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

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Abstract. This paper examines the impact of exogenous shocks on sovereign debts in an incomplete monetary union. We assume that financial stability is a public good which can be undermined by sovereign debt problems in fragile (peripheral) members. Our model shows that, unlike the common misconception, active monetary policies do not induce the peripheral government to relax its fiscal constraints; on the contrary, these policies tend to incentivize fiscal discipline by reducing the cost of balance consolidation. Active monetary policies, in fact, partially reallocate the stabilization costs from the periphery to the core of the union, preserving the common good and facilitating fiscal discipline in the periphery.

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

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1. Introduction

After the 'bail in' of a large part of the private holders of Greek debt and the dramatic increase in the probability of Greece's exit from the Euro Area (EA) during the summer of 2015, sovereign default was no longer seen as an extreme event.[1] This dramatic change highlighted that the EA's institutional design was, at the same time, too rigid and too fragile to absorb the impact of external shocks. The financial turmoil of 2007-2009, the sovereign debt crisis, and the Covid-19 pandemic of 2020-2021 proved to be, after all, strong elements of instability in an incomplete economic and monetary union such as the EA. These events have also underlined how financial crises even in small EA countries can have pervasive effects leading to a generalized contagion in the absence of exceptional initiatives (Buti, 2020). The natural implication is that the EA's financial stability should be considered as a public good.

Our paper focuses on the European Central Bank's (ECB) response to the sovereign debt crisis. During the financial turmoil and the related European recession, the instability was driven by the liquidity and insolvency crises of the EA's banking sector, the vicious circle between those banking crises and the sovereign debt crisis (the so-called 'doom-loop'), and the limited effectiveness of conventional monetary policies under lower-bound interest rates. To cope with these events, the ECB made recourse to new policy tools, such as the Longer-Term Refinancing Operations (LTRO) and then various unconventional monetary policies. Here, we focus on the new approach outlined in Mario Draghi's famous quote "whatever it takes" and implemented through the approval of the Outright Monetary Transactions, OMT (2012). The announcement of the OMT is assumed to be the ECB's first unconventional monetary policy initiative that includes, in a stylized way, the main ingredients of the subsequent unconventional tools (such as the Assets Purchase Program). A lively economic and political debate has been assessing the effects of these policy initiatives.[2]

We aim to address two crucial policy questions. If the EA's stability is a common good which can be undermined by asymmetric sovereign debt shocks, will handling the consequent disequilibria in the most fragile (peripheral) countries as a *private* problem be efficient and effective? And will commitments to active monetary policies be effective in producing adjustments from asymmetric shocks in peripheral member states without the support of national or centralized fiscal policies?

To address these two questions, we analyze the rationale and effects of the interaction between monetary and fiscal policies under different central bank policy options in a stylized core-periphery

[1] Indeed, the 2008 crisis in the Baltics can be interpreted as a prequel of the increased risk of an EA breakdown.

[2] For a review of this debate, see Benigno *et al.* (2020).

monetary union. We maintain that the financial stability of the monetary union is a public good for the whole area. In our model this stability can be undermined by idiosyncratic sovereign debt shocks. Specifically, it is worthwhile to refer to a shock hitting a (peripheral) country and generating an excess deviation of its government debt from a 'natural' equilibrium threshold. This deviation potentially destabilizes the whole union. We assume that cooperative equilibria are unfeasible due to the lack of a fiscal and political union (incomplete economic and monetary union), and we focus on non-cooperative solutions in which policymakers are unable to fully internalize the externalities implied by their actions in the presence of a public good.

The outcomes of policymakers' non-cooperative interactions are suboptimal. However, the degree of suboptimality depends on the monetary regime in place. We consider three stylized options for the central bank: 1) no intervention; 2) strict inflation targeting; 3) commitments to an active monetary policy. In a nutshell, under no intervention, the common central bank does not react at all to the sovereign debt shock in the periphery. Under strict inflation targeting, the central bank narrowly follows its mandate and only acts to take price stability under control. Through an active monetary policy, the central bank commits to an active feedback reaction conditional on the impact of the sovereign debt shock on fiscal policies. We will show that this reaction is based on a sort of optimal "whatever it takes" strategy.

By implementing active monetary policies, the common central bank partially internalizes that the financial stability of the union is a public good that can be protected by partially reallocating the cost of debt consolidation from the periphery to the core. Our main finding is that this monetary policy choice reinforces fiscal discipline at national level. Compared to strict inflation targeting and non-intervention, active expansionary monetary policies in fact facilitate debt control in the peripheral countries and, thus, preserve financial stability. These policies operate as a sort of indirect risk-sharing mechanism that improves the macro-financial stability of the union and potentially its welfare.

Our paper is based on rich literature. As already mentioned, we introduce the financial stability issue as a public good in a quite standard strategic-interaction model between fiscal and monetary authorities following, among others, Beetsma and Bovenberg (1998, 2001), Beetsma and Uhlig (1999), Dixit and Lambertini (2001, 2003b). We share with these models the approach emphasizing the strategic nature of the link between fiscal policies and the behavior of a common central bank. However, the quoted authors do not focus on sovereign debt shocks and financial stability. We expand the idea of financial stability as a public good potentially undermined by sovereign debt shocks expressed in, among

others, Bénassy-Quéré *et al.* (2018) and Buti (2020).[3] These papers provide a broad discussion on the possible evolution in the institutional and fiscal setting of a monetary union and on the appropriate policy mix after the lessons learned from the European crises, respectively.

Our paper is also related to the literature on fiscal space. Ghosh *et al.* (2013) define (and estimate) 'fiscal space' as the difference between current government debt-to-GDP ratios and the endogenous limit beyond which this debt cannot be rolled over. The debt limits are derived from the concept of 'fiscal fatigue', whereby the government's ability to increase its primary balances cannot keep pace with rising public debt.[4] We use this concept to formalize the short-run constraints on fiscal policies, while we assume that fiscal authorities honor their commitment of stabilizing their respective government debt-to-GDP ratio at a reasonable level in the long run. We adapt (and simplify) the approach of Ghosh *et al.* (2013) to the case of a monetary union. However, we do not focus on the possibility that national fiscal policies become a vehicle for opportunistic behavior.[5] In our framework, shocks are not induced by the irresponsible conduct of national fiscal policy authorities; conversely, these national authorities operate in a benevolent way to keep the government debt at its 'natural' level, even if they face a trade-off between financial stability and economic recovery. In this sense, we complement the literature that accounts for strategic default and domino effects.[6]

Finally, our paper pursues a different approach in addressing to the open debate on risk sharing in a monetary union, with specific reference to the EA. This debate highlights the pros and cons of various explicit risk sharing mechanisms by showing that the effects of each mechanism are very sensitive to its specific design.[7] However, in the end, different views strongly depend on the weight assigned to *ex-ante* vs. *ex-post* incentives. In this respect, we are biased toward the latter since we do not consider the issue of fiscal irresponsibility in the long run and focus on the short-run effects of external shocks.

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[3] See also Beetsma and Giuliodori (2010) or Groll and Monacelli (2020).

[4] See also Bohn (1998 and 2007) and Mendoza and Ostry (2008).

[5] The importance of 'moral hazard' in driving the sovereign debt is predicated by, e.g., Benassy-Quéré et al. (2018). However, there is scant evidence that countries' debt policies are motivated by 'moral hazard'; therefore, a reference to this concept in our framework would be highly questionable both analytically and empirically (see Tabellini, 2017). Let us add, in this last respect, that 'moral hazard' is analytically different from the general concept of opportunistic behavior.

[6] 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), Canofari and Di Bartolomeo (2017), and Eijffinger *et al.* (2018).

[7] See, e.g., Favero and Missale (2012), Issing (2009), Corsetti *et al.* (2011), Beetsma and Mavromatis (2014), Furceri and Zdzienicka (2015), and Giudice *et al.* (2019).

The rest of the paper is organized as follows. Section 3 describes our analytical stylized setup. Section 4 illustrates our results and provides some suggestions on the viability and the welfare impact of monetary regimes. Finally, Section 5 concludes the paper.

3. A model of a stylized monetary union[8]

This section introduces our model, which refers to a 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 policy parameters.[9] These countries control their respective fiscal policies through national authorities, whereas the single central bank sets the common nominal interest rate. Our model is asymmetric, also in the sense that an exogenous shock just hits the periphery.

The central bank strategically interacts with national fiscal authorities in a simple two-period dynamic model characterized by price stickiness.[10] In the first period (short run), the economy is hit by a sovereign debt shock which vanishes in the long run. Due to price stickiness, the monetary policy is nonneutral in the short run. Following Beetsma and Bovenberg (1998, 2001), policy interactions fully characterize the structure of the game, which does not take account of the possible fiscal spillovers induced by international trade.[11] Thanks to this last simplification, our two-period game has a closed form solution.

The following two subsections outline the model. Subsection 3.1 illustrates the functioning of the two-period model, specifies its short-run results, and defines the long-run equilibrium. Subsection 3.2

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[8] Our model is built on Benigno (2015), which is extended to the case of a monetary union affected by a sovereign debt shock. Details and micro-foundations of our model are confined to a technical appendix, which is available upon request.

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

[10] 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).

[11] However, considering policy interactions as well as trade channels would make the model much more complex without significant improvements in the analysis of our main topic, which is the fiscal-monetary interaction. 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).

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

Our stylized monetary union is described by equations (1) and (2), which represent the demand and supply side of the economy of country *i*. Formally:

$$x_i = \bar{x}_i^e + a(g_i - \bar{g}_i^e) - b(r - \bar{\pi}_i^e - r^n) \tag{1}$$

$$\pi_i = \beta\bar{\pi}_i^e + \kappa x_i \tag{2}$$

where x_i is the output gap, g_i is a measure of fiscal policy (primary balance), r is the common nominal interest rate, π_i is the inflation rate; r^n is the natural interest rate. Bars denote long-run variables, while "e" indicate expectations. *a*, *b*, $\kappa > 0$ are defined by non-linear combinations of the deep parameters of the economy.

In the economy characterized by equations (1) and (2), the central bank controls the common interest rate, r, whereas the national governments set the fiscal policies of their respective countries. Government balance can be managed by adopting different taxation instruments.[12] We define the short-run primary balance in terms of deviations from its long-run equilibrium as:

$$f_i = \bar{g}_i - g_i \tag{3}$$

In the long run, the primary balance is $f_i = 0$, since (3) is built as a deviation from the long-run value assumed to be consistent with the long-run sustainability of the government debt (cf. Subsection 3.3). We also assume that agents perfectly forecast long-run fiscal policies, so that $\bar{g}_i^e = \bar{g}_i$.

The long-run equilibrium (natural equilibrium) can easily be obtained considering the absence of stochastic disturbances. Formally, 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

[12] An analysis of the specific effects due to different tax compositions is beyond the scope of our paper. This is the reason why we assume that the governments use lump-sum taxes to keep the tax revenues constant without changing the tax rates on consumption and labor income. The primary balance is, thus, determined by adjustments in government expenditure.

equal to zero for the sake of brevity. Optimal long-run monetary and fiscal policies are then characterized by: $\bar{r} = r^n$ and $\bar{f}_i = 0$.[13] As can easily be verified, it follows that $\bar{\pi}_i = \bar{x}_i = 0$.

The previous result means that all the policymakers' targets are met in the long run. Hence, if the economy does not face any stochastic disturbance, these targets are also achieved in the short run. In a model of the kind exposed here, several shocks and policy options can be investigated (see Benigno, 2015). The novelty of our paper is that it focuses on the sovereign debt shock. Therefore, we need to augment the monetary union model with a fiscal suitability argument. As already stated, we assume that national authorities are fiscal responsible. This means that these authorities, implicitly or explicitly, honored 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 the fiscal authorities of the two countries was systematically able to increase the primary surplus of its government balance 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.

3.2. The sovereign debt shock and the financial stability

Let us now assume that the peripheral country is hit by a sovereign debt shock. Its fiscal authority may be unable to handle the primary balance to keep this long-run equilibrium even in the short run. The possible consequent fiscal disequilibrium is costly for the peripheral country; moreover, it could create negative externalities for the monetary union that would also affect the welfare of the core country and of the central bank. This is equivalent to stating that deviations from the long-run fiscal equilibrium in the periphery undermine the financial stability of the monetary union. In accordance with the concept of financial dominance (Brunnermeier, 2016), unexpected government deficits could (directly or indirectly) induce agents who operate in financial markets to take larger risks, opportunistically anticipating and/or influencing policy interventions to improve their expected returns (cf. Benigno *et al.*, 2021).[14]

We model the above situation by stating that both countries of the monetary union do not face a government debt sustainability problem in the long run; however, the peripheral country can be

[13] 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.

[14] It is worth noting that problems of sovereign debt sustainability and of financial stability reinforce each other due to mutual exposure between the public and the private sectors. According to the doom-loop view, deteriorating creditworthiness of the public sector hurts financial sector balance sheets, which are a major holder of public debt, forcing the government to bailout banks. This, in turn, implies a further deterioration of the government's fiscal capacity.

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 financial instability in the monetary union. In this case, even the core country indirectly suffers short-run costs.

Denoting s_i^T as the goal for the government balance surplus that is consistent with long-run fiscal sustainability in country *i*, we assume that this fiscal target evolves as follows:

$$s_i^T = \bar{s}_i^T + \varepsilon_i \tag{4}$$

where $\bar{s}_i^T$ is the long-run balance surplus goal,[15] and ε_i is a short-run exogenous 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 can be measured by:

$$s_i - s_i^T = s_i - \bar{s}_i - \varepsilon_i = f_i - \varepsilon_i \ . \tag{5}$$

The meaning of equation (5) is that country i can avoid (or, at least, reduce) the risks of its short-run fiscal unsustainability by adopting a restrictive fiscal policy (i.e., $s_i - \bar{s}_i > 0$).

The financial instability of the monetary union depends on the short-run unsustainability of the periphery's government debt. The peripheral country is so fragile that its fiscal short-run disequilibrium can turn into national fiscal unsustainability. The latter could compromise the financial stability of the monetary union, and in the extreme case it could result in a risk of contagion and domino effects to the extent of leading to the union's breakup. The related costs are captured by S. Given the assumptions that a sovereign debt shock hits only the periphery (that is, $\varepsilon_p = \varepsilon > 0$ and $\varepsilon_c = 0$), we set:

$$S = \left(\min\left\{0, s_p - s_p^T\right\}\right)^2 \tag{6}$$

Equation (6) states that the monetary union's financial stability is undermined by large enough short-run fiscal disequilibria in the periphery. However, equation (5) shows that the fiscal authority of

[15] Determining this value is beyond the scope of the paper. Let us just recall that, by assumption, governments must be fiscal responsible so that long-run sustainability is satisfied. In this respect, the long-run primary government balance consistent with fiscal sustainability can be 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 nominal interest rate on debt. It follows that fiscal sustainability implies that, in the long run, the primary balance satisfies $B = -\beta D$. Hence, a positive debt in the long run requires a positive target for the government balance to be sustainable.

country *p* is potentially able to offset the threat of disequilibria in its government debt, due to a sovereign debt shock ($\varepsilon_P > 0$). This conclusion implies that policymakers should become active to minimize the negative consequences of a debt shock hitting the peripheral economy and causing possible tradeoffs.

The policymakers' short-run actions are driven by their expected losses, which they attempt to minimize. National fiscal authorities focus on macroeconomic domestic outcomes (x_i, π_i), and on fiscal sustainability ($s_i - s_i^T$). In the short run, they aim at minimizing their short-run loss.[16] Formally, the short-run loss of country *i's* fiscal authority is defined by:[17]

$$F_i = \frac{1}{2}\left[x_i^2 + a_i\,\pi_i^2 + b_i\,(s_i - s_i^T)^2 + c_i\,S\right] \quad i \in \{p, c\} \tag{7}$$

where s_i represents the primary balance-to-actual output ratio; s_i^T denotes the long-run level of that ratio, which also represents the target value of s_i; and a_i, b_i, and c_i are country-specific parameters.

Note that the short-run loss (7) also depends on the financial stability of the monetary union, which is captured by S. As we have repeatedly stated, S represents a public good for the whole area.

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 and financial stability.[18] Formally, the central bank's loss function is given by:

$$B = \frac{1}{2}\left(\pi^2 + c\,S\right) \tag{8}$$

where parameter c denotes the weight that the central bank assigns to the cost of financial instability relative to the inflation goal; π is the average inflation of the union.

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[16] The loss should be minimized over the two periods (short and long run) that characterize the dynamics of our model. However, losses in the long run are equal to zero because policymakers successfully equalize the market values of their outcomes to the relative target (or natural) values.

[17] Our representation of the fiscal authorities' preferences follows the existing literature (cf., among others, Dixit and Lambertini, 2001, 2003a, and 2003b). A general discussion on the introduction of fiscal policy in policy games is offered in Ciccarone *et al.* (2007) and Beetsma and Giuliodori (2010).

[18] In the extreme case, the central bank is interested in avoiding the breakup of the monetary union. In the EMU, this can be related to the OMT program, announced by Draghi at the end of July 2012 and launched by the ECB at the beginning of the following September.

4. The monetary union stability and the central bank's action

Our simple model allows us to analyze how different policy responses to a sovereign debt shock in the periphery of a monetary union can lead to specific interactions between the central bank and the national fiscal authorities. These interactions lead to different outcomes.

4.1. The monetary policy regimes

We explore three monetary policy regimes. Each of these regimes leads to a specific game, and it is defined as follows:

1. The first regime, which represents our benchmark, is characterized by **no monetary intervention** (*NM*). The central bank here does not react to exogenous shocks in any way, limiting its policies to keeping the nominal interest rate constant. Hence, when a sovereign debt shock hits the periphery, the national fiscal authorities of the two countries simultaneously react by setting their government balances; in the meantime, the central bank keeps the nominal interest rate constant. Formally, we derive the Nash equilibrium between the two fiscal players constrained by an interest rate fixed at its natural level.
2. The second regime is **strict inflation targeting** (*IT*). After the shock, the central bank intervenes to achieve the inflation target; hence, it modifies its policy interest rate to stabilize prices. Under this regime, the central bank's action will occur only if the observed sovereign debt shock determines an excessive average inflation rate of the monetary union and only if the national fiscal policies are ineffective in adjusting the inflation to its original equilibrium. Formally, after the shock hits the periphery, all policymakers react to minimize their losses: fiscal authorities set their government balances, and the central bank manages the interest rate in a three-player Nash equilibrium.
3. Finally, the regime associated with **active monetary policies** (*AP*) is characterized by the central bank's (*ex-ante*) commitment to stabilizing prices and to avoiding financial instability. The central bank announces that its monetary policy will accommodate the peripheral country's effort to adjust the domestic government debt hit by the sovereign debt shock. Formally, the central bank credibly announces its stance before the fiscal authorities set their

balances. This interaction leads to a Stackelberg equilibrium, in which the monetary authority is the game leader.[19]

The next subsections provide the outcomes of the different regimes, solving the corresponding policy games. Subsection 4.2 describes the no monetary intervention regime which is used as a benchmark; Subsection 4.3 analyzes the other two regimes, in which the central bank has an active role.

4.2. No monetary intervention

The policy game equilibrium associated with no monetary intervention is only determined by the strategic interactions between national fiscal authorities. The central bank has a passive role, i.e., the interest rate does not change.

Both fiscal authorities choose f_i to minimize (7) subject to (1)-(3) and (5). Solving the equation, the fiscal authorities' reaction functions become:

$$f_i = A_i\varepsilon_i - B_i(r - r^n) \quad \text{for } i \in \{p, c\} \tag{9}$$

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 respective reaction of the fiscal authorities to a debt shock and to the related monetary policy.

Equation (9) 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 ($f_i > 0$). Hence, this same equation characterizes the optimal fiscal actions in all the three policy regimes examined.

Now, let us recall that we are focusing on an idiosyncratic shock and on the consequent sovereign debt disequilibrium in the periphery, i.e., $\varepsilon_p = \varepsilon > 0$ and $\varepsilon_c = 0$. Moreover, the passive behavior of the common central bank implies $r = r^n = \bar{r}$. The shock in the periphery produces negative effects also in the core country since it increases the financial 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 as well as the inflation rate of this country are unaffected by the sovereign shock in the periphery. Formally, equation (9) for the core implies that:[20]

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[19] 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.

[20] We use the *NM* apex to denote the equilibrium outcomes of *NM*. Subsequently, apexes *IT* and *AP* will refer to the other two regimes.

(10) $$f_c^{NM} = x_c^{NM} = \pi_c^{NM} = 0.$$

Conversely, ε_p 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 government debt consolidation with the aim of avoiding short-term fiscal unsustainability. This consolidation plan has a recessionary and deflationary impact, in the sense that it causes a negative output gap and an inflation rate below the target. Hence, consolidation in the periphery faces a trade-off: its intensity is determined by the equalization of the periphery's marginal benefits, measured by the reduction in its risk of government debt unsustainability and in the related risk of financial instability in the monetary union, and periphery's marginal costs, measured by the adverse change in its output gap and by an inflation rate below the target. The government debt consolidation in the periphery that meets the above equalization is:

(11) $$f_p^{NM} = A_p\varepsilon\ .$$

The corresponding outcome for the peripheral country is:

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

It is worth noting that the inflation rate in the monetary union is proportional to the inflation rate in the peripheral country so that the inflation rate in the union falls below the target, i.e., $\pi^{NM} = -a\kappa A_p\varepsilon/2 < 0$. It is also worth noting that $\left(1 - A_p\right)\varepsilon > 0$ is a measure of the risk of a monetary union's financial instability.

The above outcomes 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 policymaker in the peripheral country does not internalize the negative externalities that its fiscal policy is producing in the core country. Moreover, the passive role played by the common central bank hinders any adjustment towards these externalities.

Our outcomes are summarized in the proposition below.

Proposition (no monetary intervention). In the case of a sovereign debt shock in the periphery without any intervention taken by the common central bank, the periphery alone faces a trade-off between fiscal and macro-financial stability. The sovereign debt shock undermines the financial stability of the monetary union and the welfare of both the core and the periphery. The former, however, does not suffer any fiscal or output instability, but it experiences large financial instability. The inflation rate of the union is below the target.

4.3. Strict inflation targeting vs. active monetary policies

Let us now analyze the central bank's strategy of adjusting the interest rate after the occurrence of the sovereign debt shock, a strategy in which the central bank plays an *ex post* active role. Fiscal authorities continue to behave according to (9).

The central bank's optimal choice is determined by minimizing (8) under constraints (1)-(3) and (5). The solution of this minimization problem requires:

$$\pi \frac{\partial \pi}{\partial r} + c\left(s_p - s_p^T\right)\frac{\partial s_p}{\partial f_p}\frac{\partial f_p}{\partial r} = 0. \tag{13}$$

Equation (13) highlights the differences between inflation targeting and active monetary policies.

1. Under a strict inflation targeting regime, the central bank adjusts *ex-post* the interest rate accounting for the fiscal actions. This means that it cannot directly affect the fiscal policy's decisions in the periphery. It follows that: $\partial f_p/\partial r = 0$. The consequence is that $\pi = 0$. The rationale of this result is evident in terms of a target/instrument approach: the central bank cannot directly affect its second target, that is, the financial stability; hence, it optimally assigns its unique instrument (r) to achieve the exact fixed target of the only variable of interest affected by its policy (price stability).[21]
2. Conversely, in the case of active monetary policies, the central bank announces its reaction to the fiscal adjustments. This move influences the decisions of the fiscal authority in the periphery: the latter will react to the expansionary monetary policy by strengthening its fiscal adjustment (see eq. (9)). The anticipation of the fiscal reaction by the central bank implies $\partial f_p/\partial r < 0$, and hence $\pi > 0$. Again, the rationale can be explained as follow. The central bank has only one instrument (r), but now it can affect both its first and second targets (price and financial stability). Hence, the central bank faces a trade-off between these two targets.

4.3.1. Strict inflation targeting

Let us focus on the inflation targeting regime. The central bank is unable to influence the management of government debt by the fiscal authority in the peripheral country. However, to counterbalance the risk of deflation caused by the fiscal consolidation in periphery, the central bank adopts an expansionary

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

monetary policy by decreasing the nominal interest rate. Formally, from (13), the central bank reduces the interest rate below its natural (long-run) level until its target (zero-inflation rate) is met:

$$r^{IT} - r^{n} = -\frac{aA_p}{\Omega}\varepsilon < 0 \tag{14}$$

where $\Omega = 2b - aB_c - aB_p$, which is positive since $b > aB_i$ for $i \in \{p, c\}$.[22]

It is worth noting that the implementation of equation (14) implies a zero-inflation rate on average ($\pi^{IT} = 0$). This implementation reduces the intensity of the deflation rate in the periphery and, in the meantime, causes a positive inflation rate in the core. Thus, the impacts of monetary expansion cause a fiscal reaction in both countries. In the end, the inflation rate in the peripheral (core) country will be below (above) the target.

Let us explain the above conclusion in some details. By attempting to restore the zero-inflation equilibrium, the core fiscal authority implements a fiscal contraction ($f_c^{IT} > 0$). The primary short-run surplus of the core country is increased above its natural (long-run) value until the national fiscal authority expects that its target (zero-inflation rate) is met:

$$f_c^{IT} = \frac{aA_pB_c}{\Omega}\varepsilon \tag{15}$$

However, the core fiscal authority's reaction does not produce the expected result. Given $\pi_P < 0$, $\pi_c = 0$ would be incompatible with price stability in the union. Hence, when the fiscal authority of the core country adopts $f_c^{IT} > 0$, the central bank expands the money supply until price stability is reached ($\pi^{IT} = 0$). Any attempt to contrast the central bank target is doomed to fail: the restrictive stance of the core fiscal policy is ineffective as its impact is fully offset by the reaction of the monetary policy. The core country will finally be characterized by a positive inflation rate, i.e.:[23]

$$\pi_c^{IT} = \frac{\kappa aA_p(b-aB_c)}{\Omega}\varepsilon > 0\,. \tag{16}$$

Consequently, this same country will experience an undesired increase of its actual output above its natural (long-run) output.

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[22] The latter inequality is easy to verify.

[23] This outcome is clearly suboptimal. The coordination between the core fiscal authority and the central bank would increase the welfare of the monetary union. If the costs of the restrictive fiscal policy in the core country were internalized, this latter country would more likely support the implementation of active monetary policies.

In this regime 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:[24]

$$f_p^{IT} = A_p \frac{2b - aB_c}{2b - aB_c - aB_p} \varepsilon > A_p \varepsilon = f_p^{PM} \tag{17}$$

Equation (17) shows that the strict inflation targeting policy implies lower financial instability for the monetary union compared to the case of no monetary intervention. Moreover, this policy mitigates the recession in the peripheral country. Formally, we have:

$$x_p^{IT} = -aA_p \frac{b - aB_c}{2b - aB_c - aB_p} \varepsilon > -aA_p \varepsilon = x_p^{NM} \tag{18}$$

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 $b - aB_p > 0$.

Equations (16), (17), and (18) show that the strict inflation targeting policy operates as an indirect risk-sharing mechanism. Although designed to eliminate deflation, the central bank's monetary policy facilitates the implementation of debt consolidation in the periphery at the cost of imposing a higher inflation rate on the core. Therefore, it partially transfers the burden of stabilizing the monetary union from the periphery to the core.

Our outcomes are summarized in the proposition below.

Proposition (strict inflation targeting). In the case of a sovereign debt shock in the periphery, strict inflation targeting always implies a zero inflation on average (i.e., the central bank target is achieved) and incentivizes fiscal discipline in the periphery. Compared to the case of no monetary intervention, the periphery experiences a less severe recession, while the core observes positive inflation. In general, strict inflation targeting reduces the financial instability in the union by transferring some costs from the periphery to the core; hence, it operates as an indirect risk sharing mechanism.

4.3.2. Active monetary policies

[24] The inequality of equation (17) holds since $b > aB_i$.

Let us now analytically specify the policy game relating to the active monetary policy regime. We determine the Stackelberg-equilibrium value for the interest rate and for the government debt consolidation in the peripheral and core countries.

By deriving (9) and inserting (13), we obtain:[25]

$$r^{AP} - r^{n} = -\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon < -\frac{aA_p}{\Omega}\varepsilon = r^{IT} - r^{n} \tag{19}$$

and substituting it back into (3), we have

$$f_p^{AP} = \left[A_p + B_p\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\right]\varepsilon > A_p\frac{2b-aB_c}{\Omega}\varepsilon = f_p^{IT} > f_p^{NM}. \tag{20}$$

Then, recalling the inefficient reaction of the core fiscal authority under the inflation targeting, we should maintain that this same fiscal authority will *a fortiori* react to a positive average inflation rate which implies $\pi_c^{AP} > \pi_c^{IT}$. This means that the core country will implement a more severe public debt consolidation. Formally, we have:

$$f_c^{AP} = B_c\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon > \frac{aA_pB_c}{\Omega}\varepsilon = f_c^{IT}\ . \tag{21}$$

Compared to the inflation targeting regime, equation (19)-(21) show that active monetary policies are associated with a more expansionary stance, while fiscal policies are more conservative in both countries. It follows that financial instability falls when active monetary policies are introduced (cf. eq. (20)).

Our conclusion is that, analogously to the case of strict inflation targeting, active monetary policies operate as an indirect risk-sharing mechanism. In fact, in both these regimes, there is a partial transfer to the core country of the costs involved in decreasing the risk of debt unsustainability as well as the related risk of the monetary union's financial instability.[26]

In a nutshell, the rationale of our result is that, under active monetary policies, the central bank acquires control of the trade-off between its two targets (price and financial stability). 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 in the

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[25] The inequality in equation (19) can be obtained with some algebra by expanding A_p and B_p. In a nutshell, it reduces to $b - aB_c > 0$. The same occurs for inequalities in (20) and (21). Mathematical proofs are available upon request.

[26] It can be shown that the recession in the peripheral country reaches its smallest size, while the core country faces the largest undesired output gap. Values are reported in the Appendix and a proof is available upon request.

periphery and, hence, on decreasing the risk of financial unsustainability in the union. It follows that, differently from inflation targeting, the central bank has the will to raise the inflation rate above the zero target. Thus, the central bank pursues a more expansionary monetary policy, generating a positive inflation rate, i.e., $\pi^{AP} > 0$.

Our outcomes are summarized in the proposition below.

Proposition (active monetary policies). Active monetary policies preserve the common good of financial stability in a monetary union by facilitating government debt control in the peripheral countries. This approach allows for a fiscal stance which is more conservative than that achieved under a pure inflation targeting regime. Analogously to inflation targeting, expansive active monetary policy operates as an indirect risk sharing mechanism; however, although its inflation rate results over the target, the latter implies larger transfers of costs and more financial stability than the former.

It is worth noting that the peripheral country and the central bank are better off in the active monetary policy regime than in the other two regimes. In fact, active monetary policies imperfectly mimic a cooperative solution aimed at internalizing the cost of monetary union stabilization. It follows that the cost of government debt consolidation in the periphery is counterbalanced by the central bank's monetary policy, so that this same cost is almost fully imposed on the core country. Nevertheless, the latter country too may prefer active monetary policies; the condition is that this country be sufficiently concerned about the financial stability of the monetary union. In other words, it is more likely that active policies improve welfare if financial stability is a public good.[27]

5. Conclusion

The EA denounces its fragility and thus the incompleteness of union whenever it faces major crises. We have built a simple model to rationalize the behavior of the ECB in these situations, in which we assume that monetary policy can adopt different tools and can operate under different designs, strategically interacting with decentralized national fiscal authorities. Different architectures lead to different outcomes in terms of financial instability and risk sharing across countries of the union.

[27] The specified condition, however, is not necessarily met. Hence, we cannot exclude that the core country is worse off under active monetary policies than under the other two regimes examined. However, if the core country cares enough about financial stability, it can also happen that active monetary policies are not expansive enough compared to a cooperative solution.

We concentrated on sovereign debt shocks. We consider a stylized model of a monetary union in which it is maintained that the financial stability of the union is a public good that can be undermined by a sovereign debt shock in the periphery. Studying the logics of the strategic interactions between monetary and fiscal authorities, we showed that when the central bank does not react at all to the sovereign debt shock ("no intervention"), all the burden for the achievement of financial stability is sustained by the peripheral country. The core does not implement any policy and does not suffer any cost in terms of recession and/or inflation, but it "imports" a suboptimal high level of financial instability, which is not under its control. This means that there is no risk sharing.

Conversely, when the central bank operates according to strict inflation targeting, financial stability is strengthened as the peripheral country implements a more conservative fiscal stance. In such a case, part of the cost of stabilization is however sustained by the core country: a positive inflation rate is experienced by the core country (although a zero-average inflation rate is obtained) and a less severe recession in the periphery is observed. It is worth noting that a zero-average inflation target implies expansionary policies in the periphery, which otherwise would experience a deflationary risk. Finally, in the case where the central bank announces active monetary policies as a response to the fiscal consolidation in the periphery, a positive inflation rate and more fiscal discipline in the periphery are observed as active monetary policy enforces the risk-sharing mechanism by reducing the cost of consolidation in the periphery. It is worth noting that, although we consider decentralized fiscal policies, a more conservative policy stance is achieved under a sort of "whatever it takes" strategy than under an inflation targeting regime.

Our results could provide a rough interpretation of the monetary policies implemented by the ECB during the sovereign debt crisis. A precise exercise would require the introduction of additional details that we cannot elaborate here. Thus, this paper just outlines a suggestive interpretation. The narrative of the ECB's reactions to the financial and sovereign debt crises can be summarized in three different stages.

The restrictive monetary stance that was adopted in July 2008 as well as in summer 2011 – that is, a few weeks before the Lehman Brothers bankruptcy and the full involvement of Italy and Spain in the 'doom loop', respectively – can be interpreted as an attempt to anchor the policy interest rates to unchanging rules despite the occurrence of economic turmoil. The "no intervention" policy approximates this contradictory reaction to the peaks of the international and European crises.

The ECB's policy implemented at the end of 2011 and at the beginning of 2012 (that is, the LTRO) represents a first reaction to the doom-loop. It was successful in overcoming the peak of the crisis in the European banking sector; however, it was insufficient to restore the macro-financial stability

of the EA. In fact, despite the huge injection of liquidity into the European banking sector, the LTRO was unable to re-activate the banking channel and to incentivize expansionary fiscal policies compatible with risk-sharing initiatives. In our context, the LTRO's initiative can roughly be assimilated to our targeting regime, which aims at implementing a partial and inefficient risk-sharing mechanism. In this regime, the ex-post adjustments of the policy interest rate represent an insufficient attempt of the central bank to react to the impact of the sovereign debt shock. The insufficiency is mainly due to the distortionary interactions between these ex-post adjustments and the national fiscal policies.

Finally, our active monetary policy regime can be interpreted as a rough approximation of some crucial features characterizing the announcement of OMT as well as the announcement and implementation of other unconventional monetary policies. It is well known that, since September 2012, the possible recourse to OMT by the EA's most fragile countries has been sufficient to overcome the financial instability inherited from the international and European crises; and the subsequent unconventional initiatives taken by the ECB since the fall of 2014 (e.g., Asset Purchase Program) have supported the short-run sustainability of government balances in deep disequilibrium and have allowed for the implementation of effective risk-sharing mechanisms. Our active monetary policies show that a central bank can handle a sovereign debt shock by credibly announcing a monetary expansion to the national fiscal authorities. This announcement is sufficient to improve the coordination between monetary and fiscal policies and the related effectiveness of risk-sharing mechanisms.

According to the above narrative, our analysis roughly determines that the unconventional initiatives taken by the ECB have ensured EA's financial stability without threatening other long-run economic equilibria in the different types of member states. In particular, the suggested rough overlapping of the results achieved by the OMT announcement and the stylized modelling of active monetary policies stresses that it is possible to achieve an increase in risk sharing by partially internalizing adjustment costs even in an incomplete monetary union and in the absence of formalized ex-ante coordination.

Appendix A – 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 $\Omega = 2b - aB_c - aB_p > 0$.

A1. No intervention regime

The regime implies that $r = r^n$. Under this condition, fiscal authorities minimize (7) constrained by (1)-(3) and (5). The corresponding reaction functions are:

(A1) $$f_p = A_p \varepsilon$$

(A2) $$f_c = 0$$

Equations (A1) and (A2) also express the equilibrium policy (i.e., $f_p^{NM} = A_p \varepsilon$ and $f_c^{NM} = 0$). Substituting them back into (1)-(3) and (5), we obtain the equilibrium values for the output gap, inflation and primary balance in the periphery and core countries:

(A3) $$x_p^{NM} = -aA_p \varepsilon$$

(A4) $$\pi_p^{NM} = -a\kappa A_p \varepsilon$$

(A5) $$s_p^{NM} - s_p^T = (1 - A_p)\varepsilon$$

(A6) $$x_c^{NM} = \pi_c^{NM} = s_c^{NM} - s_c^T = 0.$$

A2. Strict inflation targeting

In this case, all the policymakers simultaneously minimize their losses under constraints (1)-(3) and (5). The resulting reaction functions are:

(A7) $$f_p = A_p \varepsilon - B_p(r - r^n)$$

(A8) $$f_c = -B_c(r - r^n)$$

(A9) $$r - r^n = -\frac{1}{2}\frac{a}{b}(f_p + f_c)$$

Solving the system (A7)-(A9), we get the Nash equilibrium:

(A10) $$f_p^{IT} = A_p \frac{2b - aB_c}{2b - aB_c - aB_p}\varepsilon$$

(A11) $$f_c^{IT} = A_p \frac{aB_c}{2b - aB_c - aB_p}\varepsilon$$

(A12) $$r^{IT} - r^n = -\frac{aA_p}{2b - aB_c - aB_p}\varepsilon$$

Equations (A10)-(A12) imply for the periphery:

(A13) $$x_p^{IT} = -aA_p \frac{b-aB_c}{2b-aB_c-aB_p}\varepsilon$$

(A14) $$\pi_p^{IT} = -a\kappa A_p \frac{b-aB_c}{2b-aB_c-aB_p}\varepsilon$$

(A15) $$s_p^{IT} - s_p^T = \left[1 - A_p \frac{2b-aB_c}{2b-aB_c-aB_p}\right]\varepsilon$$

Similarly, for the core, we obtain:

(A16) $$x_c^{IT} = aA_p \frac{b-aB_c}{2b-aB_c-aB_p}\varepsilon$$

(A17) $$\pi_c^{IT} = a\kappa A_p \frac{b-aB_c}{2b-aB_c-aB_p}\varepsilon$$

(A18) $$s_c^{IT} - s_c^T = -A_p \frac{aB_c}{2b-aB_c-aB_p}\varepsilon$$

The aggregate inflation rate is:

(A19) $$\pi^{IT} = 0\,.$$

A3. Active monetary policy

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., (A10) and (A11)), whereas the central bank minimizes (8), anticipating (A10) and (A11). Optimal monetary policy then implies:

(A20) $$r^{AP} - r^n = -\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

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

By using (A10) and (A11), it follows that

(A21) $$f_p^{AP} = \frac{aA_p\Omega(aB_p+\Omega)\kappa^2+4cB_p^2}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(A22) $$f_c{}^{AP} = \frac{aA_pB_c\Omega\kappa^2+4cB_cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

By using (A20), (A21), and (A22) in (1)-(3) and (5), we get:

(A23) $$x_p^{AP} = -\frac{aA_p\Omega(b-aB_c)\kappa^2-4cB_p(b-bA_p-aB_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(A24) $$\pi_p^{AP} = -a\kappa \frac{aA_p\Omega(b-aB_c)\kappa^2 - 4cB_p(b-bA_p-aB_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(A25) $$s_p^{AP} = s_P^T + \frac{\Omega\kappa^2[(1-A_p)\Omega - aA_pB_p]}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(A26) $$x_c^{AP} = (b - aB_c)\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(A27) $$\pi_c^{AP} = \kappa(b - aB_c)\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

(A28) $$s_c^{AP} - s_c^T = -B_c\frac{aA_p\Omega\kappa^2+4cB_p(1-A_p)}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon$$

The aggregate inflation is:

(A29) $$\pi^{AP} = \frac{2cB_p[\Omega - A_p(2b-aB_c)]}{\Omega^2\kappa^2+4cB_p{}^2}\varepsilon.$$

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Technical appendix*

This appendix extends the two-period macro model developed by Benigno (2015) to the case of a core-periphery monetary union, where the financial stability is potentially undermined by sovereign debt shocks in the periphery. Other possible shocks and the policy measures reproduce the effects analyzed in Benigno (2015).

A. A model of a stylized monetary union

This appendix describes our asymmetric model which refers to a 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.[28] 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 dynamic model characterized by price stickiness.[29] In the first period (short run), the economy is hit by a sovereign debt shock that has a negative macroeconomic impact; and, 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 of the possible fiscal spillovers induced by trade.[30] Thanks to this last simplification, our two-period game has a closed form solution.

The following three subsections outline the model. Subsection A.1 illustrates the functioning of the two-period model and specifies its short-term results through the micro-foundations of agents' behavior. Subsection A.2 outlines the long-run equilibrium. Subsection A.3 formalizes the sovereign debt shock and defines the stability property of the monetary union; it also describes the preferences of the different policymakers.

A.1. The economy of the monetary union

The core aim 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 macroeconomic stability of the

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[28] This assumption represents the minimum requirement for differentiating the two countries.

[29] Cf. Goodfriend (2004) and Benigno (2015). This kind of dynamic 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).

[30] This is a heroic simplification. However, considering policy interactions as well as trade channels would make the model much more complex without significant improvements in the analysis of our main topic. 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).

monetary union as a public good. Our analysis first requires a description of the private agents' behavior in the markets and of the consequent working of the economy in the two-period dynamic.[31] 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.

We first 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:[32]

$$U_i(C_i, L_i) = \frac{1}{1-\sigma^{-1}} C_i^{1-\sigma^{-1}} - \frac{1}{1+\eta} L_i^{1+\eta} + \beta E\left[\frac{1}{1-\sigma^{-1}} \bar{C}_i^{1-\sigma^{-1}} - \frac{1}{1+\eta} \bar{L}_i^{1+\eta}\right] \tag{A1}$$

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 expenditures over the two periods under a binding budget constraint:

$$(1+\tau_i^C)C_i + \frac{\Pi_{i,+1}^e}{1+R}(1+\bar{\tau}_i^C)\bar{C}_i^e = \frac{(1-\tau_i^L)W_i L_i}{P_i} + \frac{(1-\bar{\tau}_i^L)\bar{W}_i^e \bar{L}_i^e}{(1+R)P_i} + T_i \tag{A2}$$

where the apex e indicates the expected value;[33] 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 her as a shareholder of some firms of country *i* – and the real lump-sum tax paid by this same household; R denotes the nominal interest rate set by the central bank and common to 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.[34]

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

$$(1+\tau_i^C)C_i^{-\frac{1}{\sigma}} = \frac{1+R_i}{\Pi_{i,+1}^e}(1+\bar{\tau}_i^C)\beta\left(\bar{C}_i^{\,e}\right)^{-\frac{1}{\sigma}} \qquad \text{(Euler equation)} \tag{A3}$$

$$\frac{W_i}{P_i} = \frac{1+\tau_i^C}{1-\tau_i^L} L_i^{\eta} C_i^{\frac{1}{\sigma}} \qquad \text{(Labor supply).} \tag{A4}$$

We can then write the Euler equation in logs as:

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

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

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

[34] 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.

(A5) $$c_i = \bar{c}_i^e - \sigma\left(r - \pi_i^e - r^n - \bar{\tau}_i^C + \tau_i^C\right)$$

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

Our model does not include any capital. Hence, given the simplification of a representative consumer, equation (A5) determines the aggregate demand in the country i. We then have:

(A6) $$y_i = \bar{y}_i^e + g_i - \bar{g}_i^e - \sigma s_{C,i}\left(r - \pi_i^e - r^n - \bar{\tau}_i^C + \tau_i^C\right)$$

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, equation (A6) does not depend on either the other country demand or the policy decisions taken by the other government (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,[35] which is characterized by:

(A7) $$Y_i(j) = A_i L_i(j)$$

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

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

(A8) $$Y_i(j) = \left(\frac{P_i(j)}{P_i}\right)^{\theta} (C_i + G_i)$$

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

The optimal price is determined by a markup over marginal costs, that is:

(A9) $$P_i(j) = \mu \frac{W_i}{A_i}$$

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

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 $\frac{A_i}{\mu} =$

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

$\frac{1+\tau_i^C}{1-\tau_i^L} Y_i^{\eta} (Y_i - G_i)^{\frac{1}{\eta}}$. The solution of this last 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:

(A10) $$y_i^n = \frac{1+\eta}{\sigma^{-1}+\eta} a_i + \frac{\sigma^{-1}}{\sigma^{-1}+\eta} g_i - \frac{1}{\sigma^{-1}+\eta} m_i$$

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

As stated above, we follow the New Keynesian vein by assuming that prices are sticky in the short run, whereas all firms can optimally adjust their prices in the long run. To formalize this assumption, we state that only a fraction $(1-\alpha)$ of firms can maximize profits by adjusting their prices, while the remaining fraction α of firms has prices fixed at the long-run level, $\bar{P}_i$.[36] Hence, this latter fraction must adapt the size of 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:[37]

(A11) $$\pi_i = \beta \pi_i^e + \frac{1-\alpha\beta}{1-\alpha}\left(\frac{1}{\sigma} + \eta\right)(y_i - y_i^n).$$

Country *i*'s economy is then composed of three equations (i.e., equations (A6), (A10), and (A11)). 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:

(A12) $$\Delta y_i^{n,e} = \frac{\sigma^{-1}}{\sigma^{-1}+\eta}(g_i^e - g_i).$$

Hence, the equation system (A6), (A10), and (A11) can be condensed into equations (A13) and (A14), which describe the demand and supply side of the economy of country *i*. We have, respectively:

(A13) $$x_i = \bar{x}_i^e + a(g_i - \bar{g}_i^e) - b(r - \pi_i^e - r^n)$$

(A14) $$\pi_i = \beta \bar{\pi}_i^e + \kappa x_i$$

where the parameters in (A13) and (A14) 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: *a*, *b*, $\kappa > 0$.[38]

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[36] As already stated, in our model the economy of country *i* follows the steady state until the sovereign debt shock hits the peripheral country. Therefore, previous firms' prices are set at their long-run level.

[37] See Appendix B for details on the derivation of the Phillips curve.

[38] 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 Section A.2.

In the economy represented by equations (A13) and (A14), the central bank sets the common interest rate, r, and the national governments decide the fiscal policies of their respective countries (i.e., their public primary balance). Government balance could be managed by adopting different taxation instruments; however, as already stated (see fn. 7 above), an analysis of the specific effects due to 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 tax revenues constant (i.e., $t_i = \bar{t}_i$) without changing the tax rates (τ_i^C and τ_i^L). The primary balance is, thus, determined by adjustments in the government expenditures. We define the short-run primary balance in terms of deviations from its long-run equilibrium as:

(A15) $$f_i = \bar{g}_i - g_i$$

Of course, the short-run primary balance converges, in the long run, to $f_i = 0$ because (A15) 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 government debt (cf. Subsection A.3). We also assume that agents perfectly forecast long-run fiscal policies, so that $\bar{g}_i^e = \bar{g}_i$.[39]

A.2. The long-run equilibrium

The equilibrium can easily be 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 $\bar{f}_i = 0$.[40] As can easily be verified, it follows that $\bar{\pi}_i = \bar{x}_i = 0$.

A.3. The sovereign debt shock and the monetary union stability

All the policymakers' targets are met in the long run. Hence, if the economy does not face any stochastic disturbance, these targets are also achieved in the short term. In a model of the kind exposed here, several shocks and policy options can be investigated (see Benigno, 2015). Our novelty is the focus on the 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. This means that these authorities, implicitly or explicitly, honored the commitment of stabilizing their respective government debt-to-GDP ratio at a reasonable level in the past (Ghosh *et al.*, 2013). This amounts to stating that each of the authorities of the two countries 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; Mendoza and Ostry, 2008). Hence, at the starting point, the government debt-to-GDP ratio equalizes the long-run equilibrium level in both countries.

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[39] See Section A.2.

[40] 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.

When the peripheral country is hit by a sovereign debt shock, its fiscal authority may be unable to handle the primary balance to keep this long-run equilibrium in the short term. The possible consequent fiscal instability is costly for the peripheral country; moreover, it would create negative externalities for the monetary union that would also affect the welfare of the core country and of the central bank. We model this situation by stating that both countries of the monetary union do not 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 financial instability in the monetary union. In this case, even the core country indirectly suffers the short-run cost of financial instability. It is worth noting that the nexus between fiscal and financial instability is discussed in the main paper. The same applies to the nexus between fiscal and financial dominance. However, let us emphasize that (financial) instability is determined henceforth by excessive primary deficits in the periphery, so that fiscal instability in the periphery is equivalent to financial instability in the monetary union.

To formalize the conditions of (in)stability, it is 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 in country *i*, we assume that the fiscal target evolves as follows:

(A16) $$s_i^T = \bar{s}_i^T + \varepsilon_i$$

where $\bar{s}_i^T$ is the long-run balance surplus goal[41] 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 (A16) is measured by:

(A17) $$s_i - s_i^T = s_i - \bar{s}_i - \varepsilon_i = f_i - \varepsilon_i \ .$$

The meaning of equation (A17) is that country i can avoid (or, at least, reduce) the risks of national fiscal unsustainability by adopting a restrictive fiscal policy (i.e., $s_i - \bar{s}_i > 0$).

As said, in our setup, the risk of financial instability 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 national fiscal unsustainability. The latter could compromise the financial 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. Given the assumptions that a sovereign debt shock hits only the periphery (that is, $\varepsilon_p = \varepsilon > 0$ and $\varepsilon_c = 0$), formally we can set:

[41] Determining this value is beyond the scope of our paper. We assume that long-run sustainability is satisfied and governments are fiscal responsible. Therefore, the long-run primary budget consistent with fiscal sustainability can be 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.

(A18) $$S = \left(\min\{0, s_p - s_p^T\}\right)^2$$

Equation (A18) states that the monetary union's financial stability is undermined by large enough short-term fiscal disequilibria in the periphery. However, equation (A17) shows that the fiscal authority of country *p* is potentially able to offset the threat of instability, due to a sovereign debt shock ($\varepsilon_P > 0$), on its government debt in equation (A18). This 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.

The policymakers' short-run actions are driven by their expected losses, which they attempt to minimize. National fiscal authorities focus on domestic outcomes (x_i, π_i), and on fiscal sustainability ($s_i - s_i^T$) which is affected by the deviation of s_i from s_i^T. In the short term, they aim at minimizing their short-run loss.[42] Formally, the short-run loss of country *i's* fiscal authority is defined by:[43]

(A19) $$F_i = \frac{1}{2}\left[{x_i}^2 + a_i\,{\pi_i}^2 + b_i\,(s_i - s_i^T)^2 + c_i\,S\right] \quad i \in \{p, c\}$$

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 also for all 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.[44] Formally, the central bank's loss function is given by:

(A20) $$B = \frac{1}{2}\left(\pi^2 + c\,S\right)$$

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 (A19) and (A20) 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.

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[42] The loss should 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.

[43] 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).

[44] The former assumption derives from the European Treaties. Moreover, it is compliant with the Outright Monetary Transactions (OMT) program, anticipated by Draghi's "whatever it takes" statement at the end of July 2012 and launched by the ECB at the beginning of the following September.

Appendix B – Price adjustments (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:

(B1) $$\pi_i = (1-\alpha)(p_i^* - \bar{p}_i)$$

The optimal price is defined as follows:[45]

(B2) $$p_i^* = \alpha\beta p_i^{*e} + (1-\alpha\beta)\left[p_i + \frac{1+\sigma\eta}{\sigma}(y_i - y_i^n)\right]$$

i.e.,

(B3) $$p_i^* - \bar{p}_i = \alpha\beta(p_i^{*e} - p_i) + \pi_i + (1-\alpha\beta)\frac{1+\sigma\eta}{\sigma}(y_i - y_i^n).$$

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

(B3) $$\frac{1}{1-\alpha}\pi_i = \frac{\alpha\beta}{1-\alpha}\pi_i^e + \pi_i + (1-\alpha\beta)\frac{1+\sigma\eta}{\sigma}(y_i - y_i^n)$$

Equation (B3) coincides with the Phillips curve in equation (A14).

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

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