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 that sovereign debt shocks can undermine 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 significant 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 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 used 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) in 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 supposing the EA's stability is a common good that asymmetric sovereign debt shocks can undermine. Will handling the consequent disequilibria in the most fragile (peripheral) countries as a *private* problem be efficient and effective? Moreover, will commitments to active monetary policies effectively produce adjustments from asymmetric shocks in peripheral member states without supporting national or centralized fiscal policies?

[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.* (2022).

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 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 excessive 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). We focus on non-cooperative solutions in which policymakers cannot 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, and 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. Finally, 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 union's financial stability 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 a national level. Compared to strict inflation targeting and non-intervention, active expansionary monetary policies 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.

The rest of the paper is organized as follows. Section 3 places our paper in the literature. Section 3 describes our stylized analytical setup. Section 4 illustrates our results and provides suggestions on monetary regimes' viability and welfare impact. Section 5 extends our model to consider endogenous sovereign debt dynamics. Finally, Section 6 concludes the paper.

2. Related literature

Our paper is based on rich literature. As already mentioned, we introduce the financial stability issue as a public good in a reasonably 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 broadly discuss the possible evolution in a monetary union's institutional and fiscal setting and the appropriate policy mix after the lessons learned from the European crises.

Our paper is 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. At the same time, we assume that fiscal authorities honor their commitment to reasonably stabilizing their respective government debt-to-GDP ratio 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,

[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.

even if they face a trade-off between fiscal-financial and macroeconomic stability. In this sense, we complement the literature that accounts for strategic default and domino effects.[6]

Finally, our paper pursues a different approach to addressing the open debate on risk sharing in a monetary union, explicitly referring 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 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.

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 second period (long run). Due to price stickiness, the monetary policy is nonneutral in the short run. Following Beetsma and Bovenberg (1998, 2001),

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[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).

[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).

policy interactions fully characterize the structure of the game, which does not take account of the possible fiscal spillovers induced by international trade.[11] Our two-period game has a closed-form solution, where the two periods refer to the short and long run, respectively.

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 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:

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

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

where x_i is the output gap, g_i is a measure of fiscal policy (primary balance on output), 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; β is the discount factor.

In the economy (1)-(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:

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

[11] However, considering policy interactions and trade channels would make the model much more complex without significant qualitative improvements in the analysis of our main topic (as these affect the size of fiscal multipliers), 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 Dixit and Lambertini (2001, 2003) and Chortareas and Mavrodimitrakis (2017). Those papers provide closed form solutions with international spillovers.

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

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. In the long run there are no shocks, and expectations are stable. This implies that expectations of 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 to minimize the output gap, the inflation deviations from a target (which is set equal to zero for the sake of brevity), and to keep the government balance consistent with the long-run fiscal sustainability (which implies a primary balance equal to the long-run target in the absence of shocks.) 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 must augment the monetary union model with a fiscal suitability argument. As already stated, we assume that national authorities are fiscally 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; 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 a sovereign debt shock hits the peripheral country. 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

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[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.

country and the central bank. This is equivalent to stating that deviations from the periphery's long-run fiscal equilibrium undermine the monetary union's financial stability. Moreover, following the concept of financial dominance (Brunnermeier, 2016), unexpected government deficits could (directly or indirectly) induce agents who operate in financial markets to take more considerable 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 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.

We define by $\bar{s}_i$ and s_i the balance surplus relative to the output in the long and short run, respectively. Denoting s_i^T the goal for the government balance surplus relative to the output that is consistent with long-run fiscal sustainability in country i, we assume that this fiscal target evolves as:

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

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, which is zero in the long run.)

By assumption, the government debt of country i is sustainable in the long run. It follows that $\bar{s}_i = \bar{s}_i^T$, while the short-run fiscal sustainability is measured by:

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

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[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, the deteriorating creditworthiness of the public sector hurts financial sector balance sheets, which are significant holders of public debt, forcing the government to bail out banks. This, in turn, implies a further deterioration of the government's fiscal capacity.

[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 at $t - 1$ paid at t. It follows that fiscal sustainability implies that, in the long run, the primary balance satisfies $B = ln\beta D$. Hence, a positive debt in the long run requires a positive target for the government balance to be sustainable.

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., $s_i - \bar{s}_i > 0$). By assumption no unsustainability is observed in the long run.

The monetary union's financial instability depends on the short-term unsustainability of the periphery's government debt. The peripheral country is so fragile that its short-run fiscal disequilibrium can turn into national fiscal unsustainability. The latter could compromise the financial stability of the monetary union. 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 assumption that a sovereign debt shock hits only the periphery (that is, $\varepsilon_p = \varepsilon > 0$ and $\varepsilon_c = 0$), we set:

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

Equation (6) states that large enough short-run fiscal disequilibria undermine the monetary union's financial stability in the periphery. However, equation (5) shows that the fiscal authority of 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 in minimizing the negative consequences of a debt shock hitting the peripheral economy and causing possible trade-offs.

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

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

[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 achieve their relative targets (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).

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:

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

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.

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

Focusing of the central bank, we explore three monetary policy regimes. Each of these regimes leads to a specific game.

1. The first regime, which represents our benchmark, is characterized by **no monetary intervention** (*NM*). We assume that the central bank plays a passive role, i.e., the monetary authority does not react to exogenous shocks. In this regime, the central bank is not minimizing any loss, and the interest rate is pegged to the value optimal in the long run (i.e., the natural rate). As a result, we derive the Nash equilibrium between the two fiscal players constrained by an interest rate fixed at its natural level as governments know the monetary regime in place.

[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.

2. The second regime results from the Nash equilibrium between all three players. However, in this case, as we will show, the central bank only intervenes to achieve the inflation target since it cannot internalize the effects of monetary policy on the sovereign debt shock.[19] We refer to this monetary regime as **strict inflation targeting** (*IT*) because it is equivalent to the case where $c = 0$ in (8). The central bank's action will only occur if the observed sovereign debt shock determines the monetary union's excessive average inflation rate and if the national fiscal policies are ineffective in adjusting the inflation to its original 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 avoiding financial instability. The central bank announces 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 (monetary leadership).[20]

The following subsections provide the outcomes of the different regimes, solving the corresponding policy games. Subsection 4.2 describes the no monetary intervention regime 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)-(6). Solving, the fiscal authorities' reaction functions become:

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

[19] For this reason, the same results are obtained if the common assumption of fiscal leadership is used.

[20] 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.

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 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 ($r < r^n$) employing a public debt consolidation ($f_i > 0$). Hence, this same equation characterizes the optimal fiscal actions in all three policy regimes examined.

Now, let us recall that we are focusing on an idiosyncratic shock and 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 also negatively affects the core country since it increases the financial instability of the monetary union. However, the core fiscal authority cannot influence the peripheral fiscal policy regarding fiscal consolidation. It follows that the core fiscal authority does not take any action, meaning that this country's output gap and inflation rate are unaffected by the sovereign shock in the periphery. Formally, equation (9) for the core implies that:[21]

(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 government's primary balance surplus deviation from its long-run target, i.e., it implements a national government debt consolidation to avoid short-term fiscal unsustainability. This consolidation plan has a recessionary and deflationary impact because 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 the related risk of financial instability in the monetary union, and the 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:

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

(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 as follows.

Result 1 (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-financial and macroeconomic stability. As a result, the sovereign debt shock undermines the financial stability of the monetary union and the welfare of both the core and the periphery. The former does not suffer any fiscal or output instability but experiences significant 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 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)-(6). The solution to this minimization problem requires:

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

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

1. Under strict inflation targeting regime, the central bank adjusts *ex-post* the interest rate, accounting for the fiscal actions. This means the central bank cannot directly affect the fiscal policy's decisions peripherally. 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, 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).[22]

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.

As said, in our narrative, we focus on monetary regimes. However, comparing the strict inflation targeting and active monetary policies is equivalent to a more common debate between fiscal and monetary leadership. In our context, the former corresponds to fiscal leadership (cf. footnote 19) and the latter to monetary leadership. To avoid confusion, however, we will only refer to our labels.

4.3.1. Strict inflation targeting

Let us focus on the inflation-targeting regime. The central bank cannot influence government debt management by the peripheral country's fiscal authority. However, to counterbalance the risk of deflation caused by fiscal consolidation in the periphery, the central bank adopts an expansionary 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 $i \in \{p, c\}$.[23]

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

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

[23] The latter inequality is easy to verify.

expansion cause a fiscal reaction in both countries. Ultimately, the inflation rate in the peripheral (core) country will be below (above) the target.

Let us explain the above conclusion in some detail. 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 the reaction of the monetary policy fully offsets its impact. A positive inflation rate, i.e., will finally characterize the core country:[24]

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

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

In this regime, the expansionary monetary policy also affects the fiscal policy in the peripheral country, which 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:[25]

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

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:

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[24] 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.

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

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

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 as follows.

Result 2 (strict inflation targeting). In the case of a sovereign debt shock in the periphery, strict inflation targeting always implies zero inflation on average (i.e., the central bank target is achieved) and incentivizes fiscal discipline in the periphery. As a result, 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 (monetary leadership)

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

By deriving (9) and inserting (13), we obtain:[26]

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

and substituting it back into (3), we have

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

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[26] 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.

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 $\pi_c^{AP} > \pi_c^{IT}$. The core country will implement a more severe public debt consolidation. Formally, we have:

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

Equations (19)-(21) compared to the inflation targeting regime show that active monetary policies are associated with a more expansionary stance, while fiscal policies are more conservative in both countries. 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 and the related risk of the monetary union's financial instability.[27]

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 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 as follows.

Result 3 (active monetary policies). Active monetary policies preserve the common good of financial stability in a monetary union by facilitating government debt control in peripheral countries. Moreover, this approach allows for a fiscal stance that is more conservative than that achieved under 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.

[27] 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.

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. This is because active monetary policies imperfectly mimic a cooperative solution to internalize the cost of monetary union stabilization. It follows that the central bank's monetary policy counterbalances the cost of government debt consolidation in the periphery, so this cost is almost entirely imposed on the core country. Nevertheless, the latter may also prefer active monetary policies; the condition is that this country is sufficiently concerned about the financial stability of the monetary union. In other words, active policies are more likely to improve welfare if financial stability is a public good.[28] Our theoretical result is quite general. Leadership often operates as a coordination device (in the same context, see, e.g., Dixit and Lambertini, 2001; 2003a 2003b; Hughes-Hallett and Weymark, 2007). Our findings are in line with some evidence. While considering the limitations of wide-ranging empirical analyses of this type, Neri and Siviero (2018), e.g., argue that "as monetary policy was quickly becoming more expansionary, fiscal policy turned increasingly restrictive. Fiscal consolidation efforts were carried out in several euro area countries." Consolidation effects were even more significant than expected (Cugnasca and Rother, 2015; Lalik, 2016).[29]

5. Endogenous sovereign debt crises

The previous section showed that monetary stimulus engenders great fiscal discipline. The argument is as follows. After a negative sovereign debt shock in the peripheral country, active monetary stimulus promotes more financial stability (i.e., it preserves the public good that is the monetary union) by freeing up the periphery to be more fiscally conservative than it otherwise would. In this respect, we assumed that the sovereign debt crises are exogenous shocks and governments are fiscally responsible, i.e., only temporary, they can face solvability problems because of the external disturbances.

Sovereign debt crises are, however, often endogenous. Therefore, our assumption is highly relevant to our conclusions. A counterargument is as follows. The monetary stimulus could not

[28] The specified condition, however, is not necessarily met. Hence, we cannot exclude that the core country is worse off under active monetary policies than 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.

[29] Se also Altavilla *et al*. (2021) and Benigno *et al*. (2022).

engender greater fiscal discipline since if the periphery knows the central bank has committed to providing stimulus to them in times of need, this provides an incentive for the periphery to be more fiscally irresponsible. As the size and likelihood of sovereign debt crises are exogenous in our model, this critical channel is omitted. With this channel in play, monetary policy not only facilitates risk-sharing between the core and the periphery but also creates more risk to be shared between the two.

In this section, at least partially, we account for the endogeneity of sovereign debt crises. To fully answer the questions at the heart of our paper, we model both channels for monetary policy. We assume that (peripherical) governments can be temporarily fiscally unresponsible and engender a sovereign debt crisis. We model this by assuming three periods, where the propensity to experience a sovereign debt crisis in the middle period is a function of the size of a country's fiscal position in the first period when the fiscal authorities could be unresponsible. However, the fiscal behavior of the unresponsible policymakers in period one will also depend on the central bank's commitment (or lack thereof) to provide stimulus if a debt crisis ensues.

Now, in our model, three periods are relevant. In the first period (short run), we assume that the periphery fiscal authority is fiscally unresponsible (i.e., we assume that a shock hits the debt target in period one). In the second period (medium run), we assume that the periphery needs to consolidate because of the fiscal behavior of the previous period in a world which can be (as in the previous section) or cannot be hit by external pressure on debt sustainability: Finally, the last period is the long run.

For the sake of brevity, we use the following notation: the variables used in the previous section are indexed by number between brackets, e.g., the periphery output at time 1 in eq. (1) is now $x_p(1)$. Similarly, $x_p^e(2)$ and $x_p(2)$ are the expected and the actual output gap in period 2, respectively. Moreover, we assume that the effects of fiscal policy on the output depend on deviations from the steady state values, $g_i(1) - \bar{g}_i$ and $g_i(2) - \bar{g}_i$.

The model cannot be solved analytically, at least not without leading to solutions that cannot be interpreted in intuitive terms. We solve this numerically for a given set of parameter values. Specifically, we calibrate the model as follows. A log-utility function is assumed for the consumer so that $b = 1$; we assume a Keynesian multiplier for the fiscal policy so that $a = 1.2$; we fix $\kappa = 0.5$ and $\beta = 0.99$. We normalize $r^n = 0$ and $\bar{g}_p = \bar{g}_c = 0$. Policymakers minimize intertemporal losses built on period losses (7) and (8) discounting by β. We assume $a_p = a_c = b_p = b_c = 1$ and $c_p = c_c = c = 0.8$.

Formally, we assume that in period one,

$$F_i = \frac{1}{2}\sum_{j=1}^{3}[x_i(j)^2 + a_i\,\pi_i(j)^2 + \ b_i\,(s_i(j) - s_i^T(j))^2 + \ c_i\,S(j)] \quad i \in \{p, c\} \tag{22}$$

$$B = \frac{1}{2}\sum_{j=1}^{3}\left[\left(\pi(j)^2 + \ c\left(\min\{0, s_p(j) - s_p^T\}\right)^2\right)\right] \tag{23}$$

We solve the model by backward induction. It is worth noting that the solution for the second stage was obtained in the previous section. Therefore, these outcomes represent the medium-term equilibrium and are used to obtain the short-run expectations for the short one.

Formally, the solution is obtained by minimizing (22) and (23) subject to the medium-run solution obtained in Section 4.3 (we restrict our comparison to the case of strict inflation targeting and active monetary policies.) As said, we assume that in the short run the periphery country can be fiscally irresponsible, i.e., $\bar{s}_i^T(1) > \bar{s}_i$, while in the medium- and long- run, it is not ($\bar{s}_i^T(2) = \bar{s}_i^T(3) = \bar{s}_i$). Moreover, we consider the case where in the medium run the periphery can be hit by a debt shock as the result of a financial crisis (that is, $\varepsilon_p(1) = 0$, $\varepsilon_p(2) > 0$, $\varepsilon_p(3) = 0$.) It is worth noting that the periphery government anticipates that the fiscal irresponsibility is temporary and that the medium-long term consolidation should be introduced, but a financial crisis in the medium term is unexpected ($\varepsilon_p^e(2) = 0$). In the short run, the periphery authorities (as well all the policymakers) also anticipate the other players' actions which in turn depends on the known policy regime (strict inflation targeting or monetary leadership.)

We consider three cases. For the sake of comparison, the first one is that investigated in the previous section. We assume that the fiscal responsible government of the periphery faces an unexpected sovereign debt crisis in the medium term (i.e., a shock of 10 pp). In the second scenario, we consider the debt as endogenous. We assume the periphery government is fiscally irresponsible in the short run, loading a sovereign debt calling for austerity in the medium terms (we assume a 3-pp deviation in the fiscal target.)[30] Finally, in the last scenario, we consider both the endogenous debt due to fiscal irresponsibility and the unexpected sovereign debt crisis. In all the scenarios, we compare the effects of the IT and AP regimes.

[30] For the sake of comparison, we choose two values for the shock that, alone considered, have similar impact on the sovereign debt in the IT regime. As we will show they imply an impact on the deviation from the debt target between 2% and 3%.

The main results are summarized in the dynamics of the periphery debt, which is illustrated in Figure 1. The outcomes are obtained by numerically implementing the backward-induction solution described in this section (details are available upon request.) We only repost the periphery debt dynamics. The operating mechanisms are those described in the previous section, so the dynamics of the other variables are intuitive.[31]

The scenario associated with the unexpected debt crisis (panel (a)) clearly shows the effects of risk sharing associated with the AP regime described in Section 4. The activism of the central bank in supporting the real economy supports more austerity in the periphery and achieves a smaller deviation from the debt target (and thus a lower probability of a monetary union collapse.) The mechanism is the same as described in the previous section. A more expansionary monetary policy strongly reduces the austerity costs in the periphery hit by the shock at the cost of a small recession in the core, which is not hit by the shock. It is worth noting that in the short run the monetary union is always on the steady state since non-exogenous perturbations occur.

In the second case (panel (b), we consider an endogenous sovereign debt generated by the fiscal irresponsibility of the peripherical country in the short run.[32] The deviation from the target leads to an increase in the sovereign debt of the periphery in the short run, followed by austerity in the medium term because of the heritage of the fiscally irresponsible government. As expected, in the medium run the activism of the central bank supports a more virtuous response of the periphery. However, as the irresponsible fiscal government of the periphery anticipates the central bank's support, it is more likely to increase the debt in the short run. The AP is thus an incentive to run higher debt for irresponsible fiscal policymakers. Of course, if it is expected that the central bank would only intervene if a debt shock occurred (i.e., extraordinary times), then, in panel (b), the AP line coincides to the IT one.

The last panel (panel (c)) puts both cases together. The austerity stemming from fiscal irresponsibility adds to the debt crisis. Quantitatively, it is clear that the AP as an incentive to create debts for irresponsible fiscal policymakers has second-order effects compared to its role as risk sharing mechanism.

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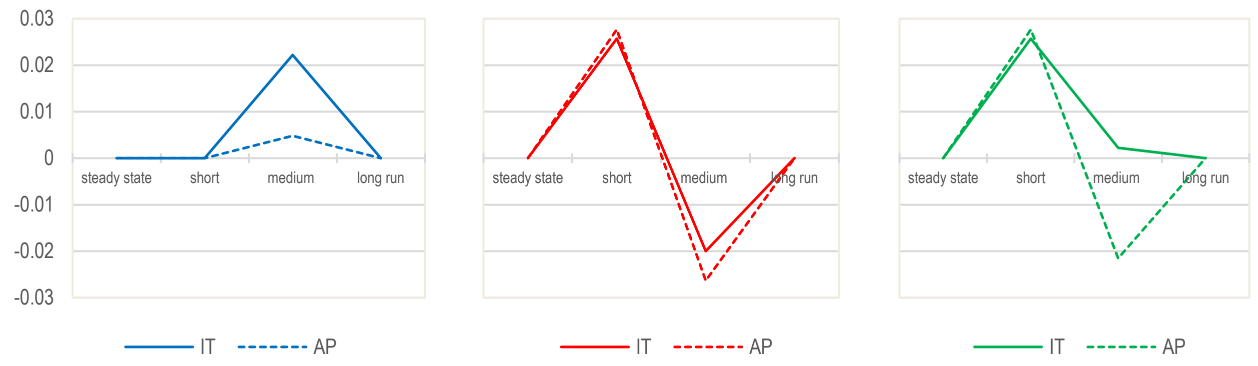
[31] A technical appendix is available upon request.

[32] In line with the aims of our study, fiscal irresponsibility can only be temporary, otherwise the debt will explode. Not that the model is linearized around the steady state.

Figure 1 – Periphery debt dynamics (target deviations)



(a) (b) (c)

Note. Panel (a) describes the case of an unexpected debt crisis (a 10-pp exogenous increase in the fiscal deficit) spurring in the medium term under the assumption that the government is always fiscally responsible (it is the case obtained in Section 4.) Panel (b) describes the case of the irresponsible fiscal government in the short term (a 3 pp increase in the target) without a debt crisis. Panel (c) describes the case of an unexpected debt crisis in the medium run with a government that is fiscally irresponsible in the short one (10 pp increase in the fiscal deficit in the medium run and 3 pp increase in the government target in the short run.)

This section shows that as the size and likelihood of sovereign debt crises are endogenous, monetary policy may create more risk to be shared between the core and the periphery if the latter temporarily suffers fiscal irresponsibility. However, we show that, at least under some parametrization, this effect has a second-order size compared to the fact that active monetary policy can prevent the cost of the debt crisis on the monetary union sustainability. It should also be noted that the existence of fiscal rules in normal times (short term) might prevent irresponsible debt accumulation behavior even if it is expected that, in the event of external shocks (in the medium term), the central bank can intervene to support countries under pressure indirectly promoting risk sharing. Clearly, if the central bank action takes place only in the case of external shocks, no incentive to run extra debt for irresponsible policymakers emerges.

6. Conclusion

The EA denounces its fragility and thus the incompleteness of union whenever it faces significant 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 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 union countries.

We concentrated on sovereign debt shocks. We consider a stylized model of a monetary union in which it is maintained that the union's financial stability is a public good that a sovereign debt shock in the periphery can undermine it. Studying the logic of the strategic interactions between monetary and fiscal authorities, we showed that when the central bank does not react to the sovereign debt shock ("no intervention"), all the burden for achieving financial stability is sustained by the peripheral country. As a result, the core does not implement any policy; it does not suffer any cost in terms of recession and 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 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, when 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.

We also showed how, in some circumstances, active central bank policies could be an incentive for fiscally irresponsible governments to create more sovereign debt endogenously. However, the incentive is reasonably limited and can be eliminated simply by assuming that the central bank intervenes only in particular circumstances, i.e., external debt shock. The problem of exogenous debt and fiscal irresponsibility does not depend so much on the monetary policy regime as on the institutional design. Budget fiscal rules should prevent irresponsible behavior by policymakers, failing which the different monetary policy regimes only have a second-order impact.

Our results could provide a rough interpretation of the monetary policies implemented by the ECB during the sovereign debt crisis. However, a specific exercise would require introducing additional details we cannot elaborate on 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 could not re-activate the banking channel and 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 a poor 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 OMT's 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 profound disequilibrium. They 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 effects 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 modeling of active monetary policies stresses that it is possible to increase 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)-(6). 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)-(6), 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) $$r - r^n = -\frac{1}{2}\frac{a}{b}\left(f_p + f_c\right)$$

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)-(6), 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[*]

The appendix details the micro-foundations of our model, which refers to a core-periphery monetary union composed of two member states, 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.

Our analysis requires a description of the private agents' behavior in the markets and of the consequent working of the economy in the two-period dynamic.[33] 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.

Regarding 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:[34]

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

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;[35] W_i denotes the nominal wage and 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

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[*] We thank Pierpaolo Benigno for his useful comments and suggestions. This appendix extends the two-period macro model developed by Benigno (2015) to the case of a core-periphery monetary union, where financial stability is potentially undermined by sovereign debt shocks in the periphery. Other possible shocks and policy measures reproduce the effects analyzed in Benigno (2015).

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

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

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

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.[36]

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

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

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

We can then write the Euler equation in logs as:

(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 the other country's 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 using a common linear technology,[37] 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:

[36] 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.

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

(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 cost$s$, 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 $\frac{A_i}{\mu} = \frac{1+\tau_i^C}{1-\tau_i^L} Y_i^{\eta} (Y_i - G_i)^{\frac{1}{\eta}}$. 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, $\bar{P}_i$.[38] 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 determine inflation ($\pi_i = p_i - \bar{p}_i$) as $\pi_i = (1 - \alpha)(p_i^* - \bar{p}_i)$. Then, after some algebra, the New Keynesian Phillips curve is obtained:

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

In detail, 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:

(A12) $$\pi_i = (1 - \alpha)(p_i^* - \bar{p}_i)$$

The optimal price is defined as follows:[39]

[38] 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.

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

(A13) $$p_i^* = \alpha\beta p_i^{*e} + (1-\alpha\beta)\left[p_i + \frac{1+\sigma\eta}{\sigma}(y_i - y_i^n)\right]$$

i.e.,

(A14) $$p_i^* - \bar{p}_i = \alpha\beta(p_i^{*e} - p_i) + \pi_i + (1-\alpha\beta)\frac{1+\sigma\eta}{\sigma}(y_i - y_i^n).$$

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

(A15) $$\frac{1}{1-\alpha}\pi_i = \frac{\alpha\beta}{1-\alpha}\pi_i^e + \pi_i + (1-\alpha\beta)\frac{1+\sigma\eta}{\sigma}(y_i - y_i^n)$$

Equation (A15) coincides with the Phillips curve in equation (A11).

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:

(A16) $$\Delta y_i^{n,e} = \frac{\sigma^{-1}}{\sigma^{-1}+\eta}(g_i^e - g_i).$$

Hence, the equation system (A6), (A10), and (A11) can be condensed into equations (A17) and (A18), which describe the demand and supply side of the economy of country i. We have, respectively:

(A17) $$x_i = \bar{x}_i^e + a(g_i - \bar{g}_i^e) - b(r - \pi_i^e - r^n)$$

(A18) $$\pi_i = \beta\bar{\pi}_i^e + \kappa x_i$$

where the parameters in (A17) and (A18) 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: $a, b, \kappa > 0$.[40]

In the economy represented by equations (A17) and (A18), 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, 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 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 government expenditures. We define the short-run primary balance in terms of deviations from its long-run equilibrium as:

(A19) $$f_i = \bar{g}_i - g_i$$

[40] 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.

Of course, the short-run primary balance converges, in the long run, to $f_i = 0$ because (A19) 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 $\bar{g}_i^e = \bar{g}_i$.[41]

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[41] See Section A.2.

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