforts have been focused on this conventional tool to launch

[6] See, e.g., Bénassy-Quéré ***et al***. (2018). For a critical comment: Messori and Micossi (2018).

expansionary monetary policies; however, let us remember that, shortly before the peaks of – respectively – the international financial crisis (July 2008) and the EMU crisis (summer 2011), the ECB increased its policy interest rate. Then, the most important central banks re-designed the boundaries of the conventional monetary policy and (re)discovered new forms of monetary expansion that had been neglected in the last thirty-five years. In the EMU these two stages are well illustrated by – respectively – the Long-Term Refinancing Operations (LTRO: December 2011-February 2012) and the different programs of unconventional monetary policy labeled as QE (QE1: September 2014; and QE2: March 2015).

LTRO was effective in temporarily overcoming the liquidity crisis of European banks which reached its peak in the fall of 2011. QE1 was justified by the aim of counterbalancing deflation risks and by pushing the euro-area average inflation rate close to – but below – 2% (Draghi, 2014). This new monetary policy did not immediately include the ECB purchasing of EMU government bonds. However, it created a widespread expectation of this purchase shortly afterwards. QE1 was, in fact, just the prelude to a stronger unconventional monetary policy program. In mid-January 2015, the ECB decided to launch the second stage of QE (QE2) to be implemented in March 2015. QE2 centered on the monthly purchase of 60 billion euro of government bonds by the European System of Central Banks (ESCB). The ESCB's purchases consisted of the national bonds of all the EMU member states not having recourse to a European aid program; and the average weight of each national bond in these purchases was fixed by the key-capital share of the corresponding member state, i.e. by the share held in the ECB's capital.

In March 2016, besides deciding to increase – since June 2016 – the amount of the ESCB's monthly purchases of government and other bonds in the secondary markets to 80 billion euro, the QE2 program was strengthened by fixing negative interest rates on ECB's loans to European banks (a new form of the targeted long-term financing operations started in Fall 2014: T-LTRO2). In December 2016, the ECB decided to reduce the ESCB monthly purchases of government and other bonds to 60 billion euro starting from April 2017. The ECB also prolonged its purchases until (at least) the end of 2017 and decided to leave the policy interest rates unchanged and to reinvest the proceeds of the expiring bonds in its portfolio for a longer time, despite the EMU's recovery. Moreover, it tacitly introduced some flexibility in the key-capital rule for overcoming the binding shortage in the supply of specific national government bonds. Then, the ECB implemented a further reduction of its purchases by September 2018 and by the end of QE2 in December of the same year.[7]

These new monetary policies interacted with national fiscal policies in the deep water of the EMU framework, stimulating a discussion on its optimal configuration. In 2011-2012, the LTRO did not overcome the euro-area recession by increasing bank loans to the real economy. However, it solved the bank liquidity crisis and put the doom-loop between bank and sovereign crises under temporary control, thus avoiding the bankruptcy of Italian and Spanish government debt and easing fiscal adjustments. Unfortunately, the solution of the bank liquidity crisis and the related stabilizing effects were inadequate to solve the fiscal problems.

[7] The persistency of inflation rates largely below 2%, the slowdown in the growth rates in the second quarter of 2019, and the negative forecasts on the economic perspectives of the EMU countries suggested a reappraisal of QE. In its two meetings of June and July 2019, the ECB's Governing Council endorsed these markets' expectations; and more recently (August 2019), the Governor of the Bank of Finland maintained that ECB would not disappoint these expectations. Hence, it did not come as a surprise that, in the meeting of September 2019, the ECB's Governing Council decided to restart an open-ended new QE program since November 2019.

European QE1 and QE2 were not so effective in increasing inflation rates in the EMU from 2015 to 2019;[8] however, QE2 and its corollaries were successful in sterilizing the risk of the public debt/GDP ratio of the most vulnerable member states in the euro area becoming unsustainable. Unfortunately, some of these fragile countries (e.g., Italy) did not exploit the opportunity to defeat the disease of their excessive government debts. It followed that the unconventional monetary policies implemented in the EMU did not lead to adequate fiscal adjustments.

Our model is too simple to assess the legacy of national fiscal disequilibria inherited from the past, as well as the hidden incentives (moral hazard) of national fiscal authorities to disregard the European rules. Hence, below we assume that both the representative core country and the representative peripheral country start with a government budget in equilibrium. Despite this simplification, there are still crucial policy questions that should be examined theoretically. It can happen that there are external asymmetric shocks that hit the peripheral country and determine its excessive government deficit;[9] and this disequilibrium tends to undermine the stability of the monetary union. Hence, two questions arise: if this stability is a common good, will it be efficient to handle the disequilibria in the peripheral country as a ***private*** problem?; and, are expansionary conventional monetary policies and/or QE effective in producing adjustments from asymmetric shocks in the peripheral member state?

Before addressing these questions, we need a more precise distinction between the passive, the conventional and the unconventional monetary policies to be compatible with the simplified setup of our stylized model. It will become apparent below that the latter allows neither an assessment of the appropriate timing to vary policy interest rates nor any reference to different policy channels (the banking channel for the conventional monetary policies, and the monetary channel for the unconventional one).[10] However, we can approximate the empirical evidence offered by the monetary policy reactions to the recent international and European crises.

The restrictive stance, adopted by the ECB's monetary policy in July 2008 and summer 2011, can be interpreted as an attempt to anchor the policy interest rates to unchanging rules despite the economic turmoil; the "no intervention" monetary policy will approximate the ECB's temptation. The conventional monetary policies were unable to inject the desired amount of liquidity into the economy through the banking channel due to the deleveraging of the EMU banking sector; hence, we will maintain that the central bank can conventionally handle a sovereign debt shock only by adjusting its policy interest rate ***ex-post***. Nevertheless, unconventional monetary policies such as QE partially overcame this problem by purchasing government

[8] According to Blanchard (2016), market internationalization and the prolonged recession could have implied a flattening of the Phillips curve, so that increases in output and decreases in the unemployment rate would be associated with smaller and delayed increases in monetary wages. Moreover, Draghi stated several times that the EMU's average inflation rate remained largely below 2% for a long time since nominal wages did not increase sufficiently (e.g., Draghi, 2017).

[9] Our model ignores symmetric shocks hitting peripheral as well as core countries. Despite empirical evidence offered by De Grauwe and Ji (2016) that the main euro-area shocks are the results of business-cycle movements, the asymmetric shocks remain the most interesting case to be theoretically analyzed by our type of model.

[10] Our terminology is consistent with the past and current management of monetary policy. During the 1980s and 1990s, a rich theoretical and policy debate led almost all central banks to switch from direct purchases of government bonds in the secondary financial markets to interest rate targeting as usual procedures. This targeting was mainly based either on the central bank's window or on open market operations reserved to (specific) banks. Hence, the banking channel became the conventional tool of monetary policy. See: Bernanke and Blinder (1988, 1992), Romer and Romer (1990), Ramey (1993), Galì and Gertler (1999), Galì ***et al***. (2000), and Ramey and Barth (2002).

bonds through the monetary channel; hence, we will maintain that the central bank can also handle a sovereign debt shock by credibly announcing a monetary expansion to the national fiscal authorities.

3. A model of a stylized monetary union

This section introduces our asymmetric model which refers to a stylized core-periphery monetary union composed of two member states (or two groups of countries), the core and the peripheral country (indexed by $i \in \{c, p\}$, respectively), and a common central bank. We assume that the two countries have the same economic fundamentals, but different structural parameters.[11] These countries control their respective fiscal policies through national authorities, whereas the single central bank sets the nominal interest rate for the whole monetary union.

The central bank strategically interacts with national fiscal authorities in a simple two-period dynamics characterized by price stickiness.[12] In the first period (short run), the economy is hit by a sovereign debt shock that cannot be absorbed through traditional market mechanisms. Therefore, policymakers' intervention is needed: in the short run, due to price stickiness, the monetary policy is nonneutral and affects the 'real' economy; in the long run, instead, the impact of the shock vanishes, and the monetary policy has no real effects. Following Beetsma and Bovenberg (1998, 2001), these interactions fully characterize the policy game which does not take account for possible fiscal spillovers induced by trade.[13] Thanks to the latter simplification, our two-period game has a closed form solution.

The following three subsections outline the model. Subsection 3.1. illustrates the functioning of the two-period model and specifies its short-term results. Subsection 3.2. outlines the long-run equilibrium. Subsection 3.3. formalizes the sovereign debt shock and defines the stability property of the monetary union. It also describes the preferences of the different policymakers.

3.1. The economy of the monetary union

The core of our paper is to study the externalities among the monetary and fiscal policy decisions taken by independent policymakers who attribute great importance to the stability of the monetary union as a public good. Our analysis first requires a description of the behavior of the private agents in the monetary union and of the consequent working of the economy in the two-period dynamics.[14] For the sake of brevity, we usually refer to the first period as the "short run" and to the second as the "long run." We use a bar over a given variable to denote its long-run value.

[11] This assumption represents the minimum requirement to differentiate the two countries.

[12] Cf. Goodfriend (2004) and Benigno (2015). This kind of dynamics is the simplest way to model non-trivial strategic interactions among policymakers. A similar approach is utilized, for example, in Carlin and Soskice (2005), Corsetti and Pesenti (2009), and Friedman (2013).

[13] A complementary approach is followed by Galì and Monacelli (2008), who analyze the impact of the trade channel in a monetary union composed of atomistic fiscal authorities. See also Chortareas and Mavrodimitrakis (2017).

[14] Our description of the economy follows Benigno (2015).

Let's us to describe the demand side of the economy. In country i, households optimally choose how to allocate consumption and the hours worked across time. Each of them maximizes the discounted value of a utility function defined over consumption (C_i) and worked hours (L_i), which takes the following form:[15]

$$U_i(C_i, L_i) = \frac{1}{1-\sigma^{-1}} C_i^{1-\sigma^{-1}} - \frac{1}{1+\eta} L_i^{1+\eta} + \beta E\left[\frac{1}{1-\sigma^{-1}} \bar{C}_i^{1-\sigma^{-1}} - \frac{1}{1+\eta} \bar{L}_i^{1+\eta}\right] \quad (1)$$

where: σ represents the intertemporal elasticity of substitution in consumption; and η is the inverse Frisch elasticity of labor supply.

In maximizing its utility, the representative household of country ***i*** discounts the future variables using the discount factor β and carries out its current expenditure over the two periods under a binding budget constraint:

$$(1+\tau_i^C)C_i + \frac{\Pi_{i,+1}^e}{1+R}(1+\bar{\tau}_i^C)\bar{C}_i^e = \frac{(1-\tau_i^L)W_i L_i}{P_i} + \frac{(1-\bar{\tau}_i^L)\bar{W}_i^e \bar{L}_i^e}{(1+R)P_i} + T_i \quad (2)$$

where the apex e indicates the expected value; [16] W_i denotes the nominal wage and/or salary of the representative household; T_i is the total sum of the public transfers to this same household, i.e., the profits distributed to the household as a shareholder of some firms of country ***i***, and the real lump-sum tax paid by this same representative household; R denotes the nominal interest rate controlled by the central bank that is common in the two countries; P_i stands for the price level of country i, $\Pi_{i,+1}^e = \bar{P}_i^e / P_i$ is the expected inflation rate of country ***i***; τ_i^L and τ_i^C denote the tax rates on – respectively – labor and consumption in this same country.[17]

Solving the households' optimization problem, we obtain two familiar first-order conditions:

$$(1+\tau_i^C)C_i^{-\frac{1}{\sigma}} = \frac{1+R_i}{\Pi_{i,+1}^e}(1+\bar{\tau}_i^C)\beta\left(\bar{C}_i^{\,e}\right)^{-\frac{1}{\sigma}} \quad \text{(Euler equation)} \quad (3)$$

$$\frac{W_i}{P_i} = \frac{1+\tau_i^C}{1-\tau_i^L} L_i^{\eta} C_i^{\frac{1}{\sigma}} \quad \text{(Labor supply).} \quad (4)$$

We can then write the Euler equation in logs as:

$$c_i = \bar{c}_i^e - \sigma\left(r - \pi_i^e - r^n - \bar{\tau}_i^C + \tau_i^C\right) \quad (5)$$

where $r^n = -\ln(\beta)$ denotes the natural interest rate.

Given that our model does not include capital and given the simplification of a representative consumer, equation (5) determines the aggregate demand in economy i. We have:

$$y_i = \bar{y}_i^e + g_i - \bar{g}_i^e - \sigma s_{C,i}\left(r - \pi_i^e - r^n - \bar{\tau}_i^C + \tau_i^C\right) \quad (6)$$

[15] If not differently indicated, the same uppercase and lowercase symbol indicates a specific variable. However, the lowercase symbol represents the log of the corresponding uppercase symbol.

[16] In the section shocks are not explicitly introduced; therefore, the terms "rational expectations" and "perfect foresight" are used interchangeably.

[17] It would be possible to set a more comprehensive fiscal structure (see Benigno, 2015). However, our focus is on the strategic interactions between fiscal authorities and the common central bank.

where: y_i and $\bar{y}_i^e$ are, respectively, the actual short-term and the expected long-term aggregate output; $s_{C,i}$ is the steady-state share of consumption in the output; and g_i and $\bar{g}_i^e$ are the actual short-term and the expected long-term public spending on output ratio.

It is worth remembering that we have assumed no trade link between the two countries. Therefore, demand (6) does not depend on either the other country demand or the other government policy (no fiscal spillovers via aggregate demand).

The supply side of the economy of country i is populated by many producers operating under monopolistic competition. Each firm offers a variety of goods j produced by means of a common linear technology,[18] which is characterized by:

(7) $$Y_i(j) = A_i L_i(j)$$

where A_i is an aggregate productivity shock, and $L_i(j)$ represents the ***j***'s demand for labor.

Each producer offers a variety j exploiting its monopoly power. The price of variety j ($P_i(j)$) is set to maximize the discounted stream of profits, given the production technology and each producer j's specific demand ($Y_i(j)$). Let us refer to a specific firm. Its demand takes the following form:

(8) $$Y_i(j) = \left(\frac{P_i(j)}{P_i}\right)^{\theta} (C_i + G_i)$$

where θ denotes the elasticity of substitution of consumer preferences among goods.

The optimal price is determined by a markup over marginal cost*s*, that is:

(9) $$P_i(j) = \mu \frac{W_i}{A_i}$$

where $\mu = \theta/(\theta - 1)^{-1}$ denotes the net mark-up.

If all firms can adjust prices, i.e., prices are flexible, we will have: $P_i(j) = P_i$ and the market clearing in the labor market, i.e., $\frac{A_i}{\mu} = \frac{1+\tau_i^C}{1-\tau_i^L} L_i^{\eta} C_i^{\frac{1}{\sigma}}$. By using, $Y_i = A_i L_i$ and $Y_i = C_i + G_i$, we can write $\frac{A_i}{\mu} = \frac{1+\tau_i^C}{1-\tau_i^L} Y_i^{\eta} (Y_i - G_i)^{\frac{1}{\eta}}$. Solving the latter equation allows us to determine the flexible-price equilibrium for the output (i.e., the natural output). After some algebra, the natural output in logs is:

(10) $$y_i^n = \frac{1+\eta}{\sigma^{-1}+\eta} a_i + \frac{\sigma^{-1}}{\sigma^{-1}+\eta} g_i - \frac{1}{\sigma^{-1}+\eta} m_i$$

where m_i represents short-term deviations from the tax-adjusted markup in country i (i.e., deviations of the term: $\mu\left(1 + \tau_i^C\right)(1 - \tau_i^L)^{-1} - 1$).

However, as stated above, we follow the New Keynesian vein by assuming that prices are not flexible in the short run. Specifically, all firms can optimally adjust their prices only in the long run, whereas in the short one prices are sticky. To formalize this assumption, we state that only a fraction $(1 - \alpha)$ of firms can maximize

[18] Goods are differentiated according to the tastes of the representative consumer.

profits, while the remaining fraction α of firms has prices fixed at the long-run level, $\bar{P}_i$.[19] Hence, this latter fraction must adapt its production to the relative demand.

The aggregate price is the average of the new set of optimal prices (p_i^*) and the predetermined long-run prices ($\bar{p}_i$). It follows that the aggregate price dynamics determines the inflation ($\pi_i = p_i - \bar{p}_i$) as $\pi_i = (1-\alpha)(p_i^* - \bar{p}_i)$. Then, after some algebra, the following New Keynesian Phillips curve is obtained:[20]

$$\pi_i = \beta\pi_i^e + \frac{1-\alpha\beta}{1-\alpha}\left(\frac{1}{\sigma} + \eta\right)(y_i - y_i^n). \tag{11}$$

Country ***i***'s economy is then composed by three equations (i.e., equation (6), (10), and (11)). These equations can be further simplified by defining the output gap as $x_i = y_i - y_i^n$. Assuming there are no productivity and markup shocks, we have:

$$\Delta y_i^{n,e} = \frac{\sigma^{-1}}{\sigma^{-1}+\eta}(g_i^e - g_i). \tag{12}$$

Hence, the equation system (6), (10), and (11) can be compacted into equations (13) and (14), which describe the demand and supply side of the economy of country ***i,*** respectively:

$$x_i = \bar{x}_i^e + a(g_i - \bar{g}_i^e) - b(r - \pi_i^e - r^n) \tag{13}$$

$$\pi_i = \beta\bar{\pi}_i^e + \kappa x_i \tag{14}$$

where the parameters in (13) and (14) are defined as follows: $a = \frac{\eta}{\sigma^{-1}+\eta}$; $b = \sigma s_C$; and $\kappa = \frac{(1-\alpha\beta)(\sigma^{-1}+\eta)}{1-\alpha}$, where: $\boldsymbol{a}, \boldsymbol{b}, \kappa > 0$.[21]

In the economy represented by equations (13) and (14), the central bank controls the common interest rate, r, and the national governments set the fiscal policies, (i.e., their primary balance). Government balance can be managed by different fiscal strategies, involving several taxation instruments. An analysis of the specific effects due to fiscal policies based on different tax compositions is beyond the scope of this paper. This is the reason why we assume that the governments use lump sum taxes to keep the tax revenues constant (i.e., $t_i = \bar{t}_i$) without changing the tax rates (τ_i^C and τ_i^L). Conversely, the primary balance is only determined by adjustments in the government expenditure. We define the short-run primary balance in terms of deviations from its long-run equilibrium as:

$$f_i = \bar{g}_i - g_i \tag{15}$$

Of course, the short-run primary balance (15) in the long run is $f_i = 0$ since is a deviation from the long run value, $\bar{t}_i - \bar{g}_i$, which is assumed to be consistent with the long-run sustainability of the public debt (cf. Section 3.3). We also assume that agents perfectly forecast long-run fiscal policies, so that $\bar{g}_i^e = \bar{g}_i$.[22]

[19] As already stated, the assumption of our model is that the economy of country ***i*** followed the steady state before the sovereign debt shock hit the peripheral country. Therefore, previous firms' prices are set at their long-run level.

[20] See Appendix A for details.

[21] It is worth noting that our assumptions imply that the consumption share on output in the steady state is the same in the two countries. See the next sub-session.

[22] See the next sub-session.

3.2. The long-run equilibrium

In our stylized monetary union model, equilibrium can be easily obtained in the absence of stochastic disturbances (natural equilibrium). In the long run, there are no shocks and expectations are stable. This implies that expectations on future inflation and the output gap are $\bar{\pi}_i$ and $\bar{x}_i$, respectively. The equilibrium is then defined by the optimal long-run monetary and fiscal policies. We assume that policymakers aim at minimizing the output gap and the inflation deviations from a target which is set equal to zero for the sake of brevity. Optimal long-run monetary and fiscal policies are then characterized by: $\bar{r} = r^n$ and $\bar{f}_i = 0$.[23] As can easily be verified, it follows that $\bar{\pi}_i = \bar{x}_i = 0$.

3.3. The sovereign debt shock and the monetary union stability

Since all the policymakers' targets are met in the long run if the economy does not face any stochastic disturbance, these targets are also achieved in the short term. In a model of the kind of that exposed here, several shocks and policy options can be investigated (see Benigno, 2015). The novelty of our paper is to focus on sovereign debt shock. Therefore, we need to augment the monetary union model with a fiscal suitability argument.

We assume that national authorities are fiscal responsible and implicitly or explicitly met the commitment of stabilizing their respective government debt-to-GDP ratio at a reasonable level in the past (Ghosh ***et al.***, 2013). In our model this amounts to stating that each of these two authorities was systematically able to increase the primary surplus of its government balance sheet to offset increases in the interest bill not compensated by the rate of economic growth (see also: Bohn, 1998 and 2007; and Mendoza and Ostry, 2008). Hence, at the starting point, the government debt-to-GDP ratio equalizes the long-run equilibrium level in both countries.

However, when the peripheral country is hit by a sovereign-debt shock, its fiscal authority is unable to handle the primary balance to keep this equilibrium in the short term; the national fiscal response can be so weak as to undermine the monetary union stability. Fiscal instability is costly for the peripheral country; moreover, it creates negative externalities for the monetary union that can also affect the welfare of the core country and of the central bank. We model this behavior of the fiscal authorities by stating that both countries of the monetary union will not have to face a government debt sustainability problem in the long run; however, the peripheral country can be confronted with this problem in the short run if its primary surplus is not sufficient to absorb the impact of the sovereign debt shock and then to avoid instability in the monetary union. In this case, even the core country indirectly suffers the short-run cost of instability.

In order to formalize the conditions of stability, it becomes necessary to define the national fiscal (un)sustainability with utmost precision. Denoting s_i^T as the goal for the balance surplus that is consistent with the fiscal sustainability, we assume that the fiscal target evolves as follows:

$$s_i^T = \bar{s}_i^T + \varepsilon_i \tag{16}$$

[23] It is worth remembering that $\bar{f}_i$ is the long-run deviation of the primary deficit from its steady state. Hence, it is zero.

where $\bar{s}_i^T$ is the long-run balance surplus goal[24] and ε_i denotes a short-run disturbance (that is, a sovereign debt shock). By assumption, the government debt of ***country i*** is sustainable in the long run.

By denoting with $\bar{s}_i$ the balance surplus set by the government of country i to satisfy the equilibrium in the long run, it follows that $\bar{s}_i^T = \bar{s}_i$. Therefore, short-run fiscal sustainability in equation (16) is measured by:

$$s_i - s_i^T = s_i - \bar{s}_i - \varepsilon_i = f_i - \varepsilon_i \,. \tag{17}$$

The meaning of equation (17) is that country i can avoid (or, at least, reduce) the risks of national fiscal unsustainability by adopting a restrictive fiscal policy (i.e., $s_i - \bar{s}_i > 0$).

The instability risk of the monetary union only depends on the unsustainability of the periphery's government debt. The peripheral country is so fragile that its fiscal short-term disequilibrium can turn into a national fiscal unsustainability. The latter would compromise the stability of the monetary union, increasing the risk of domino effects that would lead to the union's breakup. The related costs are captured by S. Formally, we set:

$$S = \left(\min\{0, s_p - s_p^T\}\right)^2 \tag{18}$$

Equation (18) states that the monetary union's stability is undermined by large enough short-term fiscal disequilibria in the periphery. Given our assumptions that a sovereign debt shock hits only the periphery, we can state that $\varepsilon_p = \varepsilon > 0$ and $\varepsilon_c = 0$. Hence, equation (4) implies that the fiscal authority of country ***p*** is potentially able to offset the consequences of a sovereign debt shock ($\varepsilon_P > 0$) on the (un)sustainability of its government debt, and consequently on the stability of the monetary union in equation (18).

This conclusion implies that policymakers would have to become active when a debt shock hits the peripheral economy and causes policy tradeoffs. We sometimes refer to $f_i > 0$ as the short-run fiscal primary surplus, which is a positive short-run deviation of this surplus from the long-run equilibrium. Hence, in our stylized model, all the policymakers' targets are met in the long run. However, policymakers would have to become active when a debt shock hits the peripheral economy and causes policy tradeoffs. We sometimes refer to $f_i > 0$ as the short-run fiscal primary surplus, which is a positive short-run deviation of this surplus from the long-run equilibrium**.**

The short-run policymakers' actions are driven by their losses, which they attempt to minimize. National fiscal authorities focus on domestic outcomes (x_i, π_i) and on the fiscal sustainability $(s_i - s_i^T)$, which

[24] Determining this value is beyond the scope of the present paper. We assume that long-run sustainability is satisfied and governments are fiscal responsible. Therefore, the long run primary budget consistent with the fiscal sustainability can obtained from the debt equation, $D_t = B_t + (1 + i_t)D_{t-1}$, where D_t (B_t) is the government debt (primary deficit) and i_t is the interest rate on debt. It follows that fiscal sustainability implies that, in the long run, the primary budget should satisfy $B = -\beta D$. Hence, a positive debt in the long run requires a positive target for the fiscal balance to be sustainable.

is affected by the deviation of s_i from s_i^T. In the short term, they aim at minimizing their short-run loss.[25] Formally, the short-run loss of country ***i's*** fiscal authority is defined by:[26]

$$F_i = \frac{1}{2}\left[{x_i}^2 + a_i\,{\pi_i}^2 + b_i\,(s_i - s_i^T)^2 + c_i\,S\right] \quad i \in \{p, c\} \tag{19}$$

where s_i represents the primary balance-to-actual output ratio; s_i^T denotes the long-term level of the latter ratio that also represents the target value of s_i; and a_i, b_i, and c_i are country-specific parameters.
Note that this short-run loss also depends on the instability risk of the monetary union, which is captured by S. As we have repeatedly stated, the union's stability represents a public good; hence, it is not surprising that the risk of instability matters for both the fiscal authorities.

Let us now refer to the loss function of the third policymaker in our stylized model: the single central bank. We assume that the latter aims to guarantee price stability but is also interested in avoiding the breakup of the monetary union.[27] Formally, the central bank's loss function is given by:

$$B = \frac{1}{2}\left(\pi^2 + c\,S\right) \tag{20}$$

where the parameter c denotes the weight that the central bank assigns to the cost of the monetary union's instability relative to the inflation goal.

Equations (19) and (20) formalize the fact that policymakers assign great importance to the stability of the monetary union. These equations also show that there are externalities among the related monetary and fiscal policy decisions. The analysis of the potential strategic conflicts stemming from these externalities is provided in the next section.

4. The monetary policy regimes

This section aims to compare the effects of three different monetary policy responses to a sovereign debt shock in the periphery. As showed above (see Section 2), these three responses can roughly capture the ECB's main initiatives from 2008 to 2018. Each of these regimes determines the different strategic interactions between both the peripheral and core fiscal authority, and the common central bank. Formally, we introduce three (monetary) policy regimes in our game. which are labelled as:

1. No monetary intervention (***NR***).
2. Conventional regime (***CR***).
3. Quantitative easing or structural rescue (***QE***).

The timing of each policy regime is as follows. In the ***NR***, a sovereign debt shock hits the periphery, the fiscal players then simultaneously set their fiscal budgets, while the central bank does not take any action

[25] The loss would have to be minimized over the two periods (short and long run) that characterize the dynamics of our model. However, as we will formally show below, losses in the long run are equal to zero since policymakers successfully equalize the market values of their outcomes to the relative targets (or natural) values.

[26] Our representation of the fiscal authorities' preferences follows the existing literature (cf. Dixit and Lambertini, 2001, 2003a, and 2003b; Demertzis ***et al***., 2004; Buti ***et al***., 2009; Di Bartolomeo and Giuli, 2011). A general discussion on the introduction of fiscal policy in policy games is offered in Ciccarone ***et al***. (2007) and Beetsma and Giuliodori (2010).

[27] The former assumption derives from the European Treaties. The latter is compliant with the Outright Monetary Transactions (OMT) program, announced by Draghi at the end of July 2012 and launched by the ECB at the beginning of the following September.

(formally we need to derive a two-players' Nash equilibrium). In ***CR***, after the shock hits the periphery, fiscal players set their fiscal budgets and, at the same time, the central bank manages the interest rate (i.e., a three-players' Nash equilibrium). Finally, in ***QE***, the central bank credibly announces its policy before the fiscal authorities set their balances in a Stackelberg equilibrium where the monetary authority is the game leader.

The intuition behind the policy regime is that in ***NR*** the common central bank keeps a passive role, even if a sovereign debt crisis occurs in the periphery. Conversely, in ***CR***, the central bank is ***ex-post*** active in the sense that it handles the interest rate to stabilize prices, which are affected by the sovereign debt shock. In this regime, when the shock hits the peripheral country, all policymakers react to minimize their losses. The peripherical fiscal authority consolidates its domestic debt by running a primary surplus; hence, the central bank reacts by cutting its interest rate to avoid deflation in the monetary union. Finally, in our rough approximation of ***QE***, the central bank credibly announces (***ex-ante***) that monetary policy will accommodate the periphery's fiscal efforts in consolidating the domestic debt due to any sovereign debt shock. Following this strategy, the central bank signals to the peripheral fiscal authority that it will reduce the cost of fiscal consolidation. Hence, the central bank can partially anticipate – and internalize in its expansionary monetary policy – that this fiscal authority will react by running a higher fiscal surplus.[28]

The next section describes the equilibria of the different policy regimes in details by solving for the Nash and Stackelberg equilibria.

5. The monetary union stability and the central bank's action[29]

5.1. No-intervention regime (NR)

In ***NR***, the policy game equilibrium is only determined by the strategic interactions between national fiscal authorities; the central bank has in fact a passive stance, i.e., the interest rate does not change. Both fiscal authorities choose f_i to minimize (19) subject to (13) – (15) and (17). Solving, the fiscal authorities' reaction functions are:

$$f_i = A_i\varepsilon_i - B_i(r - r^n) \quad \text{for } i \in \{p, c\} \tag{21}$$

where: $A_i = \frac{z_i}{a^2(1+\kappa^2 a_i)+z_i} \in (0,1)$ and $B_i = \frac{ab(1+\kappa^2 a_i)}{a^2(1+\kappa^2 a_i)+z_i} > 0$, $z_p = b_p + c_p$ and $z_c = b_c$, measure the reaction of the fiscal authorities to a debt shock and to the related monetary policy, respectively. Equation (21) implies that the national fiscal authorities always react to a fiscal shock ($\varepsilon_i > 0$) and to the related monetary expansion ($r < r^n$) by means of a public debt consolidation ($f_i > 0$). Note that (21) characterizes the fiscal actions in all the policy regimes and not only in ***NR***.

Let us recall that we focus on $\varepsilon_p = \varepsilon > 0$ and $\varepsilon_c = 0$, i.e., on an idiosyncratic shock and on the consequent sovereign debt disequilibrium in the periphery. Furthermore, in ***NR***, the central bank does not

[28] It is worth repeating that both national fiscal authorities pursue a responsible fiscal policy. Therefore, the probability of observing a future sovereign debt shock is independent of the current monetary policy regime adopted by the central bank.

[29] The formal derivation of all the equilibria are provided in Appendix B.

have an active stance. The behavior of the common central bank is $r = r^n = \bar{r}$. The shock in the periphery produces negative effects also in the core country, since it increases the instability of the monetary union. However, the core fiscal authority cannot influence the peripheral fiscal policy in terms of fiscal consolidation. It follows that the core fiscal authority does not take any action, meaning that the output gap and the inflation rate of this country are unaffected by sovereign shock in the periphery. Formally, equation (21) implies that:[30]

$$f_c^{NR} = x_c^{NR} = \pi_c^{NR} = 0\,. \tag{22}$$

Conversely, this same shock determines the reaction of the peripheral fiscal authority. The latter increases the deviation of the government's primary balance surplus from its long-run target, i.e., it implements a national public debt consolidation with the aim of avoiding fiscal unsustainability. This consolidation plan has a recessionary and deflationary impact. Hence, it is carried out to equalize its marginal benefits, measured by the reduction in the risk of government debt unsustainability in the periphery and in the related risk of instability in the monetary union, and its marginal costs, measured by the adverse change in the output gap and by deflation. Formally, the government debt consolidation in the periphery that meets the above equalization is expressed by:

$$f_p^{NR} = A_p\varepsilon\,. \tag{23}$$

The corresponding outcome for the peripheral country is:

$$y_p^{NR} = -aA_p\varepsilon, \pi_p^{NR} = -a\kappa A_p\varepsilon, \text{and } \left(s_p - s_p^T\right)^{NR} = \left(1 - A_p\right)\varepsilon. \tag{24}$$

It is worth noting that, in our stylized model, the inflation rate in the monetary union is proportional to the inflation rate in the peripheral country, $\pi^{NR} = -a\kappa A_p\varepsilon/2$, so that the union as a whole is in deflation. It is also worth noting that $\left(1 - A_p\right)\varepsilon$ is a measure of the risk of monetary union instability. These two elements show that the policy of government debt consolidation, implemented by the peripheral fiscal authority, is suboptimal for the monetary union. The rationale is that the periphery's policymaker is unable to internalize the negative externalities that its fiscal policy will produce in the core country. Moreover, the passive role played by the common central bank hinders any adjustment towards these externalities.

5.2. Conventional regime (CR)

Let us now analyze the central bank's strategy to adjust the interest rate after the occurrence of the sovereign debt shock, when this central bank has an active role. In both ***CR*** and ***QE***, recall that, at the first sight, the policy regime only matters for the central bank in the sense that fiscal authorities continue to behave according to (21). The central bank's optimal choice is determined by minimizing (20) under the constraints (13)-(15) and (17). The solution of this minimization problem must satisfy:

$$\pi\frac{\partial\pi}{\partial r} + c\left(s_p - s_p^T\right)\frac{\partial s_p}{\partial f_p}\frac{\partial f_p}{\partial r} = 0. \tag{25}$$

[30] We use the ***NR*** apex to denote the equilibrium outcomes of ***NR***. Subsequently, apexes ***CR*** and ***QE*** will refer to the other two regimes.

Equation (17) highlights the differences between the ***CR*** and ***QE*** regimes. In ***CR***, the central bank adjusts ***ex-post*** the interest rate but does not announce its optimal monetary policy and the related rescue plan. Thus, by definition, this policy cannot affect the fiscal policy of the peripheral authority. It follows that: $\partial f_p/\partial r = 0$. The consequence is that ***CR*** always leads to: $\pi = 0$. The rationale of this result is evident: the central bank cannot directly affect its second target, that is, the stability of the monetary union, since it utilizes only one instrument (r) to efficiently achieve its first target: $\pi = 0$.[31] Conversely, in ***QE***, the central bank announces its optimal monetary policy. This policy incorporates ***ex-ante*** the expected impact on the choices of the peripheral fiscal authority, that is, it already considers that the peripheral authority will react to the expansionary monetary policy by strengthening its fiscal consolidation (cf. equation (21)). Therefore, $\partial f_p/\partial r < 0$, and hence $\pi > 0$. The rationale of this result is also evident: the central bank has still only one instrument (r); however, it pursues both targets ($\pi = 0$, and the stability of the monetary union). Hence, it should face a tradeoff between these two targets.

Let us focus on ***CR***. The central bank, similar to the core fiscal authorities in ***NR***, is unable to influence the management of government debt by the fiscal authority in the peripheral country. To counterbalance the risk of deflation caused by the fiscal consolidation in periphery, the central bank can adopt an expansionary monetary policy by decreasing ***ex-post*** the interest rate. However, it cannot affect the risk of instability in the monetary union. Formally, from (17), the central bank reduces the interest rate below its natural (long-run) value until its target (zero-inflation rate) is met:

(26) $$r^{CR} - r^n = -\frac{aA_p}{\Omega}\varepsilon < 0$$

where $\Omega = 2b - aB_c - aB_p$ (which is positive, since $b > aB_i$ for $i \in \{p, c\}$).[32]

Note that the central bank's inflationary target is defined in average terms, i.e., $\pi^{CR} = 0$ for the monetary union as a whole. Hence, the implementation of equation (26) does not imply a zero-inflation rate in the peripheral and core countries: it reduces the intensity of the deflation rate in the periphery and, in the meantime, causes a positive inflation rate in the core. These impacts of monetary expansion cause a reaction in both countries.

To restore the previous zero-inflation equilibrium in the core country, the relative national fiscal authority implements a fiscal contraction ($f_c^{CR} > 0$). Formally, we see that the primary short-run surplus of the core country is increased above its natural (long-term) value until the national fiscal authority expects that its target (zero-inflation rate) is met:

(27) $$f_c^{CR} = \frac{aA_pB_c}{\Omega}\varepsilon$$

However, this reaction produces the expected result only temporarily and not as a final equilibrium of the game. In fact, given that the deflationary policy implemented by the national authority in the periphery implies $\pi_P < 0, \pi_c = 0$, the zero-inflation target of the core country would be incompatible with the target of the

[31] The target-instrument approach to policy game is illustrated in Acocella ***et al***. (2012).

[32] The latter inequality is easy to verify.

central bank ($\pi^{CR} = 0$ for the monetary union as a whole). Hence, if the fiscal authority of the core country adopts $f_c^{CR} > 0$, the central bank will expand the money supply until its target ($\pi^{CR} = 0$) is reached.

These partial outcomes of ***CR*** emphasize that the attempt to contrast the central bank target is doomed to fail. The restrictive stance of the core fiscal policy is ineffective since its impact is fully offset by the ***ex-post*** reactions of the monetary policy. In the final equilibrium of the game, the core country will be characterized by a positive inflation rate:

(28) $$\pi_c^{CR} = \frac{\kappa a A_p (b - aB_c)}{\Omega} \varepsilon > 0 \,.$$

Consequently, as showed by equation (13), this same country will experience an undesired increase of its actual output above its natural (long-term) output, that is, it will record a positive output gap. Our first conclusion with respect to ***CR*** is, thus, that the adoption of an active monetary policy by the central bank does not eliminate inefficiencies. The latter are due to a lack of coordination between the single central bank and the core fiscal authority.

In ***CR*** the expansionary monetary policy also affects the fiscal policy in the peripheral country. The relative national authority finds it advantageous to implement further public debt consolidation, since the monetary stance reduces the costs of fiscal restrictions in terms of output reductions. Formally, we have:[33]

(29) $$f_p^{CR} = A_p \frac{2b - aB_c}{2b - aB_c - aB_p} \varepsilon > A_p \varepsilon = f_p^{NR}$$

Equation (29) shows that the expansionary monetary policy implies lower instability and breakup risks for the monetary union with respect to the case of a passive monetary policy (see above, ***NR***). Moreover, together with equations (13) and (14), it shows that this same monetary policy mitigates the recession (and the deflation rate) in the peripheral country. Formally, we have:

(30) $$x_p^{CR} = -aA_p \frac{b - aB_c}{2b - aB_c - aB_p} \varepsilon > -aA_p \varepsilon = x_p^{NR}$$

where the inequality depends on the fact that $\frac{b - aB_c}{2b - aB_c - aB_p} = \frac{b - aB_c}{\Omega} \in (0,1)$, i.e., $b - aB_c < 2b - aB_c - aB_p$ as $b - aB_p > 0$.

The outcomes of the ***CR*** policy game in the peripheral and core countries emphasize that monetary policy operates as an indirect risk-sharing mechanism. Although designed to eliminate deflation, the central bank's active policy of decreasing ***ex-post*** the interest rate facilitates the implementation of debt consolidation in the peripheral country even if at the cost of imposing a higher inflation rate in the core country. Therefore, it partially transfers the burden of stabilizing the monetary union from the periphery to the core. The analyzed inefficiencies of ***CR*** depend on the fact that this form of risk sharing is the result of non-cooperative interactions between the three policymakers.

Coordination between the core fiscal authority and the single central bank would eliminate the costly and useless consolidation of government debt in the core country, and it would thus increase the likelihood that ***CR*** will become a Pareto improving policy compared to a passive monetary policy. As long as the core

[33] The inequality of equation (30) holds since $b > aB_i$.

country is sufficiently concerned about the stability of the monetary union as a whole, this could hold true even without coordination. In terms of welfare effects, this is equivalent to stating that the central bank and the peripheral country are always better off in the case of ***CR*** than in the case of ***NR***. Nevertheless, the core country could more than compensate its losses (inflation rate higher than zero and useless public debt consolidation) in ***CR*** with respect to ***NR***, if it sufficiently cared about the minimization of instability and the breakup risk of the monetary union.

5.3. Quantitative easing (QE)

The third policy regime is based on a ***QE*** program that has a specific feature with respect to ***CR***: the single central bank can influence the management of the peripheral public debt (and hence, the monetary union's stability), by anticipating the policy reaction of the related national fiscal authority to its announced monetary policy. In this situation, the (credible) central bank acquires full control over the trade-off between its two targets (zero inflation rate and monetary union stability) in the strategic interaction with the peripheral fiscal authority. This implies that, in decreasing the interest rate, the central bank can calibrate each further increase of the inflation rate above the zero target in terms of its impact on strengthening government debt consolidation and, hence, on decreasing the risk of unsustainability of the relative government debt in the peripheral country. It follows that, in ***QE***, differently from ***CR***, the central bank has the willingness to raise the inflation rate above the zero target. Thus, the central bank pursues a more expansionary monetary policy, generating a positive inflation rate $\pi^{QE} > 0$ (where: $\pi^{QE} > \pi^{CR} = 0$).

To prove these results, we can formally determine the Stackelberg equilibrium value for the interest rate and for the government debt consolidation in the peripheral country. By deriving (21) and plug in (25), we obtain:[34]

(31) $$r^{QE} - r^{n} = -\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon < -\frac{aA_p}{\Omega}\varepsilon = r^{CR} - r^{n}$$

and substituting back into (15), we have

(32) $$f_p^{QE} = \left[A_p + B_p\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\right]\varepsilon > A_p\frac{2b-aB_c}{\Omega}\varepsilon = f_p^{CR} > f_p^{LT}.$$

Recalling the inefficient reaction of the core fiscal authority to π^{CR} but $\pi_c > 0$ in ***CR***, we have to maintain that this same fiscal authority will ***a fortiori*** react to a positive average inflation rate which implies $\pi_c^{QE} > \pi_c^{CR}$. The core country will thus implement a more severe public debt consolidation. Formally, we have:

(33) $$f_c^{QE} = B_c\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon > \frac{aA_pB_c}{\Omega}\varepsilon = f_c^{CR}\ .$$

Our conclusion is that, analogously to ***CR***, ***QE*** operates as an indirect risk-sharing mechanism. ***QE*** facilitates the implementation of government debt consolidation policies in the peripheral country, and it partially transfers the cost of decreasing the risk of the related debt unsustainability and of the monetary union's instability to the core country. The equilibrium in the ***QE*** policy regime, as stated by equations (31) –

[34] The inequality in equation (31) can be obtained with some algebra by expanding $\boldsymbol{A_p}$ and $\boldsymbol{B_p}$. In a nutshell, it reduces to $b - aB_c > 0$. The same occurs for inequalities in (32) and (33). Mathematical proofs are available upon request.

(33), is associated with the lowest breakup risk of the monetary union with respect to the other two policy regimes. However, the core country faces an undesired increase in its inflation rate ($\pi_c^{QE} > 0$) and a consequent undesired increase in its actual output above its natural (long-term) output. It is worth noting that these increases are greater than the corresponding increases in the case of ***CR***; on the other hand, the recession in the peripheral country is smaller.

In terms of welfare analysis, we can state that the peripheral country and the central bank are better off in ***QE*** than in ***NR*** and even in ***CR***. The core country also may prefer ***QE*** to the other two monetary regimes, if it is sufficiently concerned about the stability of the monetary union. This result allows us to state that ***QE*** imperfectly imitates a cooperative solution aimed at internalizing the cost of monetary union stabilization. In this regime, the cost of government debt consolidation is counterbalanced by the central bank's monetary policy; on the other hand, this cost is almost fully imposed on the core country. We cannot exclude that this cost is so high that the core country is worse off with respect to ***NR*** and ***CR***; and that, in any case, the final equilibrium of the game is suboptimal. Therefore, the coordination between the core fiscal authority and the ECB would increase the welfare of the monetary union. Once the costs of the restrictive fiscal policy in the core country are internalized, this latter country would probably support the implementation of the ***QE*** policy game.

Even if it seems paradoxical, the core country can maintain that the intensity in the decrease of the interest rate by the central bank to support public debt consolidation in the peripheral country is insufficient. To obtain this result, it is enough to consider that coordination meets two conditions: the costs of the core country could also be internalized, and this country's actual concern about monetary union stability and the zero-inflation rate could be aligned with the central bank's preferences.

6. Discussion and conclusion

Since the launch of the euro area in 1999 the European institutional and governance design has been a construction site. The tension between risk sharing and risk reduction remains unresolved, tending to produce a stalemate in this design and the consequent recourse to market discipline. The latter hinders the convergence between the core and the peripheral EMU member states, thus worsening their relationships and feeding a growing lack of reciprocal trust. The same applies to the attitude of national governments and populations towards European institutions. A possible exit from this dangerous situation would be strengthened coordination between European and national policy authorities. If this coordination had been operative in the recent past, there would have been a dramatic reduction in the costs of overcoming the European banking and sovereign debt crises. The European economic recession would have been shorter and less severe. Today, the existence of this coordination could improve the stability of the euro area as well as its actual growth rate.

In this paper, we have considered the impact of financial instability on sovereign debts of a representative peripheral country. The aim was to show that quantitative easing might operate as an indirect risk-sharing mechanism that could improve EMU stability and the welfare of (some of the) member states. The rationale of our finding is twofold. First, quantitative easing reduces the cost of fiscal adjustment in the periphery, incentivizing consolidation policies that decrease the default probability and stabilize the EMU.

Secondly, although the representative core country benefits from euro area stabilization (which is a public good), it must face some costs; hence, quantitative easing is not compatible with the optimal equilibrium in the core country. Consequently, although it is certainly true that the periphery improves its welfare, the government of the core country faces a trade-off between the improved stability of the euro area and its national cost; and it is impossible to state, as a general rule, that the expected gain of improved stability is higher than the expected related costs.

To specify these results, we focused on the potential costs of the lack of coordination when an indirect risk-sharing mechanism is introduced through the ECB's monetary policy reaction to sovereign debt shocks. We compared the effects of three different monetary policy responses to a shock in the peripheral country: no intervention regime (***NR***), conventional regime (***CR***), and quantitative easing regime (***QE***). These three regimes provide three different levels of risk sharing.

1. In the case of no intervention regime, the entire burden of EMU stabilization falls on the periphery. Moreover, fiscal consolidation in the periphery cannot be influenced by the core and does not have direct effect on the core, so that the fiscal authority of the core country does not take any action. However, if we recognize that the stability of the euro area is a public good, the core country can be willing to pay a moderate cost for more stabilizing consolidation in the periphery and, thus, to look for cooperative solutions. This implies that ***NR*** is suboptimal. In a sort of prisoner dilemma, the core fiscal authority does not play an active role only because of the non-cooperative approach.
2. In the conventional regime, the monetary policy becomes effective even if it cannot influence the peripheral country's decisions on fiscal consolidation. The central bank can only react to the deflationary and recessionary effects of this consolidation in the periphery and, as a byproduct, in the core country. The expansionary monetary policy leads to an average inflation rate in the union which is equal to zero. This expansionary policy has beneficial effects on the peripheral country, because it reduces the cost of fiscal consolidation and allows for more stabilizing fiscal adjustments. However, this greater stability has a cost for the core country, since the latter suffers an undesired positive inflation rate and, therefore, an excessive expansion. Moreover, if the core country does not internalize the effects of the monetary expansion (by means of coordination with the ECB), it will react to its inflation rate by reducing its public spending. This fiscal adjustment is useless, since it is always fully offset by the central bank but generates an additional cost for the core country.

   From the welfare point of view, conventional monetary policies act as a risk-sharing mechanism that roughly approximates cooperative solutions by shifting the cost of stabilization from the peripheral to the core country. The welfare of the periphery undoubtedly increases, whereas the welfare of the core depends on the relative weight attributed by the latter to its costs of higher inflation and positive output gap with respect to the benefits deriving from greater stability of the monetary union. The empirical evidence makes it reasonable to assume that, in the EMU's recent crises, the stability benefits would have been higher than the inflation's costs and excessive output gaps. However, the core country also suffers the costs of a "useless" spending reduction. Hence, it is impossible to generally state that, in ***CR***, the welfare of the core country would improve. An appropriate policy intervention

could tip the scales in favor of a welfare improving conventional monetary policy: it would be sufficient to establish coordination between the fiscal authority in the core country and the central bank.

3. In this last respect, the quantitative easing regime seems to work more efficiently. In this regime, the central bank anticipates that the peripheral country will react to an expansive monetary policy with more fiscal consolidation. Then, the central bank can choose the inflation rate that equalizes the marginal benefits (EMU stability) and the marginal costs (higher inflation) of the monetary expansion, giving up the (zero-) inflation target. The result is a greater monetary expansion and stronger EMU stability. This mechanism reproduces the main features of ***CR***, except that the policy's aim is not to achieve a zero-inflation rate but to optimize the trade-off between EMU stabilization and the EMU's inflation rate. The welfare effects are also similar to those discussed in ***CR***. Let us just add that the central bank acts in the interests of the EMU countries. Hence, the ECB's trade-off between the inflation rate and the stabilization of the monetary union would have to coincide with that of the core country. Consequently, if it was possible to eliminate the useless costs of fiscal restriction in the core, the quantitative easing would come very close to the cooperative solution.

Our conclusion is that the quantitative easing program or any active central bank's policy tends to imperfectly mimic a cooperative solution. These policies imply risk sharing between the periphery and the core. Moreover, to improve its feasibility, quantitative easing also requires cooperation between the core country and the central bank. In that case, there is a high probability that quantitative easing can also increase the core country's welfare.

The effects of strategic interaction between independent authorities is a challenging issue for the European institutional and governance design. This paper has focused on the strategic interactions between the common central bank and the national fiscal authorities (a sort of strategic monetary channel). A natural extension would be to consider the strategic interactions between governments stemming from the existence of fiscal spillovers through aggregate demands (a sort of fiscal strategic channel). This clearly requires introducing demand spillovers from intra-European trade into the model. However, we can roughly translate some insights derived from our paper to the case of fiscal spillovers. Potentially, fiscal expansions in the core may play a role that is similar to the active monetary policy's intervention described in our paper; therefore, fiscal expansions could also act as an implicit risk-sharing mechanism. In fact, as active monetary policies, they could reduce the cost of consolidation for the peripheral government and internalize the risk of instability in the monetary union. However, as in the case of expansionary monetary policies, these results could become fully effective only if there was a sort of core fiscal leadership; but the latter would be politically unfeasible without a fiscal union and a centralized fiscal budget in the EMU. We leave this investigation to future extensions.

Appendix A – Phillips curve

The level of price (p_i) is an average of the optimal price (p_i^*) and the past price ($\bar{p}_i$), i.e., $p_i = \alpha p_i^* + (1-\alpha)\bar{p}_i$. Then, inflation in country i , $\pi_i = p_i - \bar{p}_i$, can be defined as:

(A1) $$\pi_i = (1-\alpha)(p_i^* - \bar{p}_i)$$

The optimal price is defined as follows:[35]

(A2) $$p_i^* = \alpha\beta p_i^{*e} + (1-\alpha\beta)\left[p_i + \frac{1+\sigma\eta}{\sigma}(y_i - y_i^n)\right]$$

i.e.,

(A3) $$p_i^* - \bar{p}_i = \alpha\beta(p_i^{*e} - p_i) + \pi_i + (1-\alpha\beta)\frac{1+\sigma\eta}{\sigma}(y_i - y_i^n).$$

Finally, by using the inflation dynamics (A1), we get

(A3) $$\frac{1}{1-\alpha}\pi_i = \frac{\alpha\beta}{1-\alpha}\pi_i^e + \pi_i + (1-\alpha\beta)\frac{1+\sigma\eta}{\sigma}(y_i - y_i^n)$$

(A3) coincides with the Phillips curve in equation (14).

Appendix B – Analytical solutions of the policy games

We assume $\varepsilon_p = \varepsilon > 0$ and $\varepsilon_c = 0$, i.e., sovereign debt shock only hits the periphery. Preliminarily, note that $b - aB_i$ for $i \in \{p, c\}$, where $A_i = \frac{z_i}{a^2(1+\kappa^2 a_i)+z_i} \in (0,1)$ and $B_i = \frac{ab(1+\kappa^2 a_i)}{a^2(1+\kappa^2 a_i)+z_i} > 0$ with $z_p = b_p + c_p$ and $z_c = b_c$. It follows $\Omega = 2b - aB_c - aB_p > 0$.

B1. No intervention regime

The regime implies that $r = r^n$. Under this condition, fiscal authorities minimize (1) constrained by (13)-(15) and (17). The corresponding reaction functions are:

(B1) $$f_p = A_p\varepsilon$$

(B2) $$f_c = 0$$

Equations (B1) and (B2) also express the equilibrium policy (i.e., $f_p^{NR} = A_p\varepsilon$ and $f_c^{NR} = 0$). Substituting them back into (13) – (15) and (17), we obtain the equilibrium values for the output gap, inflation and primary balance in the periphery and core countries:

(B3) $$x_p^{NR} = -aA_p\varepsilon$$

(B4) $$\pi_p^{NR} = -a\kappa A_p\varepsilon$$

(B5) $$s_p^{NR} - s_p^T = (1-A_p)\varepsilon$$

(B6) $$x_c^{NR} = \pi_c^{NR} = s_c^{NR} - s_c^T = 0.$$

[35] We roughly follow Galì's (2008) textbook. For an alternative derivation, see, for example, Benigno (2015).

A2. Conventional regime

In this case, all the policymakers simultaneously minimize their losses under constraints (13) – (15) and (17). The resulting reaction functions are:

(B7) $$f_p = A_p\varepsilon - B_p(r - r^n)$$

(B8) $$f_c = -B_c(r - r^n)$$

(B9) $$r - r^n = -\frac{1}{2}\frac{a}{b}\left(f_p + f_c\right)$$

Solving system (B7)–(B9), we get the Nash equilibrium:

(B10) $$f_p^{CR} = A_p\frac{2b-aB_c}{2b-aB_c-aB_p}\varepsilon$$

(B11) $$f_c^{CR} = A_p\frac{aB_c}{2b-aB_c-aB_p}\varepsilon$$

(B12) $$r^{CR} - r^n = -\frac{aA_p}{2b-aB_c-aB_p}\varepsilon$$

Equations (B10)–(B12) imply for the periphery:

(B13) $$x_p^{CR} = -aA_p\frac{b-aB_c}{2b-aB_c-aB_p}\varepsilon$$

(B14) $$\pi_p^{CR} = -a\kappa A_p\frac{b-aB_c}{2b-aB_c-aB_p}\varepsilon$$

(B15) $$s_p^{CR} - s_p^T = \left[1 - A_p\frac{2b-aB_c}{2b-aB_c-aB_p}\right]\varepsilon$$

Similarly, for the core, we obtain:

(B16) $$x_c^{CR} = aA_p\frac{b-aB_c}{2b-aB_c-aB_p}\varepsilon$$

(B17) $$\pi_c^{CR} = a\kappa A_p\frac{b-aB_c}{2b-aB_c-aB_p}\varepsilon$$

(B18) $$s_c^{CR} - s_c^T = -A_p\frac{aB_c}{2b-aB_c-aB_p}\varepsilon$$

The aggregate inflation rate is:

(B19) $$\pi^{CR} = 0\,.$$

A3. Quantitative easing

Now we consider the Stackelberg equilibrium with the central bank as the game leader. The fiscal authorities behave as stated in the previous equations (i.e., (B10) and (B11)), whereas the central bank minimizes (20), anticipating (B10) and (B11). Optimal monetary policy then implies:

(B20) $$r^{QE} - r^n = -\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

where we recall that $\Omega = 2b - aB_c - aB_p > 0$.

By using (B10) and (B11), it follows that

(B21) $$f_p^{QE} = \frac{aA_p\Omega(aB_p+\Omega)\kappa^2+4cB_p^2}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(B22) $$f_c^{QE} = \frac{aA_pB_c\Omega\kappa^2+4cB_cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

By using (B20), (B21), and (B22) in (13) – (15) and (17), we get:

(B23) $$x_p^{QE} = -\frac{aA_p\Omega(b-aB_c)\kappa^2-4cB_p(b-bA_p-aB_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(B24) $$\pi_p^{QE} = -a\kappa\frac{aA_p\Omega(b-aB_c)\kappa^2-4cB_p(b-bA_p-aB_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(B25) $$s_p^{QE} = s_P^T + \frac{\Omega\kappa^2[(1-A_p)\Omega-aA_pB_p]}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(B26) $$x_c^{QE} = (b-aB_c)\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(B27) $$\pi_c^{QE} = \kappa(b-aB_c)\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(B28) $$s_c^{QE} - s_c^T = -B_c\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

The aggregate inflation is:

(B29) $$\pi^{QE} = \frac{2cB_p[\Omega-A_p(2b-aB_c)]}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon.$$

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