Sovereign risk and macroeconomic stability in the euro area

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– Preliminary and incomplete –

Abstract

Sovereign risk premia have risen markedly in several countries in the euro area, driving up credit spreads in the private sector as well. We show that if monetary policy cannot offset these higher credit spreads because it is constrained by the zero lower bound, sovereign risk in some countries of a currency union can threaten macroeconomic stability in the union as a whole, as private-sector beliefs of a weakening economy may become self-fulfilling. We propose a two-country model of a monetary union featuring a "sovereign risk channel" and analyze the extent to which (i) fiscal austerity and (ii) measures to pool sovereign risk are suited to contain elevated risk premia and restore macroeconomic stability.

Keywords: Sovereign risk channel, monetary union, euro area, zero lower bound, risk premium, pooling of sovereign risk
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1 Introduction

In the wake of the global financial crisis, the euro area has been experiencing a deep and, in some member states, long-lasting recession. As of early 2013, the ECB has reduced policy rates to an all-time low and implemented a number of unconventional measures, but economic activity remains well below pre-crisis levels and unemployment is still on the rise. Governments, in turn, have made significant efforts to reduce budget deficits, but several member states continue to face a bleak fiscal outlook and an elevated sovereign risk premium. This, in turn, adversely affects private sector financing costs and aggregate demand. The possibility of a vicious circle, whereby a weakening economy contributes to a deterioration of fiscal indicators and vice versa, remains a latent threat to the very existence of the euro area, even though financial market conditions have stabilized since mid-2012.[1] In response to these developments, the heart of the policy debate has moved on to extraordinary policy measures to contain sovereign risk and restore macroeconomic stability.

In this paper, we put forward a New Keynesian two-country model of a currency union with country-specific sovereign risk. Within this stylized model, we analyze the macroeconomic effects of two widely discussed strategies, typically opposed to each other in the policy arena. The first, more conventional, strategy is centered on *fiscal austerity*. Indeed, following a fiscal expansion in response to the great recession of 2008/09, most countries in the euro area started to reduce their structural budget deficits as early as 2010 to comply with the Stability and Growth Pact and, more recently, with the new "fiscal compact". In some cases fiscal adjustment was precipitated by an overt sovereign risk crisis; in other cases policymakers speeded up its implementation as a pre-emptive measure to insure against such a crisis. By 2013 most euro area member states are projected to run a structural surplus. However, the underlying austerity measures are frequently criticized for being self-defeating, that is for effectively causing a deterioration in fiscal indicators.[2]

[1] One lingering risk is outright sovereign default which would make government bonds of the respective country ineligible as collateral with the ECB, plunging domestic banks into a severe funding crisis that might force a disorderly exit from the euro. Another concern is that an extended period of economic contraction and high unemployment may undermine political support in the population for membership in the currency area. Either way, the irrevocability of the euro might be called into question, causing disruptive capital flight from the countries suspected of edging toward euro exit.

[2] This point has been raised by various commentators and backed up by informal evidence, such as the

The second strategy consists of *pooling sovereign risk* at the euro area level, through various measures and to various extents. Already in place is the possibility of joint lending to fiscally distressed governments in the euro area, and/or extending guarantees to borrowers on a multilateral basis. Under the European Stability Mechanism (ESM), up to EUR 700 billion, corresponding to 6 percent of euro area GDP, are made available through multilateral guarantees for conditional lending. Another element that can be interpreted as a conditional pooling of sovereign risk is the European Central Bank's (ECB) program of Outright Monetary Transactions (OMT). Under this program, which was first announced in September 2012, the ECB stands ready to buy, under well-specified conditions, potentially unlimited amounts of government bonds with a remaining maturity between 1 and 3 years. While the statutory goal of such interventions in the sovereign debt market is to ensure the functioning of the monetary transmission mechanism, they necessarily imply some mutualisation of risk.[3] Further measures still under discussion include the issuance of some form of joint liabilities to replace some or all of the debt of individual member states ("eurobonds"), and the creation of a full-fledged banking union with a common euro area-wide deposit insurance scheme, which would entail a common fiscal backstop for contingent financial sector liabilities.

The focus of our analysis is on *macroeconomic stability*, i.e., the existence of a uniquely determined equilibrium in which private-sector beliefs of a weakening economy cannot become self-fulfilling. Specifically, we are interested in the conditions and policies under which a sovereign crisis in one part of the currency union will not undermine stability in the union as a whole, in the sense of causing indeterminacy problems. Our model framework is a two-country version of the model in Corsetti et al. (2013). Following Cúrdia and Woodford (2009), heterogeneous households in our model engage in borrowing and lending via financial intermediaries. The main innovation relative to Cúrdia and Woodford (2009) is what we

increase of actual debt-GDP-ratios during the austerity period. Erceg and Lindé (2013) calibrate a quantitative business cycle model to the euro area and find that debt-to-GDP ratios may indeed rise in response to government spending cuts, provided that monetary policy is constrained by the zero lower bond. However, this effect is limited to the short-run; debt is found to decline relative to GDP in the long run.

[3]Since the beginning of the crisis, many observers had pleaded for the ECB to act as a lender of last resort to governments that were on the verge of losing access to the capital market. The announcement of OMT was commonly interpreted as delivering on those pleas, albeit in a conditional manner. See, for instance, De Grauwe (2012), Economist (2012), and Reuters (2012). Corsetti and Dedola (2013) provide an analysis of the conditions under which the central bank can successfully provide a monetary backstop to governments.

have previously dubbed the "sovereign risk channel".[4] To activate this channel, we allow for sovereign risk premia that respond to changes in the fiscal outlook of the country, and let private credit spreads rise and fall along with sovereign risk.[5] Put differently, strained public finances are assumed to increase the cost of financial intermediation. This transmission channel reflects the empirical observation that as sovereign default looms, domestic firms face a higher risk of financial difficulties due to the risk of tax hikes, increases in tariffs, disruptive strikes, social unrest, and general economic turmoil, all of which may raise the challenge of monitoring and enforcing loan contracts.[6]

Extending our previous results for a closed economy, we first detail how, in the presence of a sovereign risk channel, a fiscal crisis in part of a currency union may undermine equilibrium determinacy in the union as a whole. To the extent that a pessimistic shift in expectations (unrelated to fundamentals) implies an upward revision of the projected government deficit in a country, the risk premium on its domestic public debt rises and, through the sovereign risk channel, increases the borrowing costs facing domestic firms and households. Higher private funding costs, in turn, slow down activity and worsen the fiscal outlook both domestically and, through cross-border demand spillovers, abroad, validating the initial adverse shift in expectations. Under normal circumstances, this scenario could be averted by the central

[4] In the spirit of Cúrdia and Woodford (2009), we specify a model in which there is complete insurance of idiosyncratic risks only in the long run, both within and across countries. We show that a consistent way to "close" the open-economy version of this model requires assuming that (infinitely-lived) households are allocated stochastically not only across types (savers and borrowers) but also across borders (Home and Foreign residents).

[5] As a caveat, we emphasise that the present paper is not meant to add to the theory of sovereign default. Following Eaton and Gersovitz (1981), a number of authors, including Arellano (2008) and Mendoza and Yue (2012), have recently modelled default as a strategic decision of a sovereign that balances the gains from foregone debt service against the costs of exclusion from international credit markets and (exogenous) output losses. In equilibrium this implies that the probability of default increases in the level of debt. In order to maintain the tractability of our model for business cycle analysis, we impose such a relationship without explicitly modelling a strategic default decision. Specifically, we link the sovereign risk premium to the expected path of public debt (or, alternatively, future fiscal deficits). Hence, implicit in our analysis is the assumption that there are limits to credible commitment on the part of fiscal policymakers.

[6] Our assumption can also be interpreted as a reduced-form approach to capture the fact that banks are exposed to their sovereigns in many ways, including through their holdings of government bonds. In times of fiscal strain, these exposures weigh on the banks' own creditworthiness, raise their funding costs, and depress new lending to customers. In a small open economy model, Mendoza and Yue (2012) obtain a link between strained public finances and private sector borrowing conditions by assuming that a defaulting sovereign can divert the repayment of private borrowers to foreign lenders. While we leave a richer theoretical account of the underlying mechanism for future research, we should stress that the sovereign risk channel is consistent with the evidence put forward by a growing empirical literature, see Neri (2013), Neri and Ropele (2013), and Zoli (2013) among others.

bank's commitment to appropriately lower the policy rate. To the extent that monetary policy is constrained, however, expectations may become self-fulfilling, especially when the average stock of debt in the union (and hence sovereign risk) is high from the outset.

In the scenario just described, we show that the anticipation of a procyclical spending policy, i.e., a systematic fiscal tightening in response to a cyclical fall in tax revenue, can help to ensure determinacy. In essence, if lower expected growth is understood to trigger fiscal austerity and if this policy response is strong enough to prevent a substantial deterioration of fiscal balances, risk premia do not rise. However, when the sovereign debt crisis is country-specific, determinacy is most likely if pro-cyclical cuts in the crisis country are accompanied by a systematic fiscal *expansion* in the rest of the union. This finding is intuitively plausible, as fiscal expansion elsewhere counteracts possible negative spillovers from (and help recovery in) the crisis country, whose fiscal tightening keeps risk premia and indeterminacy problems in check, but otherwise weighs on activity. Our analysis thus provides a new argument in favour of coordinated asymmetric fiscal stances in a monetary union: such a strategy may shield the union from the disruptive effects of self-fulfilling debt runs. At the same time, our analysis also provides a rationale for the pooling of sovereign risk. To the extent that the risk premium rises non-linearly with the level of public debt, pooling sovereign liabilities across countries with high and low risk weakens the sovereign risk channel. Depending on initial conditions, this effect in and by itself can be sufficient to assure macroeconomic stability.

Lastly, we analyze the sign and the size of the government spending multiplier, distinguishing between area-wide and country-specific policies. Regarding area-wide policies we find that the sovereign risk channel has the potential to alter the sign of the multiplier, confirming a finding from our earlier work (Corsetti et al. 2013).[7] With respect to country-specific policies, we identify a strong case for asymmetric fiscal policies (expansion in low-risk, contraction in high-risk countries) in terms of their effect on aggregate economic activity.

This paper is organised as follows. Section 2 presents some evidence on the fiscal stance of the euro area, both in the aggregate and at the country level, as well as estimates regarding the

[7] Yet, assuming GHH preferences, we find that the sovereign risk channel tends to amplify (positive) multiplier effects for most scenarios under consideration. This reflects strong multiplier effects even in the absence of sovereign risk which tend to make fiscal expansions self-financing.

scope for debt pooling under current institutional arrangements. Section 3 presents the model. Section 4 discusses its calibration. Section 5 presents analytical results derived under some simplifying assumptions, while Section 6 introduces the results from a full-fledged numerical analysis. Section 7 concludes.

2 Financial conditions and policy measures in the euro area

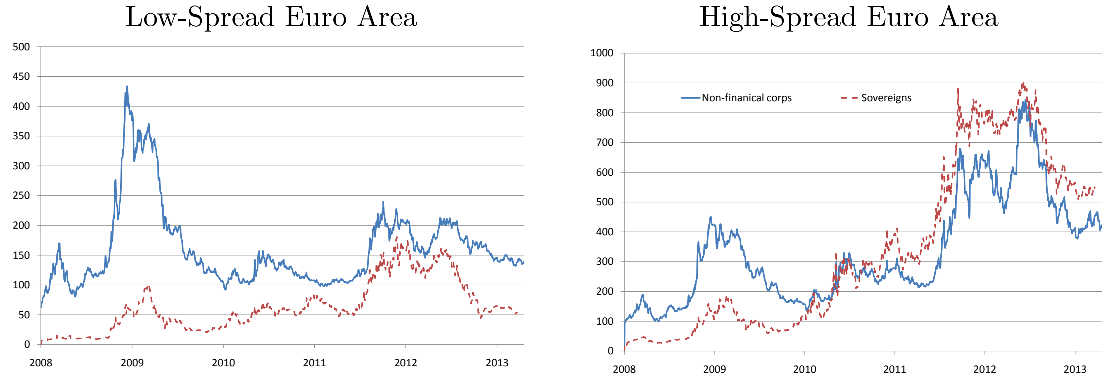
In this section we first provide some evidence on the sovereign debt crisis in the euro area and its impact on borrowing costs in the private sector, which is a key feature of the sovereign risk channel embedded in our model. We then document the post-2010 switch to pro-cyclical fiscal austerity in response to the crisis. Austerity is, indeed, one of the candidate strategies to counter a sharp rise in risk premia and restore stability. Finally, we turn to the main alternative strategy, i.e., greater sovereign risk pooling at the union level. We briefly discuss the relevant policy debate and assess the extent to which such risk pooling has already been established or at least made possible to date.

2.1 Evidence on the Sovereign Risk Channel

The panels in Figure 1 display time series data on credit default swap (CDS) spreads for government debt and nonfinancial corporate debt in the euro area. The two panels refer to different sets of countries within the euro area (and hence all facing the same monetary policy): the left panel to countries with relatively low sovereign spreads, and the right panel to those with relatively high sovereign spreads. As shown by the first column of Table 2 below, these two sets of countries also differ by their average debt level, with lower debt among the low-risk countries.

The series display different phases of the crisis. After a common deterioration of the financial conditions for governments in 2008–2009, a substantial divergence between core and periphery set in after 2010. For the peripheral countries, the period between the summer of 2011 and the summer of 2012 marks the height of the crisis. Since then, spreads have substantially subsided again, notably following the announcement of OMT by the ECB.

Figure 1: Sovereign and Nonfinancial Corporate CDS Spreads



Notes: 5-year CDS spreads in low-spread and high-spread euro area countries, as well as for nonfinancial corporations headquartered there. Low-spread euro area includes Austria (number of firms in our sample: 1), Finland (1), France (24), Germany (18), and the Netherlands (8). High-spread euro area includes Belgium (number of firms: 1), Greece (1), Ireland (0), Italy (4), Portugal (2), and Spain (4). The corporations in our sample are the constituents of the Itraxx Europe index. The same relative weights are adopted for the sovereign and corporate index series. For example, of the 52 firms in the low-spread euro area sample, 24 are headquartered in France. As a result, in the sovereign low-spread euro area series, France has a weight of 24/52. Data sources: Bloomberg; Markit.

The Figure also documents substantial comovement of CDS for sovereigns and large corporates, particularly in countries that face intense fiscal strains (right panel). For the time period shown, the daily correlation between corporate and sovereign CDS spreads in high-spread countries is 0.9. For the low-spread countries, it is lower, but still positive at 0.34.

The notion that strains in sovereign funding spill over into private credit markets is prominently embedded in the notion of a "sovereign ceiling." In a strict interpretation, the sovereign ceiling posits that no debtor in a given country can have a better credit quality than the government, a primary reason being the latter's capacity to extract private-sector resources through taxation. In reality, several authors, including Durbin and Ng (2005), have documented exceptions to this rule, notably for firms with substantial export earnings or foreign operations. These exceptions are also apparent from our Figure 1 above. Nevertheless, sovereign and corporate bond yields tend to comove significantly; see also the literature review in Cavallo and Valenzuela (2007) or Harjes (2011).

Causation can, in principle, run either way. In particular, sovereign risk might conceivably increase in response to fundamental weakness in the domestic corporate sector, foreshadowing a fall in tax revenue and larger spending commitments. In this paper, however, we pursue the idea that, once a full-blown sovereign crisis has erupted, the opposite direction becomes more relevant: sovereign risk premia spill over to private funding costs, as fears about potential sovereign default unfold a broad-based negative effect on domestic financial markets. Because of such spillovers, rising sovereign indebtedness can negatively affect economic activity through its effects on borrowing costs faced by firms and households.

These spillovers are documented by recent studies focused on the euro area. For Italy, Zoli (2013) concludes that about 30-40 percent of the increase in sovereign spreads is transmitted to firm borrowing rates within three months, and 50-60 percent within six months. For the euro area, Neri (2013) estimates that, between April 2010 and the end of 2011, sovereign spreads in the crisis countries have driven borrowing costs for non-financial firms and households up by 130 and 60 basis points, respectively. Albertazzi and Signoretti (2012) further documents the effects of rising spreads on the growth rate of lending to firms.[8]

2.2 Austerity

With the emergence of fiscal stress and elevated sovereign risk premia, the members of the European Union agreed in early 2012 to tighten the existing set of fiscal rules by concluding a new "Fiscal Compact", formally enshrined in the "Treaty on Stability, Coordination and Governance in the Economic and Monetary Union". The compact, which became effective on January 1, 2013, commits its signatories—all 27 EU members except the Czech Republic and the United Kingdom—to achieve budget balance or a surplus within the treaty's definition, with temporary deviations allowed under exceptional circumstances only. In addition, the compact foresees an automatic correction mechanism by which countries are required to make up for deviations from the budget target over a well-defined period of time.

The conclusion of the fiscal compact confirmed earlier commitments to reduce the large fiscal deficits that had emerged during the global financial crisis of 2008/09. Indeed, euro area governments generally shifted into fiscal tightening by 2010. To gauge the extent of fiscal policy changes across the euro area, it is useful to focus on changes over time in the cyclically adjusted primary government balance.

[8] See also International Monetary Fund (2010) and European Central Bank (2010).

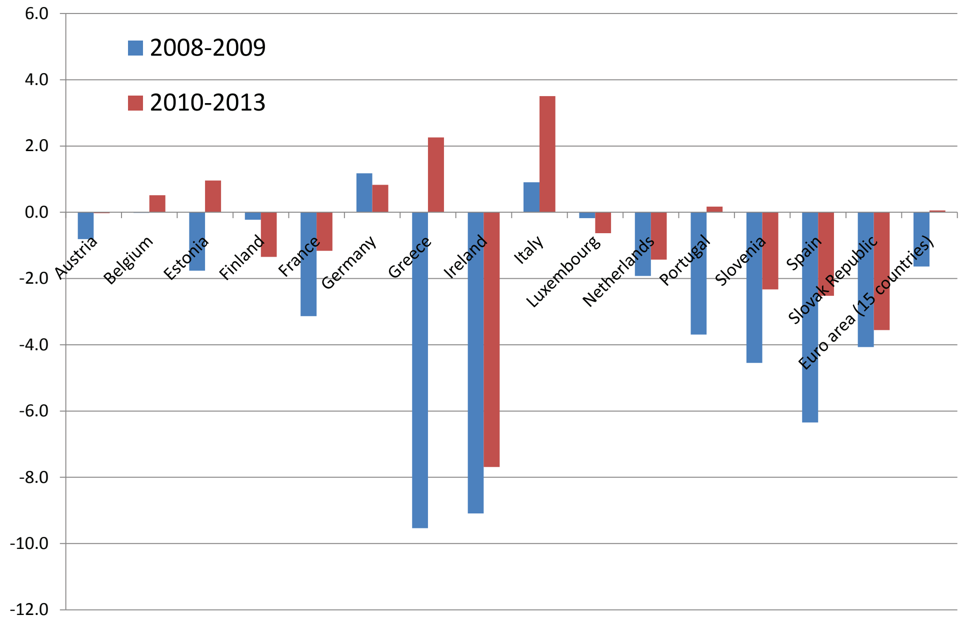


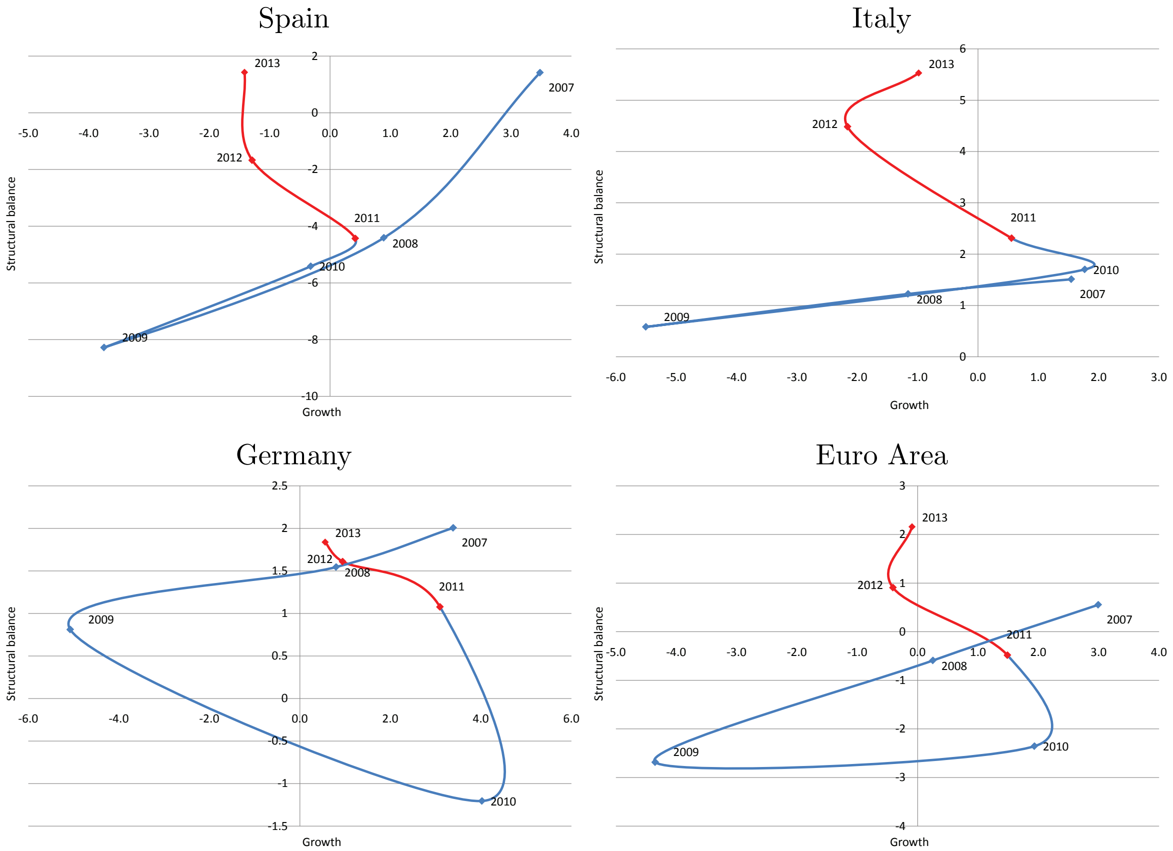
Figure 2: Average structural balance 2008–2009 and 2010–2013. Notes: Cyclically adjusted government primary balance, as a percentage of potential GDP. Source: OECD Economic Outlook 92.

Figure 2 displays average structural balances for the periods 2008–2009 and 2010–2013, respectively. In the earlier period, fiscal policy was very expansive across the euro area, with the notable exceptions of Germany and Italy. Second, fiscal policy subsequently tightened almost everywhere, moving into a modest structural primary surplus.

Figure 3 confirms this trend, while also relating the structural balance to output growth in Germany, Italy, Spain, and the euro area as a whole. For the latter, the average structural balance improved by more than 3.5 percentage points of GDP between 2009 and 2012, indicating a fiscal tightening of more than 1 percentage point of GDP per year. For 2013, this trend is expected to continue.

Turning to the interaction with GDP growth, a similar pattern emerges for most countries in the euro area. For the period 2007–2010 we observe a positive relationship between the structural balance and output growth, in line with the notion of a countercyclical fiscal stance. From 2011 onward, however, the relationship turns negative, that is, low output growth is associated with an improving structural balance. This suggests a clear shift toward a procyclical fiscal stance, as the euro area embraced fiscal austerity as part of its strategy to

Figure 3: Output growth and structural balance



Notes: Cyclically adjusted government primary balance, as a percentage of potential GDP and annual GDP growth in percent. Source: OECD Economic Outlook 92.

overcome the debt crisis.

2.3 Pooling sovereign risk

The crisis in the euro area has also given much greater salience to the long-standing debate over the appropriate extent of fiscal risk sharing among member states. Proponents of fiscal integration argue that some pooling of risk is necessary to deal with the kind of asymmetric shock that has hit the euro area. Abstracting from the possibility of outright fiscal transfer mechanisms, the focus of the debate has been on strategies to mutualise a certain portion of sovereign risk.

In what follows, we briefly review various phases of this debate and propose a rough assessment of how much risk pooling is available, as of today, based on the existing arrangements.

The most prominent idea in the debate on risk pooling concerns the creation of so-called eurobonds, i.e., common euro area bonds issued with joint and several liability of all member states. Claessens et al. (2012) provide an overview of the leading eurobond proposals. According to its supporters, the introduction of a eurobond scheme would put a quick end to the euro area crisis by replacing vulnerable, national funding mechanisms with a stronger, centralised scheme. For fiscally weak members currently facing market pressures, issuing bonds jointly with other euro area members would deflect investor concerns about national solvency and the resulting risk of default.

However, resistance to eurobonds has remained strong in a number of member states, preventing any formal move in this direction. At the same time, the escalation of the euro area crisis has led policymakers to develop other tools of providing support to weaker sovereign debtors. One critical tool is the European Stability Mechanism (ESM), a permanent fund that can lend to euro area members in financial difficulty. Established in September 2012, the ESM replaces the euro area's earlier (temporary) rescue fund, i.e., the European Financial Stability Facility (EFSF). To fulfill its purpose, the ESM can raise funds in the capital market by issuing debt instruments with maturities of up to 30 years. The ESM's debt is backed by capital contributions from member states. Although only EUR 80 billion of capital need to be paid in initially, the ESM's total capital commitments amount to EUR 700 billion, with

Table 1: Government debt outstanding by maturity

	Maturities in calendar year				
	2013	2014	2015	Total debt	Share in 1-3-year bracket
Italy	280.8	187.9	181.3	1.634.2	22.6
France	246.8	124.0	129.1	1.359.4	18.6
Germany	190.0	147.0	96.0	1.114.0	21.8
Spain	133.3	102.7	97.1	740.1	27.0
Belgium	59.6	29.4	30.6	340.0	17.7
Netherlands	39.0	32.0	48.2	315.3	25.4
Greece	25.3	15.8	7.0	288.9	7.9
Austria	21.7	24.6	15.1	203.8	19.4
Portugal	18.6	19.5	15.6	183.2	19.1
Ireland	6.1	7.6	3.8	143.9	7.9
Finland	11.6	7.1	7.6	85.0	17.2
Slovak Republic	4.1	4.1	4.0	34.9	23.0
Slovenia	1.6	1.8	1.1	17.2	16.8
Cyprus	2.1	0.9	1.5	9.7	24.4
Luxembourg	2.0	-	-	5.0	0.0
Malta	0.7	0.5	0.2	4.3	17.4
Estonia	-	-	0.0	0.2	3.5
Total	1.043	705	638	6.479	20.7

Notes: billions of EUR; source: Bloomberg as of Feb. 4, 2013.

contributions from individual countries set as a function of economic weight.

Unlike eurobonds, the ESM does not create a regular funding source for euro area sovereigns. Yet, it allows sovereigns facing market pressures to obtain, under certain conditions, a loan that is backed by the credit of other euro area members. As such, it can be interpreted as a partial transfer of creditworthiness from stronger to weaker euro area members. The counterpart is a partial assumption by stronger euro area members of exposures to the sovereign risk of weaker euro area members. The scale of this risk transfer depends on the actual utilization of the ESM, but it seems fair to argue that the mere possibility of tapping the ESM already provides a significant benefit to countries struggling with elevated risk premia. Accordingly, we treat the ESM's capital commitments as one aspect of tentative risk pooling in the euro area.

The second important element to consider is the ECB's readiness to intervene in the government bond markets of member states. Two specific programs are relevant in this context. First, the ECB launched its so-called Securities Markets Program (SMP) in May 2010 with the stated purpose of ensuring sufficient depth and liquidity in dysfunctional bond market segments to restore an appropriate monetary policy transmission mechanism. Under the program, the eurosystem bought a total of some EUR 220 billion in government bonds issued by Greece, Ireland, Italy, Portugal, and Spain until its operations were discontinued in September 2012. At that time, the ECB announced a new program dubbed Outright Monetary Transactions (OMT). While formally serving a similar purpose as the earlier SMP, the OMT scheme allows the ECB to buy potentially unlimited amounts of government paper with a remaining maturity of 1 to 3 years. The amount of government paper outstanding in this maturity bracket is summarized in Table 1.

As noted above, the stated objective of OMT-related purchases is to address "dysfunctions" in national government bond markets that prevent the transmission of a common monetary policy stance and cause fragmentation of financial conditions across member states. While this explanation points to a narrow focus on monetary policy implementation, OMTs inevitably involve some transfer of fiscal risks. Specifically, by purchasing government bonds of a member state, the eurosystem assumes a sovereign risk exposure previously held by other (private) bond investors. Many proponents of the program view this as a decisive and indispensable element in resolving the euro area crisis, as the funding risks of weaker member states are effectively underwritten (under well-defined conditions) by the eurosystem acting with the backing of all euro area members. De Grauwe (2011, 2012), for instance, refers to ECB bond purchases as corresponding to a "buyer of last resort" policy. Critics, while disagreeing on the costs and benefits of such a policy, tend to agree with the basic notion that ECB purchases of government bonds constitute an element of risk transfer or pooling of sovereign liabilities. We follow this logic in our treatment below.

With these two elements—the ESM and the ECB's OMT—-in mind, it is possible to quantify the extent of potential risk transfers between subgroups of euro area member states that are in place today. Given that we use a two-country model below, we distinguish between "Core" and "Periphery". The former comprises France, Germany, Belgium, the Netherlands, Austria, Finland, the Slovak Republic, Luxembourg, Malta, and Estonia. The latter comprises Italy, Spain, Greece, Portugal, Ireland, Slovenia, and Cyprus. In terms of GDP, the two regions

Table 2: Effective liabilities (% of GDP)

	W/o pooling	Pooling	
		ESM	OMT
Core	92.5	99.8	106.6
Periphery	126.0	111.6	98.4

Notes: Effective liabilities, in percent of 2012 GDP.

account for two-thirds and one-third of total euro area output, respectively.

We compute liabilities of Core and Periphery from the vantage point of mid-2012, i.e, before the OMT program was announced, drawing on the IMF's WEO database of April 2012. At that point, debt levels (stock of general government debt outstanding) for end-2012 were projected to equal 80 and 110 percent of GDP, respectively. In addition to these explicit liabilities, we include contingent liabilities related to potential support for domestic banking sectors, based on estimates by (see Arslanalp and Liao 2012). These contingent liabilities add another 12 and 17 percentage points of GDP to the liabilities of Core and Periphery, respectively

In computing how ESM and OMT affect the effective liabilities in Core and Periphery we assume that *de facto* only debt of the Periphery will be covered by these instruments, while both Core and Periphery remain liable for a fraction of the total depending on their respective GDP weights. Regarding the ESM, we thus assume an increase in the liabilities of the Core of about EUR 460 billions euros. The volume of debt eligible for OMT is about EUR 640 billion (see Table 1), thereby raising the Core's liabilities by about EUR 430 billions. Given the arguments above we assume that the effective liabilities in the Periphery are reduced accordingly.

Table 2 summarizes our calculations. It turns out that the effective liabilities of Core and Periphery are fairly similar in relation to GDP, once the existing mechanisms for risk pooling are taken into account. In fact, under our assumptions, liabilities are slightly larger in the Core under the pooling scheme considered here. This result is not inconsistent with the notion that overall sovereign risk in the euro area is reduced as a result of ESM and OMT, as the implied levels of indebtedness become more even. Moreover, fiscal capacity may differ across the two regions, with countries in the Core potentially able to sustain somewhat higher debt levels, perhaps on account of stronger fiscal institutions.

3 The model

We assess the implications of fiscal imbalances on macroeconomic stability in a highly stylized model of a two-country monetary union. Central to the model is that, in each country, sovereign risk affects private-sector borrowing conditions, driving up the spread between borrowing rates and interest earned on deposits which arises due to costly financial intermediation. Specifically, building on Cúrdia and Woodford (2009), henceforth CW, we assume that the demand for intermediation arises as a result of heterogeneity among households.

As in previous work of ours, Corsetti et al. (2013), we allow the state of public finances in each country to affect the costs of financial intermediation. In order to retain the analytical tractability, we assume that there is eventual financial risk sharing across types of households. However, risk sharing is not immediate, leaving room for differential dynamics in the two countries at business cycle frequencies.

Countries, denoted Home and Foreign, are symmetric, but differ in size; our exposition focuses on "Home". Foreign-country variables are indexed by an asterisk. There is perfect specialisation in production: goods produced in the Home country carry subscript H; goods produced in the Foreign country an F. Where applicable, and unless noted otherwise, Home and Foreign variables are expressed per capita of the Home and Foreign population, respectively.

3.1 Households

Households are indexed by their type and their country of residence. Namely, following CW, households can be "borrowers" (indexed by superscript b) or savers (indexed by an s). Savers can save into domestic government bonds or make one-period risk-free deposits with a union-wide financial intermediary. Borrowers draw funds from financial intermediaries. Their borrowing rates are subject to country-specific spreads.

As a novel feature of our model relative to the literature, household's location changes over time. At each point in time, a fraction $\theta \in (0, 1)$ of the population resides in Home, and the remaining $1-\theta$ households in Foreign. Each period, however, a share $(1-\delta)$, $\delta \in (0,1)$, of household members change their type. Upon so doing, the type changers receive a transfer that depends on their past type. The transfers ensure that in equilibrium all type changers have the same wealth and thus the same ex-ante marginal utility. After the transfers have taken place, the type changers redraw their location and types. Type changers are then assigned a country of residence. θ is the probability of being assigned to Home. $1-\theta$ is the probability of being assigned to Foreign. Conditional on having been assigned to a country of residence, with probability π_b the type changer ends up with a borrower's preferences. With the opposite probability $\pi_s = 1-\pi_b$, he ends up being a saver.

We assume that there is complete pooling of assets within households of a particular location and type ("family").[9] Note that the type changes of a fraction of the population partially insure households against their type. However, in the short run financial conditions and, hence, the consumption and labor supply decisions of the different types of households will differ.

Let $\tau \in \{(H,b),(H,s),(F,b),(F,s)\}$ collect the two characteristics of a household. As Households supply labor only in the country where they reside, utility of an individual household member is given by

$$E_0 \sum_{t=0}^{\infty} (e_t \beta^t) \left[u_\tau(c_t^\tau, h_t^\tau) \right].$$

Note that expectations are formed both about aggregate shocks and the future type. h_t^τ denotes hours worked by the household. e_t is a unit-mean shock to the time-discount factor, $\beta \in (0,1)$.

The composite good c_t^τ is a bundle of, respectively, the Home-produced and Foreign-produced differentiated goods that a household of type τ consumes. Namely, for each household τ the consumption index is given by

$$c_t = \frac{c_{H,t}^{\theta} c_{F,t}^{1-\theta}}{\theta^\theta (1-\theta)^{1-\theta}}.$$

where $c_{H,t}$ and $c_{F,t}$, in turn, are bundles of Home and Foreign-produced intermediate goods.

[9] With positive government debt, assets of type changers will be positive on average. Therefore, if household members lived, saved, and borrowed on their own, newly-minted "b"-types will have positive assets – and will, therefore, not borrow immediately. We, therefore, cannot aggregate borrowers and savers with different histories the way that Cúrdia and Woodford (2009) do.

They are bundled according to the CES technology

$$c_{H,t} = \left[\left(\frac{1}{\theta} \right)^{\frac{1}{\mu}} \int_0^{\theta} c_{H,t}(j)^{\frac{\mu-1}{\mu}} dj \right]^{\frac{\mu}{\mu-1}}, \qquad c_{F,t} = \left[\left(\frac{1}{1-\theta} \right)^{\frac{1}{\mu}} \int_{\theta}^{1} c_{F,t}(j)^{\frac{\mu-1}{\mu}} dj \right]^{\frac{\mu}{\mu-1}}, \tag{1}$$

where $c_{H,t}(j)$ and $c_{F,t}(j)$ denote differentiated goods produced by firm $j \in [0, 1]$ in Home and Foreign, respectively. $\mu > 1$ denotes the price elasticity of demand for differentiated output goods. $P_{H,t}(j)$ and $P_{F,t}(j)$ are the prices denoted in the common currency of Home good j and Foreign good j, respectively. We assume that the law of one price applies, so that consumers in Home and Foreign pay the same price for the same good. The price indices for Home and Foreign good bundles are defined as $P_{H,t} = \left((1/\theta) \int_0^{\theta} P_{H,t}(j)^{1-\mu} dj \right)^{\frac{1}{1-\mu}}$ and $P_{F,t} = \left(1/(1-\theta) \int_{\theta}^{1} P_{F,t}(j)^{1-\mu} dj \right)^{\frac{1}{1-\mu}}$. The consumer price index is given by

$$P_t = P_{H,t}^{\theta} P_{F,t}^{1-\theta}. \tag{2}$$

The terms of trade are defined as the relative price of Home goods to Foreign goods

$$\tau_t = P_{H,t}/P_{F,t}. \tag{3}$$

Saving and borrowing is intermediated by perfectly competitive union-wide financial intermediaries. Throughout the paper, we assume that the intermediaries do not default. At the beginning of the period, and before type changes have played out, the combined wealth (denoted in nominal terms and per capita of the domestic population) of Home households who are savers, is given by

$$A_t^{s-} = S_{t-1}^p (1 + i_{t-1}^d) + (1 - \vartheta_t) B_{t-1}^g (1 + i_{t-1}^g) + T_t^c. \tag{4}$$

S_{t-1}^p denotes Home households' deposits at financial intermediaries at the end of the previous period. The deposits earn the deposit rate i_{t-1}^d. Savers may also hold their domestic government's debt $B_{t-1}^g \geq 0$. We depart from CW by assuming that, for the individual household, government debt is not riskless: In any period, the government may honor its debt obligations, in which case $\vartheta_t = 0$; or it may partially default, in which case $\vartheta_t = \vartheta_{\text{def}}$, with $\vartheta_{\text{def}} \in (0,1)$ indicating the size of the haircut. i^g_{t-1} is the notional interest rate on government debt. This drives a wedge between the risk-free rate, i^d_t, and the interest rate on government debt, i^g_t. The *risk* of default affects the investment decisions of savers and thus the wedge. The wedge, as discussed below, plays a crucial role in financial intermediation, thereby impacting the allocation prior to a sovereign default. To focus on this sovereign risk channel, we abstract from the possible consequences of an *actual* default through appropriate assumptions. Specifically, we assume transfers T^c_t which, in case of a sovereign default, compensate savers for the losses associated with the default (see Schabert and van Wijnbergen (2008) for a similar setup). These transfers do not affect investment decisions, as they are not proportional to the bond holdings of an individual saver. Formally, we set

$$T^c_t = \vartheta_t B^g_{t-1}(1 + i^g_{t-1}). \tag{5}$$

Analogous to the case of savers, at the beginning of the period, before type changes have played out, the combined debt of Home households, who are borrowers, is given by

$$A^{b-}_t = B^p_{t-1}(1 + i^b_{t-1}). \tag{6}$$

where B^p_{t-1} denotes nominal private debt and i^b_{t-1} denotes the Home borrowing rate. The beginning-of-period wealth of Foreign households is defined analogously. It bears noting that savers in Home and Foreign receive the same rate of interest i^d_t on their deposits. As further specified below, we assume that this rate is the central bank's policy rate.

Denote by $A^\dagger_t$ the beginning-of-period wealth of the pool of individuals who were selected to redraw their characteristics. Before they are randomly assigned a new type, the wealth of households in this pool is (in per capita terms):

$$\begin{aligned} A^\dagger_t \quad = \quad & \theta \left[S^p_{t-1}(1 + i^d_{t-1}) + B^g_{t-1}(1 + i^g_{t-1}) - B^p_{t-1}(1 + i^b_{t-1})\right] \\ & +(1-\theta)\left[S^{p*}_{t-1}(1 + i^d_{t-1}) + B^{g*}_{t-1}(1 + i^{g*}_{t-1}) - B^{p*}_{t-1}(1 + i^{b*}_{t-1})\right] \\ = \quad & \theta B^g_{t-1}(1 + i^g_{t-1}) + (1-\theta) B^{g*}_{t-1}(1 + i^{g*}_{t-1}), \end{aligned}$$

The first line provides the value of wealth contributed by Home households (selected to redraw their type). This is the net of domestic assets and domestic liabilities. The second line presents the same values for those who have previously resided in Foreign.

The combined wealth of Home saver households at the end of the period, that is, after type changes have taken place, is given by:

$$S_t + B_t^g = \delta \left[S_{t-1}(1 + i_{t-1}^d) + B_{t-1}^g(1 + i_{t-1}^g) \right] - \pi_s X_t^s + \pi_s(1 - \delta)A_t^\dagger. \tag{7}$$

Here X_t^s denotes expenditures of a saver household net of its non-financial income.

$$X_t^s = P_t c_t^s - w_t P_t h_t^s - D_{H,t}^f - D_t^{int} + T_t^g.$$

Above, w_t is the (Home)economy-wide real wage; $D_{H,t}^f$ are profits earned by goods-producing firms (per capita, again, of the Home population). The ownership of these firms is assumed to remain domestic. D_t^{int} are profits arising at the financial intermediaries. The intermediaries are assumed to be owned in Home and Foreign in proportion to their respective population size. Last, T_t^g are lump-sum taxes levied by the Home government.

The combined end-of-period debt of Home borrower households (per capita, again, of the Home population) is given by

$$B_t^p = \delta B_{t-1}^p(1 + i_{t-1}^b) + \pi_b X_t^b - \pi_b(1 - \delta)A_t^\dagger, \tag{8}$$

Net expenditures for the borrower, X_t^b, are defined analogously to those for the saver; and the Foreign terms are defined in the same way as those for Home households.

Turning to the intertemporal consumption decisions, note that, as a result of the assumption we make about partial insurance, all households of a specific type have a common marginal utility of real income, λ_t^τ, and choose the same level of expenditure. For Home households, we have for example,

$$\lambda_t^s = \frac{\partial\, u_s(c_t^s, h_t^s)}{\partial c_t^s}, \tag{9}$$

$$\lambda_t^b = \frac{\partial\, u_b(c_t^b, h_t^b)}{\partial c_t^b}. \tag{10}$$

And similarly for Foreign households.

In Home, the optimal choices regarding borrowing from and lending to intermediaries, as well as to the government, are then governed by the following Euler equations:

$$\begin{aligned} e_t\lambda_t^s &= \beta E_t \Bigg[e_{t+1}\frac{1+i_t^d}{\Pi_{t+1}} \Big\{ \delta\lambda_{t+1}^s \qquad (11) \\ &\qquad + (1-\delta) \underbrace{\left[\theta[\pi_b\lambda_{t+1}^b + \pi_s\lambda_{t+1}^s] + (1-\theta)[\pi_b\lambda_{t+1}^{b*} + \pi_s\lambda_{t+1}^{s*}] \right]}_{:=\bar{\lambda}_{t+1}} \Big\} \Bigg], \\ e_t\lambda_t^s &= \beta E_t \left[e_{t+1}\frac{(1-\vartheta_{t+1})(1+i_t^g)}{\Pi_{t+1}} \left\{ \delta\lambda_{t+1}^s + (1-\delta)\bar{\lambda}_{t+1} \right\} \right], \qquad (12) \\ e_t\lambda_t^b &= \beta E_t \left[e_{t+1}\frac{1+i_t^b}{\Pi_{t+1}} \left\{ \delta\lambda_{t+1}^b + (1-\delta)\bar{\lambda}_{t+1} \right\} \right], \qquad (13) \end{aligned}$$

The consumption Euler equations have the same structure for the Foreign households. Note, in particular, that the assumptions on partial risk sharing imply that for borrowers and savers, and Home and Foreign households, the continuation values share a common element ($\overline{\lambda}_{t+1}$). Optimal labour supply by each type of household, in turn, is given by

$$w_t = mrs_t^b, \tag{14}$$

$$w_t = mrs_t^s, \tag{15}$$

and again the same for Foreign households. Recall that, by assumption, households supply labor only in the country where they reside. Above, mrs_t^b and mrs_t^s are the respective types' marginal rates of substitution between consumption and leisure.

Across household types, average labour supply is dented by $h_t = \pi^b h_t^b + (1-\pi^b)h_t^s$. Finally, for future reference we define

$$\lambda_t = \pi^b \lambda_t^b + (1 - \pi^b)\lambda_t^s \tag{16}$$

as the average marginal utility of real income across types in the Home country.

3.2 Financial intermediaries

Savers and borrowers have access to area-wide perfectly competitive intermediaries. The intermediaries accept risk-free deposits. The intermediaries pay interest rate i_t^d on the deposits. This is the same interest rate that the intermediaries would need to pay in order refinance themselves at the central bank. The borrowing conditions, instead, depend on the jurisdiction in which the borrower resides. As in CW we assume that in each period a fraction of loans χ_t and χ_t^* cannot be recovered in Home and Foreign, respectively (due to, say, fraud). Intermediaries are assumed to collect the largest quantity of deposits that can be repaid with the proceeds of the loans that they originate, that is,

$$(1 + i_t^d)(\theta S_t^p + (1 - \theta)S_t^{p*}) = (1 + i_t^b)\theta B_t + (1 + i_t^{b*})(1 - \theta)B_t^{p*}.$$

Using ω_t as the spread between lending and deposit rates in Home, we have

$$1 + \omega_t := \frac{1 + i_t^b}{1 + i_t^d}. \tag{17}$$

Choosing the amount of lending, B_t^p and B_t^{p*} to maximise profits, the first-order conditions for loan origination yield

$$\omega_t = \chi_t \quad \text{and} \quad \omega_t^* = \chi_t^*. \tag{18}$$

In departing from CW, as in our previous work, Corsetti et al. (2013), we assume that χ_t and χ_t^* depend on sovereign risk in each country. This assumption is meant to capture the adverse effect of looming sovereign default risk on private-sector financial intermediation. Conceptually related is the notion that in case of a sovereign default the government diverts funds from the payments made by borrowers, see Mendoza and Yue (2012). Specifically, we assume that in Home

$$\chi_t = \chi_\psi[(1 + i^g_t)/(1 + i^d_t)]^{\alpha_\psi} - 1, \tag{19}$$

where parameter $\chi_\psi > 0$ is used to scale the private spread in the steady state, and $\alpha_\psi \geq 0$ measures the strength of the spillover from the (log) sovereign risk premium to the (log) private risk premium. In Foreign we have

$$\chi^*_t = \chi^*_\psi[(1 + i^{g*}_t)/(1 + i^d_t)]^{\alpha^*_\psi} - 1. \tag{20}$$

The spreads in Home and Foreign may thus differ. We allow for two distinct reasons: Either the yields on sovereign bonds in Home and Foreign differ, or the parameters that govern the spread (χ_ψ, α_ψ and $\chi^*_\psi, \alpha^*_\psi$) differ. Finally, while the intermediaries in equilibrium do not make profits, in accounting for the value of the intermediary to the households, we have to take account of the transfers from intermediaries to households that loans which are not recovered by the intermediaries effectively constitute. Therefore, $D^{int}_t = \omega_t\theta B^p_t + \omega^*_t(1-\theta)B^{p*}_t$.

3.3 Firms

In each of the two countries, there is a continuum of firms. Home firms are indexed by $j \in [0, \theta)$, Foreign firms by $j \in [\theta, 1)$. Each of these produces a differentiated good using linear technology

$$y_{H,t}(j) = zh_t(j), \tag{21}$$

where z is the aggregate productivity level. In each period only a fraction $(1-\alpha)$ of firms is able to reoptimize its prices. Firms that do not reoptimize adjust their price by the steady-state rate of inflation, Π. Prices are set in period t to maximize expected discounted future profits.The resulting first-order condition for a generic firm that adjusts its price, $P^{opt}_{H,t}$, is given implicitly by

$$F_t = K_t \tag{22}$$

with

$$K_t = \lambda_t e_t \frac{\mu}{\mu-1} w_t \frac{y_t}{z} \left(\frac{P_{H,t}^{\text{opt}}}{P_{H,t}}\right)^{-\mu} + \alpha\beta E_t \left(\frac{P_{H,t}^{\text{opt}}\Pi}{P_{H,t+1}^{\text{opt}}}\right)^{-\mu} K_{t+1}, \tag{23}$$

$$F_t = \lambda_t e_t y_t \left(\frac{P_{H,t}^{\text{opt}}}{P_{H,t}}\right)^{1-\mu} \left(\frac{P_{H,t}}{P_t}\right) + \alpha\beta E_t \left(\frac{P_{H,t}^{\text{opt}}\Pi}{P_{H,t+1}^{\text{opt}}}\right)^{1-\mu} F_{t+1}. \tag{24}$$

The law of motion for prices of the Home-produced basket ($\Pi_{H,t} := P_{H,t}/P_{H,t-1}$) is given by

$$1 - \alpha \left(\frac{\Pi}{\Pi_{H,t}}\right)^{1-\mu} = (1-\alpha) \left(\frac{P_t^{opt}}{P_{H,t}}\right)^{1-\mu}. \tag{25}$$

For future reference, it is also useful to define price dispersion of Home goods as $\Delta_{H,t} := \int_0^\theta \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\mu} dj$, which evolves according to

$$\Delta_{H,t} = \alpha \Delta_{H,t-1} \left(\frac{\Pi_{H,t}}{\Pi}\right)^{\mu} + (1-\alpha) \left(\frac{P_t^{opt}}{P_{H,t}}\right)^{-\mu}. \tag{26}$$

Analogous expressions apply for the corresponding Foreign terms. Finally, nominal profits distributed to households by these firms are (in per capita terms) given by $D_{H,t}^f = \frac{1}{\theta}\left[\int_0^\theta P_{H,t}(j) y_{H,t}(j) - P_t w_t h_t(j) dj\right]$; or, in equilibrium,

$$D_{H,t}^f = P_{H,t}\, y_{H,t} - P_t w_t h_t.$$

Above, $y_{H,t} = \left[(1/\theta) \int_0^\theta y_{H,t}(j)^{\frac{\mu-1}{\mu}} dj\right]^{\frac{\mu}{\mu-1}}$ denotes the bundle of differentiated goods produced in the Home country.

3.4 Government

We describe the government sector's behavior for the Home country. The government sector in Foreign is structurally identical. Exhaustive government spending, g_t, is isomorphic to private consumption, hence falls on both Home and Foreign goods.

Per-capita Home government debt evolves according to:

$$B_t^g = (1 - \vartheta_t) B_{t-1}^g (1 + i_{t-1}^g) + P_t g_t + T_t^c - T_t^g,$$

Below, we will consider different assumptions regarding the law of motion for government spending. Taking into account (5), the government flow budget constraint is thus given by

$$B_t^g = B_{t-1}^g (1 + i_{t-1}^g) + P_t g_t - T_t^g. \tag{27}$$

We assume that

$$\frac{T_t^g}{P_t} - t^g = \phi_{T,y}(y_{H,t} - y_H) + \phi_{T,b^g}(b_{t-1}^g - b^g), \quad \phi_{T,y} > 0,\ \phi_{T,b^g} > 0. \tag{28}$$

Here and in the following, variables without a time subscript refer to steady-state values. $b_t := B_t/P_t$, the real value of debt. Tax revenue rises when economic activity improves, with parameter $\phi_{T,y}$ denoting the semi-elasticity of revenue with respect to output. Similarly, it rises whenever debt exceeds its target value. Throughout the paper, we assume that ϕ_{T,b^g} is large enough so as to eventually stabilize public debt.

While *actual* default *ex post* is neutral in the sense described above, the *ex ante probability* of default is crucial for the pricing of government debt (i_t^g) and for real activity.[10] In the current paper, as in our previous work, Corsetti et al. (2013), we operationalize sovereign default by appealing to the notion of a fiscal limit in a manner similar to Bi (2012). Whenever the debt level rises above the fiscal limit, default will occur. The fiscal limit is determined stochastically, capturing the uncertainty that surrounds the political process in the context of sovereign default. Specifically, we assume that in each period the limit will be drawn from a generalized beta distribution with parameters α_{b^g}, β_{b^g}, and $\overline{b}^{\mathrm{g,max}}$. As a result, the *ex ante* probability of default, p_t, at a certain level of sovereign indebtedness, b_t^g, will be given by the

[10]This implication of our setup is in line with evidence reported by Yeyati and Panizza (2011). Investigating output growth across a large number of episodes of sovereign default, they find that the output costs of default materialise in the run-up to defaults rather than at the time when the default actually takes place.

cumulative distribution function of the beta distribution as follows:

$$p_t = F_{\text{beta}} \left(\frac{b_t^g}{4 y_H} \frac{1}{\overline{b}^{\text{g,max}}}; \alpha_{b^g}, \beta_{b^g} \right). \tag{29}$$

Note that $\overline{b}^{\text{g,max}}$ denotes the upper end of the support for the debt-to-GDP ratio. Regarding the haircut this implies

$$\vartheta_t = \begin{cases} \vartheta_{\text{def}} & \text{with probability } p_t, \\ 0 & \text{with probability } 1 - p_t. \end{cases} \tag{30}$$

Turning to monetary policy, we assume throughout that the central bank follows a Taylor-type interest rate rule for the aggregate economy that also seeks to insulate aggregate economic activity from fluctuations in risk spreads. In particular, we assume:

$$\begin{aligned} \log(1 + i_t^{d,target}) \quad = \quad & \log(1 + i^d) + \phi_\Pi \left[\theta \log(\Pi_t / \Pi) + (1 - \theta) \log(\Pi_t^* / \Pi) \right] \\ & - \phi_\omega \tfrac{1}{2} \left[\theta \log((1 + \omega_t)/(1 + \omega)) + (1 - \theta) \log((1 + \omega_t^*)/(1 + \omega)) \right]. \end{aligned} \tag{31}$$

Here, $i_t^{d,target}$ marks the target level for the deposit rate, i_t^d, and $\phi_\Pi > 1$, $\phi_\omega > 0$. For the closed economy, Cúrdia and Woodford (2009) show that optimal policy in the presence of credit frictions involves some adjustment of policy rates in response to interest rate spreads. However, in deep recessions the target level and the actual interest rate can diverge. The reason is that in implementing rule (31), the central bank relies on steering the riskless nominal interest rate i_t^d, which cannot fall below zero. Therefore, $i_t^d = i_t^{d,target}$ can only be ensured if $i_t^d \geq 0$. Otherwise, $i_t^d = 0$. As a result, an increase in the spread ω_t cannot be offset if monetary policy is constrained by the ZLB.

3.5 Market clearing

Goods-market clearing requires at the level of intermediate goods

$$y_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\mu} \left\{ \left(\frac{P_{H,t}}{P_t} \right)^{-1} \left[\theta (c_t + g_t) + (1 - \theta)(c_t^* + g_t^*) \right] \right\}. \tag{32}$$

where per capita consumption in Home and Foreign are given by $c_t = \pi_b c_t^b + \pi_s c_t^s$ and $c_t^* = \pi_b c_t^{b*} + \pi_s c_t^{s*}$, respectively.

The supply of Home and Foreign output, in the respective per capita terms is given by

$$y_{H,t}\Delta_{H,t} = zh_t. \tag{33}$$

and

$$y_{F,t}\Delta_{F,t} = zh_t^*. \tag{34}$$

Next, we turn to our calibration.

4 Calibration

To solve the model numerically, we assign baseline parameter values on the basis of observations for the euro area. The relationship between sovereign risk, private-sector spreads, and debt levels is calibrated based on global cross-country evidence. A time period in the model is one quarter. Table 3 lists the resulting parameterization.

First, we discuss the parameters that govern the link between strained public finances and elevated private-sector spreads. Actual haircuts in case of a sovereign default show large variation; see Panizza et al. (2009) and Moody's Investors Service (2011). $\vartheta_{\text{def}} = 0.5$ appears to be a reasonable average value. With respect to the specification of the fiscal limit, we choose parameters $\alpha_{b^g} = 3.70$, $\beta_{b^g} = 0.54$, and $\overline{b}^{\text{g,max}} = 2.56$. These follow Corsetti et al. (2013) who in turn choose these values to match the relationship between the sovereign risk premium and public debt in a sample of industrialized economies. Figure 1 is suggestive of a sovereign risk channel that runs from sovereign spreads to spreads in private credit markets. For the calibration, we set $\alpha_\psi = 0.55$; in line with Harjes (2011).

With respect to monetary policy, we assume an average inflation rate of 2 percent per year. The coefficient on inflation in the Taylor rule is set to a customary value of $\phi_\Pi = 1.5$. With regard to the response of the interest rate to the private spread, ϕ_ω, we choose a value such that, up to a first-order approximation, the central bank fully neutralises the effect of the

Table 3: Parameters

α	0.925	δ	0.975	θ	0.333	ϑ	0.500
α_{b^g}	3.702	μ_p	1.200	ψ_b	5.405	ξ_b	0.137
β_{b^g}	0.539	ν	0.526	ψ_s	3.871	ξ_s	0.016
$\overline{b}^{g,\max}$	2.559	ϕ_Π	1.500	σ_s	1.260	$\overline{\Pi}$	1.005
$\alpha_p si$	0.550	ϕ_ω	0.618	σ_b	0.708	z	3.000
β	0.990	$\phi_T y$	0.500	$\bar{\sigma}$	0.216		
χ_ψ	1.005	π_b	0.500	s_Ω	0.118		

Notes: Parameters of the baseline calibration.

sovereign risk premium on aggregate economic activity in normal times. This is the case for $\phi_\omega = 0.618$. The price stickiness parameter is fixed at $\alpha = 0.925$. Judging by *microeconomic* evidence on price rigidities, the implied frequency of price adjustment may appear too low. However, our calibration implies an appropriately flat Phillips curve, causing inflation to respond relatively little to a recessionary shock, in line with the actual behaviour of inflation during the latest crisis.

Next, we discuss the remaining targets. We set productivity such that the steady-state output per capita in both Home and Foreign equals unity. Government spending (consumption and investment) relative to GDP is set to $g = g^* = 0.2$. We set $\phi_{T,y} = 0.5$, as appears reasonable for the euro area; see Girouard and André (2005). Last, we assume that taxes react to debt sufficiently strongly (ϕ_{T,b^g} large enough) so as to ensure that the debt level remains bounded throughout, eventually returning to a certain debt-to-GDP level. Unless noted otherwise, our baseline value is 60% government debt to (annual) GDP in Home and Foreign. In regard to the steady-state spread between deposit and lending rates, we target a steady-state value of 2.5 percent (annualized), corresponding to the pre-crisis average (1999–2007) difference between the rate on loans (over 1 and up to 5 years, up to and including EUR 1 million, new business) and the EONIA rate. The steady-state level for the central bank's target interest rate, i^d, is targeted to be 4.5 percent (annualized).

A central element in our calibration is the share of borrowers in the economy, π^b. We set $\pi_b = 0.5$, thus using for the euro area a value that Corsetti et al. (2013) argue is reasonable for the US. We furthermore target a ratio of private debt to annual GDP, $b/4y$, of 130 percent, in line with average values (1999–2007) for non-financial private sector debt (loans, debt securities and pension fund reserves). Households redraw their type on average every 40 quarters, meaning $\delta = 0.975$. With regard to the preference parameters, we set the curvature of the disutility of work to $\nu = 1/1.9$, in line with the arguments provided by Hall (2009). We target a gross price markup of $\mu^p = 1.2$, which is in the range of values typically used in the literature. We target a steady state value for aggregate hours worked of $h = 1/3$. As in Corsetti et al. (2013), we assume that the consumption-weighted average intertemporal elasticity of substitution takes a value of $\pi_b \sigma_b c_b + \pi_s \sigma_s c_s = 0.8$. We choose the relative values of the intertemporal elasticity of substitution for the two types of households (σ^b and σ^s), and of the scaling parameters for the disutility of work (ψ^b and ψ^s), such that the above targets are satisfied and that, in addition, the linearized model can be represented in the canonical three-equation New Keynesian format.[11] We turn to this representation next.

5 Sovereign risk, fiscal policy, and macroeconomic stability

In this section, we consider special cases of a linear approximation of the equilibrium conditions of the model.[12] Based on these cases, we characterize conditions under which, in the presence of the sovereign risk channel, a fiscal crisis in part of the union can make the union as a whole vulnerable to self-fulfilling beliefs. We will then analyze the extent to which i) area-wide fiscal austerity, that is, a procyclical fiscal stance during a recession, ii) coordinated asymmetric fiscal stances or iii) pooling of sovereign risk can be successful in precluding such possibility in equilibrium.

5.1 A tractable special case of the model

We start by stating and discussing in detail the assumptions we make. These make our model analytically tractable, so that we obtain intuitive closed-form solutions for the approximate model. We posit four main assumptions.

Assumption 1: Utility is of the GHH form: $u_\tau(c_t^\tau, h_t^\tau) = \xi_\tau^{\frac{1}{\sigma_\tau}} \frac{1}{1-1/\sigma_\tau}\left(c_t^\tau - \psi_\tau \frac{h_t^{1+\nu}}{1+\nu}\right)^{1-1/\sigma_\tau}$. As a consequence, changes in the marginal utility of consumption do not directly affect the

[11] The resulting parameters are $\sigma_b = 0.86$, $\sigma_s = 1.18$, $\psi_b = 3.66$, $\psi_s = 3.47$, $\xi_b = 0.14$, $\xi_s = 0.03$. Our calibration implies a value of $\overline{\sigma} := \pi^b \xi_b \sigma_b \lambda_b^{\sigma_b} + \pi^s \xi_s \sigma_s \lambda_s^{\sigma_s}. = 0.35$. It implies steady-state values for hours worked of $h_b = 0.31$ and $h_s = 0.35$, respectively.

[12] We follow closely Corsetti et al. (2013), extending our previous results for a closed economy to the case of two countries in a currency union.

equilibrium wage level. Therefore, wages in Home and Foreign are not directly affected by changes in the spread and the terms of trade remain constant in the policy scenarios we will consider; output in Home and Foreign move in lock-step. Under this assumption, the area-wide Phillips curve is given by:

$$\overline{\widehat{\Pi}}_t = \beta E_t \overline{\widehat{\Pi}}_{t+1} + \kappa_y \overline{\tilde{y}}_t, \tag{35}$$

where $\kappa_y = \kappa\nu$, with $\kappa = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}$. As regards notation, $\tilde{y}_t = y_t - y$, and $\widehat{\Pi}_t = \log(\Pi_t/\Pi)$, where variables without a time subscript continue to refer to steady-state values (throughout, we assume a parametrization such that $y = y^* = 1$). A bar over a variable means area-wide averages; for example, $\overline{\widehat{\Pi}}_t := \theta\widehat{\Pi}_t + (1-\theta)\widehat{\Pi}^*_t$. Note that equation (35) governs the dynamics of CPI inflation which is identical in Home and Foreign.

Assumption 2: Parameters are restricted such that only the current period's spread enters into the IS-equation directly.[13] The IS-equation links output to real government spending and the effective real interest rate through

$$\overline{\tilde{y}}_t = E_t\overline{\tilde{y}}_{t+1} + \frac{1}{1-wh}\left[\overline{\tilde{g}}_t - E_t\overline{\tilde{g}}_{t+1}\right] - \bar{\sigma}\frac{1}{1-wh}\left[\widehat{i}^d_t + (\pi_b + s_\Omega)\,\overline{\widehat{\omega}}_t - E_t\overline{\widehat{\Pi}}_{t+1}\right]. \tag{36}$$

Here $\widehat{\omega}_t := \log((1+\omega_t)/(1+\omega))$, and $\widehat{i}^d_t := \log((1+i^d_t)/(1+i^d))$. From the IS-relationship, it is clear that fluctuations in the private-sector spread can influence economic activity if they are not neutralized by monetary policy. The degree to which the spread affects economic activity for a given policy rate is determined by the sum of parameters $\pi_b + s_\Omega$. A positive s_Ω indicates that an increase in the interest rate affects the consumption demand by borrowers more adversely than that of savers, which is always the case in our calibration ($s_\Omega > 0$).

As regards monetary policy, equation (31) implies that during normal times:

$$\widehat{i}^d_t = \phi_\pi\overline{\widehat{\Pi}}_t - \phi_\omega\overline{\widehat{\omega}}_t. \tag{37}$$

We assume that, to a first-order approximation, in normal times the central bank fully neu-

[13] More formally, we assume that $s_\Omega(\bar{\delta}-1) = \psi_\Omega$. Here, $s_\Omega := \pi_b\pi_s[\phi_b - \phi_s]/\bar{\sigma}$, with $\bar{\sigma} = \pi_b\phi_b + \pi_s\phi_s$, and $\phi_\tau = \sigma_\tau\xi_\tau\lambda_\tau^{-\sigma_\tau}$. $\psi_\Omega := \pi_b(1-\chi_b) - \pi_s(1-\chi_s)$, with $\chi_\tau = \beta\frac{R^\tau}{\Pi}\{\delta + (1-\delta)\pi_\tau\}$. Last, $\bar{\delta} := \chi_b + \chi_s - 1$.

tralizes the effect of the sovereign risk premium on aggregate economic activity; see equation (36). In particular, for our baseline we set $\phi_\omega = (\pi_b + s_\Omega) = 0.61$, a value which nonetheless vary in line with calibration.

Assumption 3: The probability of sovereign default—and thus the sovereign risk premium—depends on the primary deficit rather than the level of public debt as in the full model. Consequently, the interest rate spread now depends on the expected deficit. For each country, we postulate

$$\widehat{\varpi}_t = \xi E_t(\tilde{g}_{t+1} - \phi_{T,y}\tilde{y}_{t+1}), \text{ and} \tag{38}$$

$$\widehat{\varpi}_t^* = \xi^* E_t(\tilde{g}_{t+1}^* - \phi_{T,y}\tilde{y}_{t+1}^*), \tag{39}$$

where, in order to ease the burden on notation, we have defined $\widehat{\varpi}_t := (\pi_b + s_\Omega)\widehat{\omega}_t$. The parameter $\xi \geq 0$ indicates the extent to which a weak fiscal position—as measured here by primary deficits—adversely affects private-sector spreads. The parameter $\phi_{T,y} \in [0, 1)$ measures the sensitivity of tax revenue with respect to economic activity. Through this simplification, dictated by analytical tractability, we nonetheless aim at accounting for the main implications of the full model. Hence, we carefully set (high) values of the parameter ξ as to approximate the behaviour of economies with high public debt and a correspondingly high responsiveness of sovereign risk premia to changes in the fiscal outlook.[14] Throughout, we assume that the countries share similar tax systems, so that parameter $\phi_{T,y}$ is the same across countries. We do, however, allow for different slopes of the spread in the two countries, so that parameter ξ need not equal ξ^*.

Under our assumptions, the average spread that enters the area-wide IS equation (36) can be expressed as

$$\overline{\widehat{\varpi}}_t = \overline{\xi}\left(\overline{\tilde{g}}_{t+1} - \phi_{T,y}\overline{\tilde{y}}_{t+1}\right) + \theta(1-\theta)\xi^D\tilde{g}_{t+1}^D, \tag{40}$$

where $\overline{\xi} = \theta\xi + (1-\theta)\xi^*$, $\xi^D = \xi - \xi^*$, and $\tilde{g}_t^D := \tilde{g}_t - \tilde{g}_t^*$. The average spread depends on the area-wide output and government spending levels, as well as the cross country difference in spending levels and the spread. Note that in the first term the average slope matters for the average risk-premium: to the extent that the slope is convex in the level of debt, this

[14] Section 3.2 in Corsetti et al. (2013) discusses how one can relate parameter ξ to the debt level.

gives a potential argument in favor of pooling. Moreover, to the extent that the slopes differ ($\xi^D \neq 0$), the second term suggests that there may be scope for different policies in Home and Foreign.

Assumption 4: Our analysis in this section posits that the interest rate is constant in the initial period. We follow Christiano et al. (2011) and Woodford (2011) in assuming that monetary policy goes back to the Taylor rule (37) in the next period with probability $1 - \mu$, where $\mu \in (0, 1)$. Otherwise, the constant interest rate persists into the next period. The same Markov structure applies to all subsequent periods. As a result, the expected length of the constant interest rate episode is given by $1/(1 - \mu)$. In the special case we consider in this section there are no endogenous state variables with regard to the first-order dynamics of area-wide output and inflation. Once the episode of constant interest rates ends, the aggregate economy, therefore, immediately reverts to the steady state.

5.2 The sovereign risk channel and equilibrium determinacy

We now turn to examining the determinacy properties for different assumptions regarding fiscal policy. As our starting point, we show that without a feedback from the state of the economy to the level of spending, and thus to the deficit, the range of parameters that ensure determinacy shrinks in the presence of sovereign risk.

Determinacy at risk

The following proposition establishes parameter restrictions that yield a (locally) determinate equilibrium when government spending is exogenously given in both countries.

Proposition 1 *In the economy summarized by equations* (35) – (37) *and* (40)*, let the interest rate be constant in the initial period. In each subsequent period, let the interest rate remain constant with probability* $\mu \in (0, 1)$*. Otherwise, let monetary policy be able to permanently return to Taylor rule* (37)*. There is a locally unique bounded equilibrium if and only if*

$$a) \quad a < 1/(\beta\mu), \qquad and \qquad b) \quad (1 - \beta\mu)(1 - a) > \mu\tilde{\sigma}\kappa_y,$$

where $a := \mu + \mu\bar{\xi}\phi_{T,y}\tilde{\sigma}$*, and* $\tilde{\sigma} = \frac{\bar{\sigma}}{1-wh}$.

Proof. See Appendix A. ■

Similar to the closed-economy case examined in our previous work, Corsetti et al. (2013), we find that the presence of a sovereign risk channel may undermine determinacy also in a monetary union. Specifically, the conditions a) and b) are more likely violated if the average interest rate spread is sufficiently responsive to the deficit ($\bar{\xi}$ and thus a is large enough).

It is important to note that what matters here for determinacy in the union is the *average* slope of the risk-premium. In other words, a large sovereign risk premium charged in a sufficiently large part of the union can have systemically destabilizing effects. However, recall that the risk-premium is convex in sovereign debt in the underlying model. Hence, pooling of sovereign liabilities may in principle move the aggregate economy from an indeterminate to a determinate equilibrium—to the extent that it reduces $\bar{\xi}$.

Determinacy with endogenous area-wide spending policy

To what extent can the indeterminacy issue just discussed be addressed by letting government spending adjust endogenously to output while the economy is at the ZLB? We look into this question in two steps. First, we analyze symmetric policies, by which government spending moves in the same direction in both the Home and Foreign country. Second, we entertain the possibility of asymmetric fiscal stances in the low- and the high-risk region.

The first exercise sheds light on a potential benefit from austerity, that is, the possibility that pro-cyclical spending cuts contain the risk of indeterminacy (increasing the region of parameters for which the equilibrium is determinate). Let area-wide government spending be given by $\bar{\tilde{g}}_t = \varphi \bar{\tilde{y}}_t$, and let each of the two countries conduct the same spending policy. Under this assumption, we have the following proposition.

Proposition 2 *In the economy specified in Proposition 1, let government spending in Home and Foreign take on the same value $\tilde{g}_t = \tilde{g}_t^* = \varphi \bar{\tilde{y}}_t$ when the interest rate is held constant, and $\tilde{g}_t = \tilde{g}_t^* = 0$ otherwise. Define $a^* := b^* - \mu\tilde{\sigma}\bar{\xi}(\varphi - \phi_{T,y})$, $b^* := \mu(1 - \frac{\varphi}{1-wh})$. Suppose $a^* \neq 0$, and $\varphi \neq 1 - wh$. There exists a locally unique bounded equilibrium if and only if:*

1. *with $a^* > 0$, $b^* > 0$*

$$a) \quad b^* > a^*\mu^2\beta, \quad \text{and } b) \quad (b^*/\mu - a^*)(1 - \beta\mu) > \mu\tilde{\sigma}\kappa_y,$$

2. with $a^* > 0$ *and* $b^* < 0$*:*

$$a) \quad (b^*/\mu - a^*)(1-\beta\mu) < \mu\tilde{\sigma}\kappa_y, \; and \quad b) \quad (b^*/\mu + a^*)(1+\beta\mu) < -\mu\tilde{\sigma}\kappa_y,$$

3. with $a^* < 0$ *and* $b^* > 0$*,*

$$a) \quad (b^*/\mu - a^*)(1-\beta\mu) > \mu\tilde{\sigma}\kappa_y, \; and \quad b) \quad (b^*/\mu + a^*)(1+\beta\mu) > -\mu\tilde{\sigma}\kappa_y,$$

4. with $a^* < 0$ *and* $b^* < 0$ *:*

$$a) \quad (b^*/\mu - a^*)(1-\beta\mu) < \mu\tilde{\sigma}\kappa_y, \quad b) \quad (b^*/\mu + a^*)(1+\beta\mu) < -\mu\tilde{\sigma}\kappa_y, \; and \quad c) \quad b^* < a^*\mu^2\beta.$$

or

$$a) \quad (b^*/\mu - a^*)(1-\beta\mu) > \mu\tilde{\sigma}\kappa_y, \; and \quad b) \quad (b^*/\mu + a^*)(1+\beta\mu) > -\mu\tilde{\sigma}\kappa_y,$$

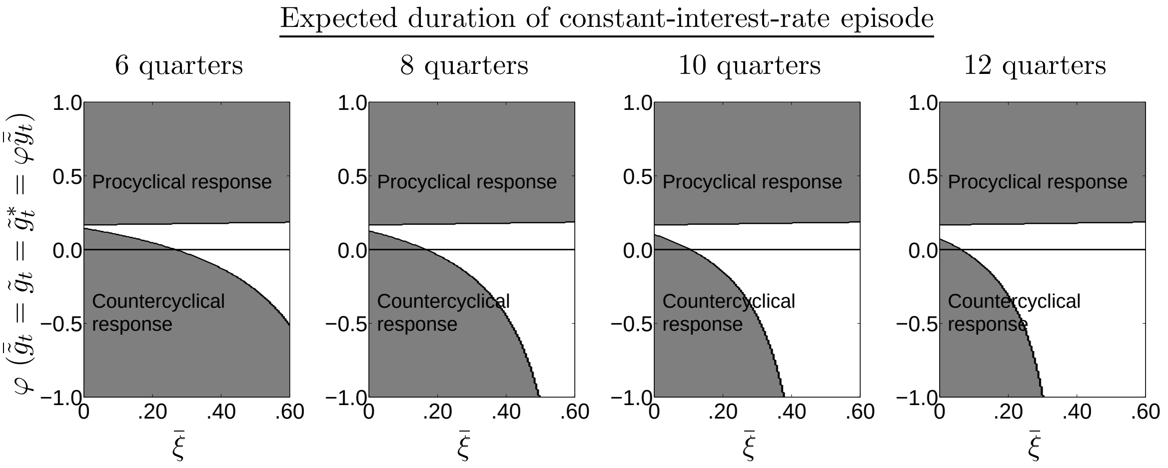
Proof. See Appendix A. ■

While the proposition itself is unwieldy, the two most relevant implications are rather intuitive. As spelled out by our corollary 7 in the appendix, absent the sovereign risk channel ($\xi = 0$), the range of (non-policy) parameters for which the equilibrium is determinate is larger if area-wide government spending is countercyclical ($\varphi < 0$). With an endogenous risk premium, instead, the opposite may hold.[15] This extends the results that Corsetti et al. (2013) derived for a closed economy to a currency union.

The main message is that systematic spending cuts while the central bank does not adjust interest rates (say, because of the zero lower bound problem) can help to anchor expectations to a unique equilibrium. To see why, assume that, for given policy rates, agents develop arbitrary expectations of a drop in output. Lower output would mean less tax revenue and, in the absence of a fiscal response, higher deficits. In high-debt economies these deficits would imply a significantly higher interest rate spread. Since a widening of the interest rate spread is not offset (or cannot be offset) by monetary policy, the real interest rate would rise. A sharp rise in the real rate will weigh sufficiently on private demand to make nonfundamental expectations of adverse output developments self-fulfilling. In such a situation, insofar as it can offset the anticipated fall in tax revenue due to lower output, a procyclical fiscal stance

[15] We focus here on standard fiscal and monetary rules, simplified to maintain analytical tractability. Rules that would make future policy behaviour depend on past developments might, in principle, help overcome problems of indeterminacy as well.

Figure 4: Determinacy regions (grey) – endogenous area-wide spending response



Notes: Determinacy regions for the case of an endogenous response of government spending to economic activity during a deep recession. Grey areas mark parameterisations that imply determinacy. y-axis: response of government spending to output, φ ($\tilde{g}_t = \varphi\tilde{y}_t$). x-axis: average response of the interest rate spread to the deficit, $\bar{\xi}$. From left to right: interest rate is expected to remain constant for 6, 8, 10, or 12 quarters ($\mu = 5/6, 7/8, 9/10, 11/12$).

may prevent adverse expectational shocks from translating into a contraction in economic activity.

Figure 4 illustrates Propositions 1 and 2. The x-axis in each panel traces out different slopes, $\bar{\xi}$, of the average interest spread with respect to the average deficit. The y-axis traces out different responses of government spending to output, φ. We plot a range from $\varphi = -1$ (so that for each one-dollar drop in GDP, government spending countercylically rises by one dollar) to a value of $\varphi = 1$, marking a very procyclical policy. Each panel of Figure 4 displays results for a different value of μ, implying, from left to right, an expected duration of the constant-interest-rate episode of 6, 8, 10, and 12 quarters, respectively. For each of the different combinations of φ, $\bar{\xi}$, and the expected length over which the interest rate remains constant, the panels indicate whether a unique equilibrium exists (grey area) or not (white area).

As the panels show, the sovereign risk channel implies a bound on the admissible degree of countercyclicality of government spending for high-debt economies. If the ZLB is expected to bind for a relatively short period of time, say 6 quarters, and the slope of the risk premium is within the range plotted in Figure 4, the equilibrium is determinate for most of the values of the response parameter φ shown (left-most panel). In other words, equilibrium determinacy is not much affected by whether government spending is pro- or countercyclical. However, the longer the interest rate is expected to remain constant, the more the determinacy region shrinks for high debt levels (high values of parameter $\bar{\xi}$). In the twelve-quarter case, for example, a countercyclical response of government spending (φ below 0) would fail to induce determinacy for values of $\bar{\xi}$ around or above 0.35; see the lower-right corner of the right-most panel. A suitably intense procyclical response, instead, would succeed in anchoring expectations on a determinate equilibrium.[16]

Determinacy with endogenous country-specific spending policy

So far, we have focused on a symmetric response of government spending. The following proposition, instead, analyzes asymmetric fiscal responses. In order to illustrate as clearly as possible how asymmetric responses in Home and Foreign affect area-wide determinacy, we keep area-wide government spending constant ($\bar{\tilde{g}}_t = 0$) while varying the country-specific responses.

Proposition 3 *In the economy specified in Proposition 1, let government spending in Home and Foreign take on values of $\tilde{g}_t = \Delta_\varphi \tilde{y}_t$ and $\tilde{g}_t^* = -\frac{\theta}{1-\theta}\Delta_\varphi \tilde{y}_t^*$ when the interest rate is held constant, and $\tilde{g}_t = \tilde{g}_t^* = 0$ otherwise. Define $a^{**} := \mu + \tilde{\sigma}\mu(\bar{\xi}\phi_{T,y} - \theta\xi^D\Delta_\varphi)$. Suppose $a^{**} \neq 0$. There exists a locally bounded equilibrium if and only if:*

1. *with $a^{**} > 0$:*

$$a)\quad a^{**} < 1/(\beta\mu), \qquad and\ b)\quad (1-\beta\mu)(1-a^{**}) > \mu\tilde{\sigma}\kappa_y,$$

2. *with $a^{**} < 0$:*

$$a)\quad (1-\beta\mu)(1-a^{**}) > \mu\tilde{\sigma}\kappa_y, \quad b)\quad (1+\beta\mu)(1+a^{**}) > -\mu\tilde{\sigma}\kappa_y.$$

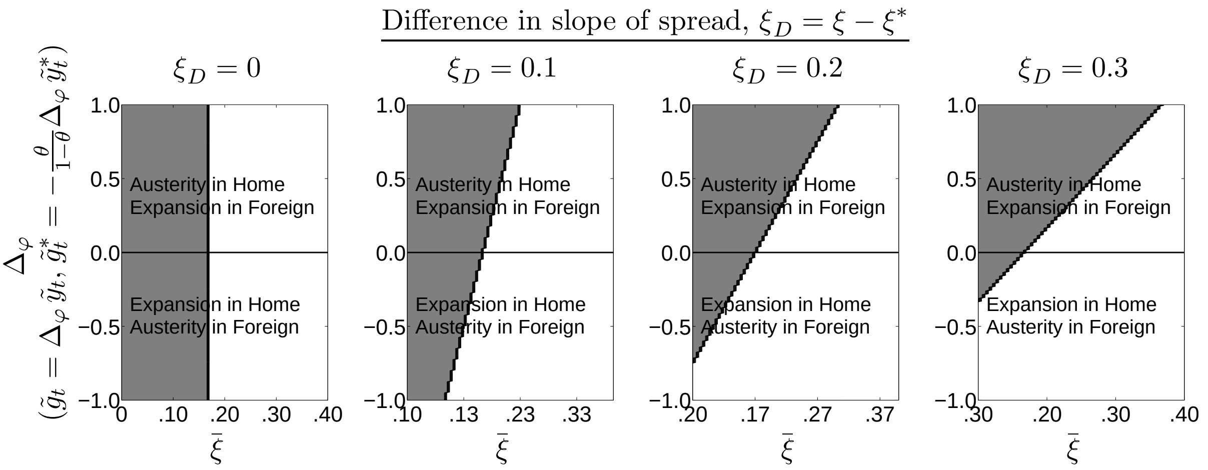
Proof. See Appendix A. ■

The central implication of our proposition, summarized by Corollary 8 in the appendix, is straightforward. Suppose that the spread is more responsive to the deficit in Home than in Foreign, so $\xi^D := \xi - \xi^* > 0$. Then, without changing the area-wide level of government

[16] As a caveat, we note that the linearized environment considered here may miss an implementability constraint for (perhaps implausibly) extreme sunspot expectations. In particular, government spending in our calibration accounts for 20 percent of GDP in steady state. Suppose that agents expect output to fall by close to 100 percent. Since government spending cannot be negative, the government cannot commit to cutting spending by more than 20 percent of steady-state GDP. Such extreme sunspot expectations, therefore, can only be fended off if a value of φ no larger than 0.2 already ensures determinacy.

spending, a combination of fiscal austerity in Home (the higher-spread region) and of fiscal expansion in Foreign (the lower-spread region) can help ensure determinacy. Figure 5 illustrates this result. In the figure, the central bank is expected not to move its interest rate

Figure 5: Determinacy regions (grey) – region-specific endogenous spending response
Expected duration of constant-interest-rate episode: 8 quarters



Notes: Determinacy regions for the case of an endogenous, region-specific response of government spending to economic activity during a deep recession. Grey areas mark parameterizations that imply determinacy. y-axis: differential response of government spending to output, Δ_φ ($\tilde{g}_t = \Delta_\varphi \tilde{y}_t$, $\tilde{g}_t^* = -\frac{\theta}{1-\theta}\Delta_\varphi \tilde{y}_t^*$). x-axis: average response of the interest rate spread to the deficit, $\bar{\xi}$. In all the panels, the interest rate is expected to remain constant for 8 quarters ($\mu = 7/8$).

for 8 quarters. The figure shows four panels. In each of these, the x-axis shows the average spread in the currency union. The y-axis shows parameter Δ_φ, which measures the differential response of government spending to output (see the proposition). The left-most panel shows the case when the two regions are identical, $\xi^D = 0$. Then, the area is homogenous and a differential response of government spending in the two regions does not affect area-wide determinacy. Moving towards the right, the sovereign risk channel becomes more and more prevalent in the Home country and relatively less important for the Foreign country. The graph on the right depicts a case in which (holding the government spending level constant for the union as a whole) determinacy is possible only with differential spending responses, with austerity in Home and a simultaneous fiscal expansion in Foreign.

5.3 Output effects of government spending cuts

We now turn to the classic question of assessing the size of the government spending multiplier, focusing on the effect of exogenous variations in spending on economic activity. As in Woodford (2011) and Christiano et al. (2011), we assume that parameters are such that the equilibrium is determinate, and that government spending deviates from its steady-state level only during the constant-interest-rate episode. Echoing the findings in the previous subsection, we establish that sovereign risk and its distribution matter also as determinants of the size and the sign of the fiscal multiplier.

5.3.1 Symmetric, area-wide spending change

As a first policy exercise, consider a symmetric, union-wide fiscal impulse such that $\tilde{g}_t = \tilde{g}_t^* = \overline{\tilde{g}}_t = g_L$ during the period of constant interest rates. The following proposition summarizes our results.

Proposition 4 *Under the conditions spelled out by Proposition 1 (which ensure that a locally unique bounded equilibrium exists), let government spending (in deviation from steady state) in both regions take on a value of g_L as long as the interest rate is constant, and 0 otherwise. As before, define $a := \mu + \mu\bar{\xi}\phi_{T,y}\frac{\bar{\sigma}}{1-wh}$, then while the interest rate is constant output is given by*

$$\overline{\tilde{y}}_L = \frac{1-\mu(1+\bar{\sigma}\overline{\xi})}{(1-a)(1-wh) - \frac{\bar{\sigma}\mu\kappa_y}{1-\beta\mu}} g_L.$$

Proof. See Appendix A. ■

Our main results are summarised by the Corollary 9 in the appendix. If there is no sovereign risk channel ($\bar{\xi} = 0$), the multiplier is unambiguously larger than unity (item 1 of the corollary). The same need not be true in the presence of sovereign risk, if $\bar{\xi}$ is large enough (item 2). In addition, if the tax revenue is sufficiently elastic with respect to economic activity ($\phi_{T,y}$ is large enough), then not only does the risk of indeterminacy increase (compare Proposition 1), but also (in a determinate equilibrium) the multiplier is typically quite large. Indeed, for large enough values of $\phi_{T,y}$, provided determinacy is preserved, government spending can be self-financing (while the interest rate is kept fixed): the primary deficit falls in spite of the increase in spending (item 3).

Indeed, when $\phi_{T,y} > 1 - wh - \kappa_y/(\bar{\xi}(1-\beta\mu))$, it is impossible for the multiplier to be negative, and the equilibrium to be determinate at the same time (item 4 of the corollary). Note that the above condition is not a particularly stringent, given the tax systems and the size of labor shares in most countries.[17]

5.3.2 Asymmetric spending, with constant area-wide spending

The transmission of spending shocks can be quite different in the case of asymmetric fiscal impulses. In order to illustrate this point, we consider a scenario in which one country expands government spending by as much as the other country cuts it, so that the area-wide spending level is unaffected.

Proposition 5 *Under the conditions spelled out by Proposition 1 (which ensure that a locally unique bounded equilibrium exists), let Home government spending take on a value of $\tilde{g}_t = g_L$ while Foreign government spending takes on a value of $\tilde{g}^*_L = -\frac{\theta}{1-\theta} g_L$ as long as the interest rate is constant. Both Home and Foreign spending are equal to 0 otherwise. As before, define $a := \mu + \mu\bar{\xi}\phi_{T,y}\frac{\bar{\sigma}}{1-wh}$, then while the interest rate is fixed, output is given by*

$$\bar{\bar{y}}_L = -\frac{\bar{\sigma}\mu\theta\xi^D}{(1-a)(1-wh) - \frac{\bar{\sigma}\mu\kappa_y}{1-\beta\mu}} \, g_L.$$

Proof. Straightforward extension to proof of Proposition 4. ■

Suppose that $\xi^D > 0$, that is, the spread is again more responsive to the deficit in Home than it is in Foreign. In this case, a Home spending expansion and a Foreign contraction has a negative effect on economic activity in the currency area. This effect comes about, because average government spending remains unchanged, such that there is no direct effect on aggregate demand in Home and Foreign. At the same time, however, the budgetary effect affects consumption more adversely in the region with a more elastic risk premium. The area-wide output contracts. This exercise warns against the consequences of a scenario in which, under the presumption that austerity is self-defeating, high-risk premium countries adopt expansionary policies, to which low-risk countries react with a precautionary budget contraction. Provided the equilibrium is still determinate, the outcome of this combined measures is likely to be quite negative.

An increase in activity instead follows when, keeping the area-wide spending constant, the country with a more elastic risk premium (Home) cuts back its government spending, while

[17] Differences relative to our previous work Corsetti et al. (2013), reflect the assumption of GHH preferences. In this case, as discussed in detail by Monacelli and Perotti (2008), the complementarity of hours worked and consumption induces consumption to rise in response to government spending shocks. As a result the multipliers tends to be larger, all else equal.

the other expands it. In this case, a reduction in the average spread causes an expansion of activity in both regions. This result suggests that coordinated fiscal packages, designed as to internalize the asymmetric elasticity of risk premia to economic conditions, can be expansionary without necessarily altering the area-wide spending level.

5.3.3 Spending in one country only, with area-wide spending change

As a final experiment, we consider an asymmetric change in government spending that does affect area-wide government consumption. Specifically, we assume that $\tilde{g}_t = g_L$ and $\tilde{g}_t^* = 0$ during the constant-interest episode. As a result $\bar{\tilde{g}}_t = \theta g_L$. The following proposition states our result, essentially combining the previous two propositions:

Proposition 6 *Under the conditions spelled out by Proposition 1 (which ensure that a locally unique bounded equilibrium exists), let home government spending take on a value of $\tilde{g}_t = g_L$ as long as the interest rate is constant, and 0 otherwise, while $\tilde{g}_t^* = 0$ throughout. As before, define $a := \mu + \mu\bar{\xi}\phi_{T,y}\frac{\bar{\sigma}}{1-wh}$, then while the interest rate is fixed, output is given by*

$$\bar{\tilde{y}}_L = \frac{1 - \mu(1 + \bar{\sigma}\xi)}{(1-a)(1-wh) - \frac{\bar{\sigma}\mu\kappa_y}{1-\beta\mu}}\,\theta g_L.$$

Proof. Simple extension of proof of Proposition 4. ■

This result illustrates the importance of accounting for the effect of government spending shocks on both the country-specific and the the average spread in the union when sovereign risk is asymmetric. Note that the average spread enters the above expression through the variable a. The denominator is strictly falling in $\bar{\xi}$: all else equal, the larger the average spread, the larger the effect on area wide economic activity, because higher tax revenues induce a reduction of interest rate spreads. This, in turn, further stimulates aggregate demand in the entire union. The country-level spread, instead, reflects the country-specific change in government spending and, hence, the country-specific deficit. Here, all else equal, the larger parameter ξ in Home, the smaller the effect of domestic government spending on area-wide economic activity.

6 Quantitative results

to be added

7 Conclusion

During sovereign risk crises, rising sovereign-risk premia appear to have systemic adverse effects on the borrowing costs in the private sector. These spillovers – the sovereign risk channel – raise a formidable stabilization issue, because they alter the conventional trade-off between budget consolidation and support of economic activity. In this paper, we make a first pass at exploring how the sovereign risk channel affects macroeconomic dynamics in a monetary union.

We find that, if the common central bank is constrained in neutralising elevated credit spreads, notably because policy rates may have fallen to the zero lower bound (ZLB), a sovereign risk crisis in one part of the monetary union may become a critical determinant of macroeconomic stability, that is, give rise to self-fulfilling expectations, in the union as a whole.

In this scenario, both systematic fiscal consolidation and cross-border risk pooling may help restore macroeconomic stability. The latter strategy works insofar as the risk premium is convex in the underlying debt level. The first one works insofar as budget cuts weaken the link between cyclical development and public deficits and debt. We show that it is most likely to be effective when consolidation is carried out by the high-risk countries only, and is accompanied by systematic expansions in the rest of the union.

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A Proofs of propositions

This appendix collects the proofs to the propositions in the main text. The appendix also presents the corollaries and their proofs.

A.1 Proof of Proposition 1

The economy, stripped from exogenous variables, is given by

$$E_t z_{t+1} = A z_t,$$

where $z_t = [\tilde{y}_t; \widehat{\pi}_t]$ and

$$A = \frac{1}{a\mu\beta} \begin{bmatrix} \mu\beta + \bar{\sigma}\mu\kappa_y & -\tilde{\sigma}\mu \\ -a\kappa_y & a \end{bmatrix},$$

where $a = \mu + \mu\bar{\sigma}\xi\phi_{T,y}$, and $\tilde{\sigma} = \bar{\sigma}/(1-wh)$, The Blanchard-Kahn conditions for determinacy require that matrix A has two roots outside the unit circle. Woodford (2003), pp. 670f., gives the following necessary and sufficient conditions for determinacy:
either (Case I): (i) $det(A) > 1$, (ii) $det(A) - tr(A) > -1$, and (iii) $det(A) + tr(A) > -1$,
or (Case II): (i) $det(A) - tr(A) < -1$ and (ii) $det(A) + tr(A) < -1$.

In the current case, $det(A) = \frac{1}{a\mu\beta}$ and $tr(A) = \frac{1}{a\mu\beta}[\mu\beta + \tilde{\sigma}\mu\kappa_y + a]$. Since both $det(A) > 0$ and $tr(A) > 0$ Case II cannot be satisfied. Checking Case I, condition (iii) holds since both terms are positive. Condition (i) of Case I is equivalent to condition a) in the proposition. Condition (ii) of Case I is equivalent to condition b) in the proposition. ■

A.2 Proof of Proposition 2

In this case

$$A = \frac{1}{a^*\mu\beta} \begin{bmatrix} \beta b^* + \tilde{\sigma}\mu\kappa_y & -\tilde{\sigma}\mu \\ -a^*\kappa_y & a^* \end{bmatrix},$$

where a^* and b^* are defined in the proposition.

1. If $a^* > 0, b^* > 0$, only Case I spelled out in the proof of Proposition 1 can be satisfied. Conditions (i) and (ii) of that case correspond to conditions a) and b) in Proposition 2. In addition, since a^* and b^* are both positive, condition (iii) of Case I is satisfied also.

2. For $a^* > 0, b^* < 0$, $det(A) < 0$, so Case I cannot hold. The conditions given in the proposition are those pertaining to Case II.

3. For $a^* < 0$, $b^* > 0$, $det(A) < 0$, so Case I cannot hold. The conditions given in the proposition are those pertaining to Case II with $a^* < 0$.

4. For $a^* < 0, b^* < 0$, both Case I and Case II can hold. The conditions given in the proposition are those pertaining to the respective case. □

A.3 Proof of Proposition 3

In this case

$$A = \frac{1}{a^{**}\mu\beta}\begin{bmatrix} \beta\mu + \tilde{\sigma}\mu\kappa_y & -\tilde{\sigma}\mu \\ -a^{**}\kappa_y & a^{**} \end{bmatrix},$$

where a^{**} is defined in the proposition.

1. If $a^{**} > 0$, $det(A) > 0$, so only Case I spelled out in the proof of Proposition 1 can be satisfied. Conditions (i) and (ii) of that case correspond to conditions a) and b) in Proposition 3. Since $tr(A) > 0$, condition (iii) of Case I is satisfied also.

2. For $a^{**} < 0$, $det(A) < 0$, so Case I cannot hold. The conditions given in the proposition are those pertaining to Case II with $a^{**} < 0$. □

A.4 Proof of Proposition 4

The assumed Markov structure means that output, and inflation and the spread (in deviations from the steady state) will take on the same respective values, $\bar{\tilde{y}}_L, \bar{\tilde{\pi}}_L, \bar{\tilde{\varpi}}_L$, in every period in which monetary policy is constrained, and values of zero thereafter.
The Phillips curve gives

$$\bar{\hat{\Pi}}_L = \frac{\kappa_y}{1-\beta\mu}\bar{\tilde{y}}_L$$

The spread is given by

$$\bar{\hat{\varpi}}_L = \bar{\xi}\mu\left(\bar{\tilde{g}}_L - \phi_{T,y}\bar{\tilde{y}}_L\right)$$

Use both in the dynamic IS equation:

$$\underbrace{\left[(1-\mu) - \frac{\bar{\sigma}}{1-wh}\left(\frac{\mu\kappa_y}{1-\beta\mu} + \bar{\xi}\mu\phi_{T,y}\right)\right]}_{=1-a-\frac{\bar{\sigma}}{1-wh}\frac{\mu\kappa_y}{1-\beta\mu}}\bar{\tilde{y}}_L = \frac{1}{1-wh}\left(1-\mu-\bar{\sigma}\bar{\xi}\mu\right)\bar{\tilde{g}}_L$$

The term in square brackets on the left-hand side is strictly positive per condition b) for determinacy in Proposition 1. Solving this for y_L thus yields the expression given in the proposition. ■

B Three corollaries

B.1 Statement and proof of Corollary 7

Corollary 7 *Under the conditions of Proposition 2, the following special cases obtain:*

1. *With no endogenous risk premium ($\bar{\xi} = 0$), the range of parameters for which the equilibrium is determinate is larger if government spending is countercyclical ($\varphi < 0$), rather than acyclical. In addition, the range of fundamental parameters implying determinacy of the equilibrium is larger the more negative φ.*

2. *With an endogenous risk premium $\bar{\xi} > 0$, instead, the range of parameters for which the equilibrium is determinate can be larger if government spending is procyclical, that is, if spending is cut systematically during a deep recession. For example, under the conditions of Proposition 2, if $a^* > 0$, $b^* > 0$ and $\mu\tilde{\sigma}\bar{\xi} > (1-\mu)$, then the range of fundamental parameters for which the equilibrium is determinate when $0 < \varphi < (1-wh)$ is at least as large as in the absence of an endogenous spending response, and can be strictly larger. This case is the more likely the more responsive the sovereign risk premium is to the deficit (the larger ξ) and the longer interest rates remain constant (the larger is μ).*

Proof.

1. If $\xi = 0$, $a^* = b^* = \mu(1 - \varphi/(1-wh))$. As a result, $det(A) > 1$. Also, as long as $\varphi \leq 0$ $tr(A) > 0$, so $det(A) + tr(A) > -1$. It remains to be checked that $det(A) - tr(A) > -1$. For $\bar{\xi} = 0$, this condition reduces to

$$(1-\mu\beta)(1-\mu) > \mu\tilde{\sigma}\frac{\kappa_y}{1-\varphi/(1-wh)}.$$

The left-hand side is positive and independent of φ. The smaller φ (with $\varphi \leq 0$), the smaller the right-hand side, proving the statement.

2. The conditions stated make item 1 of Proposition 2 the relevant case. In order for the range of fundamental parameters for which determinacy holds to be bigger with $\varphi \in (0, 1-wh)$ under the stated conditions than with $\varphi = 0$, we have to have $b^* - a^*\mu^2\beta > \mu - a\mu^2\beta$, which boils down to $\mu^2\beta\bar{\sigma}\bar{\xi} > (1-\mu^2\beta)$. We also need $b^*/\mu - a^* > 1 - a$, which reduces to $\mu\bar{\sigma}\bar{\xi} > 1 - \mu$, which is the tighter of the two conditions.

■

B.2 Statement and proof of Corollary 8

Corollary 8 *Under the conditions of Proposition 3, suppose that $\xi^D := \xi - \xi^* > 0$, so that the Home spread is more responsive to the Home deficit than the Foreign spread is to the Foreign deficit. Then the range of parameters for which the equilibrium is determinate can be larger if $\Delta_\varphi > 0$, that is, if government spending is cut in Home in response to a recession and raised in Foreign. For example, under the conditions of Proposition 3, if $a^{**} > 0$, with a suitable choice of $\Delta_\varphi > 0$ the range of fundamental parameters for which the equilibrium is determinate is at least as large as in the absence of an endogenous spending response, and can be strictly larger.*

Proof. By assumption, the relevant case is that of item 1 of Proposition 3. Under the stated conditions, with suitably chosen $\Delta_\varphi > 0$, $a > a^{**} > 0$. So condition (i) holds for a bigger set of fundamental parameters for this $\Delta_\varphi > 0$ than for $\Delta_\varphi = 0$. The same is true for condition (ii).

■

B.3 Statement and proof of Corollary 9

Corollary 9 *This corollary collects useful implications of the propositions regarding the government spending multiplier. Let, ϑ_g denote the government spending multiplier, $\vartheta_g := \partial\bar{\tilde{y}}_L/\partial\bar{\tilde{g}}_L$. Under the conditions of Propositions 1 and 4:*

1. *If $\xi = 0$, provided that the conditions for determinacy in Proposition 1 are satisfied, the government spending multiplier is strictly larger than one. This case corresponds to the analysis by Christiano et al. (2011) and Woodford (2011).*

2. *The government spending multiplier, $\partial\bar{\tilde{y}}_L/\partial\bar{\tilde{g}}_L$ is positive if and only if*

$$(1-\mu) > \mu\bar{\xi}\bar{\sigma}. \tag{41}$$

   Note, conversely, that the spending multiplier can be negative if the risk premium has a sufficiently detrimental effect on the economy, that is, if $\bar{\xi}$ is large enough.

3. *Let government spending at the lower bound be defined to be "self-financing" if $\vartheta_g > 1/\phi_{T,y}$. This is the case if*

$$\phi_{T,y} > \frac{(1-\beta\mu)(1-\mu)(1-wh) - \mu\bar{\sigma}\kappa_y}{(1-\beta\mu)(1-\mu)}.$$

   This cutoff is independent of ξ.

4. *Suppose $\bar{\xi} > 0$ and $\phi_{T,y} > 1 - wh - \frac{\kappa_y}{\xi}\frac{1}{1-\beta\mu}$. Then one <u>cannot</u> have both of the following at the same time: a) determinacy and b) a negative government spending multiplier.*

5. *The spending multiplier is increasing in $\bar{\xi}$, i.e. $\partial\vartheta_g/\partial\bar{\xi} > 0$ if*

$$\phi_{T,y} > (1-wh) - \frac{\bar{\sigma}\mu\kappa_y}{(1-\beta\mu)(1-\mu)}.$$

   Note that this is the more likely, the more responsive tax revenue is to economic activity.

Proof.

1. The conditions for determinacy require that $(1-\beta\mu)(1-a)-\mu\bar{\sigma}\kappa_y > 0$. The denominator of ϑ_g is, therefore, positive. $\vartheta_g > 1$ then boils down to

$$(1-\mu) > (1-\mu)(1-wh) - \frac{\bar{\sigma}\mu\kappa_y}{1-\beta\mu},$$

   which is true.

2. Under the restrictions for determinacy provided by Proposition 1, the denominator of the multiplier is unambiguously positive. A positive multiplier then requires $1-\mu(1+\bar{\sigma}\bar{\xi})$, which solves to the expression in equation (41).

3. The primary deficit (in deviation from the steady state) is given by $\bar{\bar{g}}_L - \phi_{T,y}\bar{\bar{y}}_L$. Government spending here is defined to be "self-financing" if $1-\phi_{T,y}\vartheta_g < 0$. Insert the multiplier, and observe that the denominator is positive by the assumption of determinacy. Simplifying yields the desired inequality for $\phi_{T,y}$.

4. From item 1., a negative multiplier (under determinacy) would require $(1-\mu) < \mu\bar{\xi}\bar{\sigma}$. Determinacy requires $(1-\mu) > \frac{\mu\kappa_y\bar{\sigma}}{(1-\beta\mu)}\frac{1}{1-wh}+\mu\bar{\xi}\phi_{T,y}\frac{\bar{\sigma}}{1-wh}$. If $\frac{\mu\kappa_y\bar{\sigma}}{(1-\beta\mu)}\frac{1}{1-wh}+\mu\bar{\xi}\phi_{T,y}\frac{\bar{\sigma}}{1-wh} > \mu\bar{\xi}\bar{\sigma}$, which reduces to the condition given in the statement, the two conditions contradict each other.

5. This follows from the derivative of the multiplier with respect to $\bar{\xi}$.

■

C Linearized Model

This section lists the linearized model equations. For the sake of brevity of exposition, we drop the expectations operator. It is implicitly understood that all terms carrying a $t+1$ index refer to the expectations as of period t of those variables. Also, in the derivations we impose that output per capita at Home and abroad in the steady state equals unity, $y_H = y_F = 1$.

C.1 Notation

Unless noted otherwise, a hat denotes percent deviations from the steady state; for example, $\widehat{x}_t$. A bar denotes area-wide averages, $\bar{\widehat{x}}_t = \theta\widehat{x}_t + (1-\theta)\widehat{x}_t^*$. A ^{D} denotes differences, $\widehat{x}_t^D = \widehat{x}_t - \widehat{x}_t^*$. Unless needed for clarity, we here present only the equations for Home not those for Foreign.

C.2 Consumption Euler Equations

Euler equation savers Home (for deposits):

$$\widehat{e}_t + \widehat{\lambda}_t^s = \beta\frac{R^d}{\Pi}\{\delta\widehat{\lambda}_{t+1}^s + (1-\delta)\frac{\bar{\lambda}}{\lambda^s}\widehat{\bar{\lambda}}_{t+1}\} + \widehat{e}_{t+1} + \widehat{R}_t^d - \widehat{\Pi}_{t+1}.$$

Euler equation savers Home (Home government bonds):

$$\widehat{e}_t + \widehat{\lambda}_t^s = \beta\frac{R^d}{\Pi}\{\delta\widehat{\lambda}_{t+1}^s + (1-\delta)\frac{\bar{\lambda}}{\lambda^s}\widehat{\bar{\lambda}}_{t+1}\} + \widehat{e}_{t+1} + \widehat{R}_t^g - \frac{p\vartheta_{def}}{1-p\vartheta_{def}}\widehat{p}_{t+1} - \widehat{\Pi}_{t+1}.$$

Euler equation savers Foreign (for deposits):

$$\widehat{e}_t + \widehat{\lambda}_t^{s*} = \beta\frac{R^d}{\Pi}\{\delta\widehat{\lambda}_{t+1}^{s*} + (1-\delta)\frac{\bar{\lambda}}{\lambda^{s*}}\widehat{\bar{\lambda}}_{t+1}\} + \widehat{e}_{t+1} + \widehat{R}_t^{\mathbf{d}} - \widehat{\Pi}_{t+1}^*.$$

Euler equation savers Foreign (Foreign government bonds):

$$\widehat{e}_t + \widehat{\lambda}_t^{s*} = \beta\frac{R^d}{\Pi}\{\delta\widehat{\lambda}_{t+1}^{s*} + (1-\delta)\frac{\bar{\lambda}}{\lambda^{s*}}\widehat{\bar{\lambda}}_{t+1}\} + \widehat{e}_{t+1} + \widehat{R}_t^{g*} - \frac{p\vartheta_{def}}{1-p\vartheta_{def}}\widehat{p}_{t+1}^* - \widehat{\Pi}_{t+1}^*.$$

Euler equation borrowers Home:

$$\widehat{e}_t + \widehat{\lambda}_t^b = \beta\frac{R^b}{\Pi}\{\delta\widehat{\lambda}_{t+1}^b + (1-\delta)\frac{\bar{\lambda}}{\lambda^b}\widehat{\bar{\lambda}}_{t+1}\} + \widehat{e}_{t+1} + \widehat{R}_t^b - \widehat{\Pi}_{t+1}.$$

Euler equation borrowers Foreign:

$$\widehat{e}_t + \widehat{\lambda}_t^{b*} = \beta\frac{R^b}{\Pi}\{\delta\widehat{\lambda}_{t+1}^{b*} + (1-\delta)\frac{\bar{\lambda}}{\lambda^{b*}}\widehat{\bar{\lambda}}_{t+1}\} + \widehat{e}_{t+1} + \widehat{R}_t^{b*} - \widehat{\Pi}_{t+1}^*.$$

Average marginal utility Home

$$\widehat{\lambda}_t = \pi_b\frac{\lambda^b}{\lambda}\widehat{\lambda}_t^b + \pi_s\frac{\lambda^s}{\lambda}\widehat{\lambda}_t^s.$$

Average marginal utility area-wide:

$$\widehat{\bar{\lambda}}_t = \frac{\lambda_b}{\lambda}\pi_b[\overline{\widehat{\lambda}}_t^b] + \frac{\lambda_s}{\lambda}\pi_s[\overline{\widehat{\lambda}}_t^s].$$

C.3 Consumption

Marginal utility of consumption savers Home:

$$c_s\widehat{c}_t^s = \psi_s h_s^{1+\nu}\widehat{h}_{st} - \phi_s\widehat{\lambda}_t^s.$$

Marginal utility of consumption borrowers Home:

$$c_b \widehat{c}_t^b = \psi_b h_b^{1+\nu} \widehat{h}_{bt} - \phi_b \widehat{\lambda}_t^b,$$

with $\phi_b := \xi_b \sigma_b \lambda_b^{-\sigma_b}$, and equivalently for the savers.

C.4 Labor Supply

FOC labor supply savers Home:

$$\widehat{h}_t^s = \frac{1}{\nu} \widehat{w}_t.$$

FOC labor supply borrowers Home:

$$\widehat{h}_t^b = \frac{1}{\nu} \widehat{w}_t.$$

C.5 Relative prices and terms of trade

Terms of trade:

$$\widehat{\tau}_t = \hat{p}_{H,t} - \hat{p}_{F,t}.$$

Then:

$$\begin{aligned} \widehat{\left(\frac{P_{H,t}}{P_t}\right)} &= (1-\theta)\widehat{\tau}_t. \\ \widehat{\left(\frac{P_{F,t}}{P_t}\right)} &= -\theta\widehat{\tau}_t. \end{aligned}$$

$$\widehat{\tau}_t = \widehat{\tau}_{t-1} - \widehat{\Pi}_{F,t} + \widehat{\Pi}_{H,t}.$$

C.6 Market clearing

Market clearing Home good (using tildes to express variables in terms of steady-state output)

$$\widehat{y}_{H,t} = \theta \left(\tilde{c}_t + \tilde{g}_t\right) + (1-\theta)\left(\tilde{c}_t^* + \tilde{g}_t^*\right) - (1-\theta)\widehat{\tau}_t.$$

Market clearing Foreign good

$$\widehat{y}_{F,t} = \theta\left(\tilde{c}_t + \tilde{g}_t\right) + (1-\theta)\left(\tilde{c}_t^* + \tilde{g}_t^*\right) + \theta\widehat{\tau}_t.$$

As a result, we have for relative output

$$\widehat{y}_t^D := \widehat{y}_{H,t} - \widehat{y}_{F,t} = -\tau_t.$$

Linking aggregate consumption to the spread and marginal utilities

$$c\widehat{c}_t = wh\widehat{h}_t - \bar{\sigma}\left[\widehat{\lambda}_t^w + s_\Omega\widehat{\Omega}_t\right].$$

where:

$$\begin{aligned}
\widehat{\lambda}_t^w \quad &:= \pi_b\widehat{\lambda}_t^b + \pi_s\widehat{\lambda}_t^s \\
\widehat{\Omega}_t \quad &:= \widehat{\lambda}_t^b - \widehat{\lambda}_t^s.
\end{aligned}$$

C.7 Inflation

Definition price index Home goods:

$$\widehat{P}_{H,t}^{opt} = \frac{\widehat{P}_{H,t} - \alpha\widehat{P}_{H,t-1}}{1-\alpha}$$

Definition price index Foreign goods

$$\widehat{P}_{F,t}^{opt} = \frac{\widehat{P}_{F,t} - \alpha\widehat{P}_{F,t-1}}{1-\alpha}$$

Home good inflation (Home NKPC)

$$\widehat{\Pi}_{H,t} = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}[\widehat{w}_t - (1-\theta)\widehat{\tau}_t] + \beta\widehat{\Pi}_{H,t+1}$$

Foreign good inflation (Foreign NKPC)

$$\widehat{\Pi}_{F,t} = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}[\widehat{w}_t^* + \theta\widehat{\tau}_t] + \beta\widehat{\Pi}_{F,t+1}.$$

CPI inflation

$$\widehat{\Pi}_t \quad = \quad \theta\widehat{\Pi}_{H,t} + (1-\theta)\widehat{\Pi}_{F,t} = \widehat{\Pi}^*_t$$

Substitute for wages:

$$\widehat{w}_t \quad = \quad \nu\widehat{h}_t = \nu\,\widehat{y}_{H,t}.$$

Therefore, producer-price inflation is given by

$$\widehat{\Pi}_{H,t} = \beta\widehat{\Pi}_{H,t+1} + \kappa\left[\nu\widehat{y}_{H,t} - (1-\theta)\widehat{\tau}_t\right]$$

$$\widehat{\Pi}_{F,t} = \beta\widehat{\Pi}_{F,t+1} + \kappa\left[\nu\widehat{y}^*_{H,t} + \theta\widehat{\tau}_t\right].$$

This implies that CPI inflation is given by

$$\widehat{\Pi}_t \quad = \quad \beta\widehat{\Pi}_{t+1} + \kappa\nu\overline{\widehat{y}}_t \tag{42}$$

where $\overline{\widehat{y}}_t := \left[\theta\widehat{y}_{H,t} + (1-\theta)\widehat{y}_{F,t}\right].$

C.8 Area-wide averages

C.8.1 Consumption Euler Equations

Average Euler equation for savers:

$$\widehat{e}_t + \overline{\widehat{\lambda}}^s_t = \beta\frac{R^d}{\Pi}\{\delta\overline{\widehat{\lambda}}^s_{t+1} + (1-\delta)\frac{\bar{\lambda}}{\lambda^s}\widehat{\bar{\lambda}}_{t+1}\} + \widehat{e}_{t+1} + \overline{\widehat{R}}^d_t - \overline{\widehat{\Pi}}_{t+1}.$$

Average Euler equation for borrowers:

$$\widehat{e}_t + \overline{\widehat{\lambda}}^b_t = \beta\frac{R^b}{\Pi}\{\delta\overline{\widehat{\lambda}}^b_{t+1} + (1-\delta)\frac{\bar{\lambda}}{\lambda^b}\widehat{\bar{\lambda}}_{t+1}\} + \widehat{e}_{t+1} + \overline{\widehat{R}}^b_t - \overline{\widehat{\Pi}}_{t+1}.$$

C.8.2 Market Clearing

Market clearing condition:

$$\overline{\widehat{y}}_t = (1-g)\overline{\widehat{c}}_t + g\overline{\widehat{g}}_t.$$

C.8.3 Deriving average IS equation

From definition of aggregate consumption in each country:

$$c\overline{\widehat{c}}_t = wh\overline{\widehat{h}}_t - \bar{\sigma}\left[\overline{\widehat{\lambda}}_t^w + s_\Omega \overline{\widehat{\Omega}}_t\right]. \tag{43}$$

where

$$\overline{\widehat{\lambda}}_t^w = \pi_b \overline{\widehat{\lambda}}_t^b + \pi_s \overline{\widehat{\lambda}}_t^s$$

$$\overline{\widehat{\Omega}}_t = \overline{\widehat{\lambda}}_t^b - \overline{\widehat{\lambda}}_t^s.$$

Use (43) in the market clearing condition:

$$\overline{\widehat{\lambda}}_t^w = -\frac{(1-wh)\overline{\widehat{y}}_t - g\overline{\widehat{g}}_t)}{\overline{\sigma}} - s_\Omega \overline{\widehat{\Omega}}_t. \tag{44}$$

Average marginal utility gap:

$$\overline{\widehat{\Omega}}_t := \overline{\widehat{\lambda}}_t^b - \overline{\widehat{\lambda}}_t^s = \overline{\widehat{\omega}}_t + \underbrace{[\chi_b + \chi_s - 1]}_{:=\bar{\delta}} \overline{\widehat{\Omega}}_{t+1}$$

$$\overline{\widehat{\lambda}}_t^b = \overline{\widehat{R}}_t^b - \overline{\widehat{\Pi}}_{t+1} + \chi_b \overline{\widehat{\lambda}}_{t+1}^b + (1-\chi_b)\overline{\widehat{\lambda}}_{t+1}^s$$

$$\overline{\widehat{\lambda}}_t^s = \overline{\widehat{R}}_t^d - \overline{\widehat{\Pi}}_{t+1} + \chi_s \overline{\widehat{\lambda}}_{t+1}^s + (1-\chi_s)\overline{\widehat{\lambda}}_{t+1}^b$$

$$\overline{\widehat{\lambda}}_t^w = \overline{\widehat{R}}_t^d + \pi_b \overline{\widehat{\omega}}_t - \overline{\widehat{\Pi}}_{t+1} + \overline{\widehat{\lambda}}_{t+1}^w - \psi_\Omega \overline{\widehat{\Omega}}_{t+1} \tag{45}$$

Use (44) in (45):

$$\left[\overline{\widehat{y}}_t - \overline{\widehat{y}}_{t+1}\right](1-wh) = g\left[\overline{\widehat{g}}_t - \overline{\widehat{g}}_{t+1}\right] - \bar{\sigma}\left[\overline{\widehat{R}}_t^d + (\pi_b + s_\Omega)\overline{\widehat{\omega}}_t - \widehat{\Pi}_{t+1} + (s_\Omega(\bar{\delta}-1) - \psi_\Omega)\overline{\widehat{\Omega}}_{t+1}\right]. \tag{46}$$

The average IS-equation will, therefore, not depend on $\overline{\widehat{\Omega}}_{t+1}$ if $s_\Omega(\bar{\delta}-1) = \psi_\Omega$.

C.8.4 Spread

As in Corsetti et al. (2013), for the analytical results, we postulate

$$(\pi_b + s_\omega)\widehat{\omega}_t := \widehat{\varpi}_t = \xi E_t \left\{ g\widehat{g}_{t+1} - \phi_{T,y}\widehat{y}_{H,t+1} \right\}.$$

Similarly,

$$(\pi_b + s_\omega)\widehat{\omega}_t^* := \widehat{\varpi}_t^* = \xi^* E_t \left\{ g\widehat{g}_{t+1}^* - \phi_{T,y}\widehat{y}_{F,t+1} \right\}.$$

We, therefore, assume that the tax elasticities are the same in both countries. The slope of the spread with respect to increments in the deficit may differ, however.
The average spread is given by

$$\overline{\widehat{\varpi}}_t = \theta\xi E_t \left\{ g\widehat{g}_{t+1} - \phi_{T,y}\widehat{y}_{H,t+1} \right\} + (1-\theta)\xi^* E_t \left\{ g\widehat{g}_{t+1}^* - \phi_{T,y}\widehat{y}_{F,t+1} \right\}.$$

This expression, in turn, can be rearranged to yield

$$\overline{\varpi}_t = \overline{\xi} E_t \left\{ g\overline{\widehat{g}}_{t+1} - \phi_{T,y}\overline{\widehat{y}}_{t+1} \right\} + \theta(1-\theta)(\xi - \xi^*) E_t \left\{ g\widehat{g}_{t+1}^D - \phi_{T,y}\widehat{y}_{t+1}^D \right\}. \tag{47}$$

where $\overline{\xi} := \theta\xi + (1-\theta)\xi^*$ and $\widehat{g}_t^D := \widehat{g}_t - \widehat{g}_t^*$.

D Definition of Auxiliary Parameters

$\overline{\delta}$:

$$\overline{\delta} = \chi_b + \chi_s - 1.$$

χ_b:

$$\chi_b = \beta \frac{R^b}{\Pi}[\delta + (1-\delta)\pi_b].$$

χ_s:

$$\chi_s = \beta \frac{R^d}{\Pi}[\delta + (1-\delta)\pi_s].$$

κ :

$$\kappa = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}.$$

κ_y :

$$\kappa_y = \kappa\nu.$$

ψ, scaling constant "aggregate disutility of work":

$$\psi^{-1/\nu} = \pi_b\psi_b^{-1/\nu} + \pi_s\psi_s^{-1/\nu}.$$

ψ_Ω :

$$\Psi_\Omega = \pi_b(1-\chi_b) - \pi_s(1-\chi_s).$$

$\overline{\sigma}$:

$$\overline{\sigma} = \pi_b\phi_b + \pi_s\phi_s,$$

with $\phi_b = \xi_b\sigma_b\lambda_b^{\sigma_b}$ and $\phi_s = \xi_s\sigma_s\lambda_s^{\sigma_s}$.

s_Ω :

$$s_\Omega = \frac{\pi_b\pi_s[\phi_b - \phi_s]}{\overline{\sigma}}.$$