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Effects of Eurobonds: a Stochastic Sovereign Debt Sustainability Analysis for Portugal, Ireland and Greece

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Abstract. This paper assesses the impact of Eurobonds on sovereign debt dynamics for selected European member states (Greece, Ireland and Portugal). For each member state, we produce sovereign debt fan charts of (i) a baseline scenario (no Eurobonds) and (ii) a Full-Fledged Eurobond introduction. The key building blocks of our methodology are (i) a debt framework (which embeds the traditional recursive debt equation), (ii) a vector autoregressive model to take into account and parametrise macroeconomic uncertainty and (iii) a fiscal reaction function. Conditional on the absence of moral hazard, we find Eurobonds to be a good instrument to absorb macroeconomic shocks and to diminish uncertainty over future debt forecasts; for Ireland and Portugal, we find debt to be 20 percentage points lower than under our baseline scenario, by 2020.

Keywords: Eurobonds, Stability Bonds, Sovereign debt sustainability, Sovereign debt crisis, Fan charts.
JEL Categories: C32 · H63 · H68 · H81

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1. Introduction

Since the onset of the European sovereign debt crisis, ample literature has claimed to provide a definite solution to temper the current crisis and prevent a similar one altogether. Hindsight has proven to be an important source of insight. Many reforms have already been implemented (e.g. the European Stability Mechanism (ESM)) whereas other propositions are still on the drawing board. Perhaps the most applauded, but equally controversial proposition, is the issuance of a Stability Bond (often called "Eurobonds" in the academic discourse). Several (albeit often only slightly divergent) Stability Bond proposals have found their way into the policy discussion. Our focus is on a Full-Fledged Eurobond design where (new) sovereign debt is issued under a joint and several guarantee from all other participating member states. This implies that every participating country is up to the full amount responsible for the reimbursement of the claimants, should the original obligor default.

A recent Green Paper authored by the EC (2011) provides a case for the introduction of such a financial instrument. Among the benefits claimed to ensue, two are of importance for this paper. The first argument provides a case for Stability Bonds as a way out of the current sovereign debt crisis through its impact on debt dynamics. Pooling European debt would prevent the current adverse debt feedback effect on the risk premium, allowing the sovereign to get its debt back on a sustainable trajectory more easily [paragraph 1.2.1. EC (2011)]. Second, a Stability Bond would shelter future sovereign debt from sudden shifts in risk aversion, unwarranted market volatility or animal spirits. Hence, by enabling member states to continually tap capital markets at a stable borrowing rate, a more resilient and less volatile debt trajectory should ensue [paragraph 1.2.1. EC (2011)]. The first effect could be seen as a beneficial "level" effect, the second a beneficial "volatility" effect.

The goal of this paper is to assess to what extent Stability Bonds deliver these claimed benefits. First, how large is the impact of Stability Bonds on sovereign debt dynamics of distressed member states? Second, are they able to reinforce stability in sovereign debt dynamics? We investigate this by means of comparing (i) a baseline sovereign debt scenario with (ii) a Full-Fledged Eurobond sovereign debt scenario. The member states under consideration are Greece, Ireland and Portugal (for economy of notation, hereafter referred to as "GIP"). Obviously, these countries are, at present, likely to gain the most from a Eurobond issue (the rationale for considering only GIP is elaborated on later). Crucial to the introduction of Eurobonds is that they might engender adverse incentive problems. Potential moral hazard problems will require that Eurobonds are embedded very carefully in an efficient and effective institutional framework that provides enough incentives to tackle moral hazard problems. We relate the theoretical moral hazard problem to the specific context of our Eurobonds analysis, showing that this is indeed an important aspect of the analysis.

The contribution of the paper is twofold. First, it adds to the vociferous discussion concerning the introduction of Eurobonds. As of this writing, the Eurobond literature is mainly conceptual in nature and at best based on "back-of-the-envelope calculations" when illustrating the merit of Eurobonds on sovereign debt dynamics. Our aim is a more profound and formal investigation. Second, with respect to sovereign debt analysis, our methodological approach builds on recent recommendations by the ECB (2012) and IMF[1] and diverges from the traditional deterministic approach.

The paper is organised as follows. Section 2 briefly reviews the rationale for Eurobonds in the light of the sovereign debt crisis. The treatment is balanced, but not meant to be exhaustive.[2] Section 3 elaborates the methodological framework. In section 4 we build a narrative around the empirical results and provide some additional insights. Section 5 concludes and identifies three policy implications.

2. The sovereign debt crisis: a rationale for Eurobonds

Since the onset of the crisis, (i) financial sector bailouts, (ii) rising unemployment, (iii) falling tax receipts and (iv) stimulus spending all contributed to a deterioration of public finances (ECB, 2011; Young and Semmler, 2011). The Euro area government debt-to-GDP rose from a pre-crisis level of 66,4% in 2007 to 92,6% in 2012 (AMECO Database). The

[1] Cherif and Hasanov (2012).

[2] For a more detailed account on the various Eurobond proposals, see Claessens et al. (2012), De Grauwe and Moesen (2009), EC (2011) and Hellwig and Philippon (2011).

elevated debt positions raised concerns on the sustainability of sovereign debt (mainly in peripheral member states). The latter in turn led to increased yield spreads which additionally burdened sovereign debt dynamics.

From an academic perspective however, the assessment of debt sustainability is neither firmly established nor standardised. A distinction is often made between (i) the long term, when assessing debt sustainability and (ii) the short term, when analysing liquidity (ECB, 2012; Giammarioli et al., 2006; IMF, 2006). Informally, the former requires that the present value of expected future primary balances equals (or surpasses) the current sovereign debt position. The latter implies that the sovereign is able to meet all upcoming liabilities in the short run. The two are linked through financial markets, where a sustainable debt outlook (long term) implies investors are willing to provide liquidity (short term). Whenever sustainability concerns arise, a sudden stop in market access can hamper the ability to rollover debt (liquidity). If the sovereign was de facto solvable, market sentiment can push a sovereign into insolvency (a "bad equilibrium"). These mechanisms are well documented in the theoretical literature. Kopf (2011) labels it the self-fulfilling nature of the sovereign debt crisis, whereas Giammarioli et al. (2006) call it the creditor coordination problem. The underlying mechanisms largely parallel that of a bank run (Diamond and Dybvig, 1983). It can be argued that the recent solvency problems of several sovereigns were of this nature.

This self-fulfilling mechanism is absent in a Eurobond scenario. Assume a hypothetical sovereign "A". A's debt is financed in full through the issuance of Eurobonds. Now suppose investors have doubts regarding the solvency of A (which de facto has a sustainable debt position). However, questionable solvability of A does not incentivise investors to sell Eurobonds issued by A: claimants can always turn to other participating member states (B, C, D, ...) to pursue A's obligations. Hence borrowing rates will not rise as before, which saves A from a bad equilibrium.

The observed solvency issues in the euro area, however, are not unequivocally of a self-fulfilling nature (De Grauwe, 2011). In effect, it can be argued that Greek sovereign debt was already unsustainable long before investors withdrew from Greek national bond markets (Afonso, 2005). In the latter case, the observed risk premium is based on de facto insolvency [the "Fundamentals-Based Argument" (Giammarioli et al., 2006)]. Presume a hypothetical, initially solvable, sovereign "E" which finances its debt through the issuance of Eurobonds. Suppose E is hit by a shock that causes its debt to no longer be sustainable (e.g. as a result of a domestic banking crisis). Previously, such a situation would lead to a sale of government bonds, which would drive up E's borrowing rates. However, under a Eurobond scenario, insolvency of the sovereign does not lead to a sale of Eurobonds issued by E. Investors know that they are guaranteed to be reimbursed (by B, C, D,...), which allows sovereign E to get its debt back on a sustainable trajectory without rising interest rates making such an adjustment burdensome. In sum, a Eurobond allows in principle: (i) a solvable sovereign to stay solvable and (ii) an insolvable sovereign to get its debt back on a sustainable track.

Although praised by many, some observers have articulated serious concerns regarding both the feasibility and the effectiveness of Eurobonds [see e.g. Issing (2009); Kösters (2009); Kopf (2011)]. We mention a set of three arguments that are too important to ignore: (i) legal obstacles, (ii) political objections and (iii) economic concerns.

(i) First, in its current form, article 125 of the Lisbon Treaty prohibits any member state to assume liabilities of other member states. Hence, certain Stability Bond designs will most likely require a Treaty change (EC, 2011). In itself, this argument is not insurmountable. It does, however, imply a long implementation time (Jones, 2010). Nonetheless, through market expectations, the sole prospect of a Eurobond could immediately ease borrowing conditions for distressed governments. In addition, a gradual introduction could already achieve favourable results without requiring an immediate Treaty change (Claessens et al., 2012).

In a way the ESM already implies a form of "mutualisation" or "federalisation" of debt: if countries would not be able to repay support received from the ESM, the other countries will need to write-off their contributions "pro-rata". The AAA status of the ESM, however, implies that it can borrow at the lowest cost, much lower than what the borrowing costs of the distressed country would be. In a similar fashion, the ECB's Securities Market Program (SMP) that has substantially increased since 2011 as a reaction to the European debt crisis could also be considered as an implicit mutualisation/federalisation of debt to the extent that it is used to buy sovereign bonds of distressed member states.

(ii) Second, fiscally sound member states (most notably Germany) oppose, as a pooling of European debt might increase their funding costs. This argument carries doubt as the scattered (empirical) evidence both confirms this claim (Berg et al., 2011) and opposes it (EC, 2011; Matziorinis, 2012). In any case, the veracity of this statement is subject to the specific design of the Eurobond (infra) causing such a general proposition to carry little weight. Nonetheless, whether it is a zero-sum game or not, the prospect of a Stability Bond crucially hinges on Germany's willingness. This hurdle casts serious doubt on the prospect of a Stability Bond. Note, however, that some other member states oppose as well. They fear that Germany might consider its key role in the Eurobond market a justification to meddle in foreign affairs (in particular, fiscal management of high deficit countries).

(iii) The third argument is perhaps the most forceful. Eurobonds could remove incentives for budgetary discipline as they allow member states to freely tap capital markets without incurring feedback on their borrowing rates (creating, in a way, a significant "common pool" problem). In effect, as other member states foot the bill in case of default, market discipline erodes and a laissez-faire fiscal policy might ensue (moral hazard).

An important literature on risk sharing and moral hazard problems in federal fiscal constitutions provides more insight on potential moral hazard problems and how to design adequate federal constitutions to deal with them. Eurobonds can essentially be considered an application of this theoretical literature.

Persson and Tabellini (1996) analyse risk sharing and moral hazard in fiscal federations taking a principal (voters)- agent (politicians) approach. It is shown that noncooperative decision making in a fiscal federation is suboptimal and that there is a trade-off between risk-sharing and moral hazard in a fiscal federation. The design of federal fiscal constitutions is of crucial importance as it defines the degree of risk-sharing and may provide incentive mechanisms to tackle moral hazard. More risk-sharing between the regions in a fiscal federation increases moral hazard as individual regions have less incentives to counteract shocks and to increase the adjustment capacity of their economies if risk-sharing is larger. Commitment problems can further aggravate the inefficiencies as it increases further the moral hazard problem. It is argued that a horizontal "US-like" federal system provides more commitment capacity (at this moment) than a vertical "EU-like" federal system. Centralisation of tasks and power from a local to the federal level is likely to reduce moral hazard problems but has to be weighted against inefficiencies inherent to centralisation such as bureaucracy and lack of information of conditions at the decentralised level.

Bordignon et al. (2001) extend the previous analysis. The optimal regional redistribution (i.e. degree of risk sharing) is determined in the presence of adverse selection problems and if spillovers or commitment capacities vary. Asymmetric information over the size of regional tax bases is focused upon: regional governments know more than the federal government can incorporate in the transfer mechanism, resulting in an adverse selection problem. The verifiability problem of the federal government leads to adverse incentive problems as regional governments mask the real size of the regional tax bases and attempt to increase the benefits from the federal transfer mechanism.

The relevance of this literature for the case of Eurobonds is quite clear: in the presence of asymmetric information problems, moral hazard and adverse selection surface, generating potential adverse incentive effects from the introduction of Eurobonds that need serious consideration. Eurobonds will also entail a trade-off between risk-sharing and moral hazard. A careful design of the regulatory and governance framework of Eurobonds, i.e. the federal fiscal constitution, can contribute to address the asymmetric information problems which would undermine efficiency and sustainability of Eurobonds in the long run. At the same time, it is important to note that there are also arguments to be made that Eurobonds may actually contribute to more fiscal discipline and fiscal responsiveness, especially if they further contribute to the strengthening of the fiscal governance framework, e.g. in the form of more fiscal transparency, credibility and accountability.

3. Methodological framework

The paper commenced by posing two fundamental questions. Answering both requires a comparison of future sovereign debt positions under a Eurobond versus a no-Eurobond (BASELINE) scenario. To this end, this section provides a comprehensive breakdown of our methodological framework. It is distinct from the classical body of literature and alludes to recent recommendations by the ECB (2012), Bank of England (BoE) and IMF, with respect to stochastic debt analysis.

We start by deriving the law of motion of debt-to-GDP [subsection 3.1]. This difference equation, embedded in a more elaborate debt framework, is solved iteratively forward in time which allows us to establish a projection of future sovereign debt. However, instead of considering one sole debt path, we simulate this equation numerous times under various macroeconomic conditions (i.e. a stochastic instead of deterministic analysis). This requires sensible macroeconomic scenarios, respecting the joint dynamics of macroeconomic variables. The latter calls for an estimation of a vector autoregression [subsection 3.2] and a fiscal policy rule [subsection 3.3]. Using these building blocks, we make an assessment of future sovereign debt which we label the BASELINE SCENARIO. Hereafter we tailor the above baseline framework to cope with a Full-Fledged introduction of Eurobonds [subsection 3.4], i.e. the EUROBOND SCENARIO.

We note that a dynamic stochastic general equilibrium (DSGE) model could act as a valid alternative (see e.g. in 't Veld et al., 2012). However, given the trade-off between theoretical soundness and data coherence in macro models (Liu and Theodoridis, 2012), we prefer the VAR framework over a DSGE model to produce time series of our macro variables.

3.1. Sovereign debt dynamics: the equation of motion

The fundamental law of motion of debt-to-GDP dominates the debt sustainability literature[3]. Its main benefit is its ease of interpretation at the cost of some fundamental flaws.[4] To address its shortcomings, some authors have recently developed more elaborate, albeit less tractable, debt frameworks [e.g. Cline 2011, 2012; Contessi 2012; ECB 2012; Ferrucci and Penalver 2003; Holland et al. 2011]. We too diverge from the traditional debt equation of motion and add some realistic features to it. As shown below, our approach carries some appealing advantages. (i) First, it allows us to account for the maturity structure of debt. This is crucial, as the effect of rising interest rates on debt sustainability hinges on the amount of debt being rolled over in adverse market conditions. (ii) Second, it allows us to mimic the empirical observation that distressed member states' debt issuance is skewed towards short term debt. (iii) Third, it allows us to model a tractable phasing in of Eurobonds, as proposed by Delpla (2010). (iv) Fourth, the approach is capable of handling a more elaborate treatment of interest payments. (v) All countries under consideration received rescue packages from the IMF and ECB. Our framework easily embeds the planned repayment structure of these funds of the EFSF/EFSM/IMF (EC, 2013a,b,c).

We define D_t as the gross nominal stock of debt (subscript denotes the end of period), GBR_t as the gross borrowing requirement and $PAYB_t$ as the amount of debt to be paid back. Debt at time t equals debt at the end of the previous period plus newly issued debt (gross borrowing requirement) minus the amount of debt reimbursed and adding a stock flow adjustment (which measures any change in debt not related to GBR_t and $PAYB_t$):

$$D_t = D_{t-1} + GBR_t - PAYB_t + SFADJ_t \tag{1}$$

The gross borrowing requirement is the sum of interest payments (INT_t) and the amount of debt to be reimbursed ($PAYB_t$) minus the primary balance (PB_t):

$$GBR_t = INT_t + PAYB_t - PB_t \tag{2}$$

where the primary balance is defined as net income minus non-interest expenditures. The maturity profile of sovereign bonds and EFSF/EFSM/IMF assistance funds (necessary for $PAYB_t$) are available from national debt agencies and *Economic Adjustment Programmes*. We ignore the possibility of debt denominated in foreign currency as this amount is negligible for the member states under consideration (Lojsch et al., 2011). Observe that substituting equation (2) in (1) yields: $D_t = D_{t-1} - PB_t + INT_t + SFADJ_t = D_{t-1}(1 + i_t) - PB_t + SFADJ_t$. The latter being the classic debt accounting equation.

Denote B_t^L and B_t^S as the amount of new long and short term debt, respectively, issued during period t. We define B_t^L and B_t^S as having an initial time to maturity of ten and one year respectively. Note that $B_t^L + B_t^S = GBR_t$. In deciding what fraction of borrowing requirements is met by short and long term debt, we rely on historical issuance practices. Define:

$$B_t^L = [\alpha_t^L]GBR_t \tag{3}$$

[3] $d_t = \frac{(1+i_t)}{(1+g_t)(1+\pi_t)} d_{t-1} - b_t$; where i_t is the average interest rate of the debt stock; g_t is the real annual growth; π_t is annual inflation; d_t is the debt stock; b_t is the primary balance.

[4] It assumes a constant value of inflation and growth. It presumes one sole interest rate for the entire stock of debt and does not account for the maturity structure of debt.

$$B_t^S = [\alpha_t^S]GBR_t \tag{4}$$

Where α_t^L and α_t^S are in turn defined as:

$$\alpha_t^L = [\mu]^{i_t^L} \tag{5}$$

$$\alpha_t^S = 1 - [\mu]^{i_t^L} \tag{6}$$

$$0 \leq \alpha_t^L, \alpha_t^S \leq 1; \alpha_t^L + \alpha_t^S = 1; 0 < \mu < 1 \tag{7}$$

(5) and (6) imply that a higher long term interest rate (proxying unfavorable market conditions) skews borrowing towards short term debt.[5] This accords with the observation that distressed sovereigns have resorted more to short term debt during the crisis (De Broeck and Guscina, 2011). The mechanics underlying (5) and (6) are related to the work of Arellano and Ramanarayanan (2012) who develop a a dynamic model of international borrowing with endogenous default and multiple maturities of debt. The parameter μ is estimated from quarterly historical data (2002Q1-2012Q4), as explained below. Use of historical data implies that borrowing behaviour will, with respect to maturity, converge to pre-crisis borrowing standards when the economic climate does (Holler, 2013). Furthermore, the interest payments are defined as (cf. Ferrucci and Penalver 2003; Cline 2012)[6]:

$$INT_t = \sum_{m=1}^{\theta} B_{t-m}^L i_{t-m}^L + B_{t-1}^S i_{t-1}^S \tag{8}$$

Where i^L and i^S represent the long (ten year) and short (one year) term nominal market interest rate respectively. i_{t-m}^L and i_{t-m}^S represent the interest rate on newly issued long and short term debt in period t-m respectively. θ represents the time-to-maturity of the outstanding debt tranche with the farthest maturity date. Note that in our baseline scenario we incur the market interest rate on new debt issued in the future, despite all three sovereigns being able to draw on available EFSF/EFSM/IMF assistance funds (with an applicable lower interest rate). This accords with the interpretation we give to the baseline scenario later on (infra).

To allow for comparisons across member states, we will work with a normalised version of this model (scaled with domestic GDP).[7] In keeping with the literature we will, unless stated otherwise, fix the value of $SFADJ_t$ to 0 (e.g. van Aarle and Konings, 2013). Hence, our central equation will take the form (9):

$$d_t = \frac{d_{t-1}}{(1+g_t)(1+\pi_t)} - pb_t + int_t \tag{9}$$

Observe that this recursive formula is the classic debt equation found in the literature, but is embedded in a larger framework. All variables are readily available from conventional data sources (sources and technicalities are detailed in appendix A.1).

We now turn to the issue of modelling the variables entering (9): $\langle g_t, \pi_t, i_t^L, i_t^S \rangle$ in subsection 3.2 and $\langle pb_t \rangle$ in subsection 3.3.

3.2. Modelling macroeconomic risk: a vector autoregression

Traditional debt solvability research fixes the values of g_t, π_t and pb_t and simulates the recursive expression (9) forward for future debt positions such that one deterministic debt path ensues. To account for risk, this exercise is repeated under less favourable conditions (e.g. lower growth, lower primary balance) by unilaterally adjusting the variables entering (9) [e.g. see Contreras (2011); Holland et al. (2011)]. These *bound tests* (Berti, 2013) or *stress tests* (EC, 2012) give a crude measure of the sensitivity of the baseline debt trajectory to adverse macroeconomic conditions. This modus operandi, however, has three flaws (Celasun et al., 2006). First, fiscal policy is deemed unable to respond to changes in the economic environment - a stringent condition unlikely to hold in reality. Second, each debt trajectory formally has a zero probability of occurrence. An unpleasant predicament if one is to base policy recommendations on the analysis. Third, it neglects the joint dynamics of

[5]The domain of this function is $\mathbb{R}^+$, the range is (0,1).

[6]The assumption made is that interest rates are fixed after issuance. For empirical observations, see De Broeck and Guscina, 2011.

[7] $\frac{D_t}{Y_t} = \frac{D_{t-1}}{(1+g_t)(1+\pi_t)Y_{t-1}} - \frac{PB_t}{Y_t} + \frac{INT_t}{Y_t} + \frac{SFADJ_t}{Y_t}$

the economy.

One way to overcome these drawbacks is to estimate a reduced form vector auto regression (Stock and Watson, 2001). This approach builds on seminal work by Garcia and Rigobon (2004) and has figured prominently in recent publications by e.g. the EC (2012), IMF and the BoE. It allows us to obtain time series of $\langle g_t, \pi_t, i_t^L, i_t^S \rangle$. We estimate the following reduced form VAR to capture the dynamics of the macro economy separately for each country ([1]):

$$X_t = A_0 + A_1 X_{t-1} + A_2 X_{t-2} + A_3 X_{t-3} + \xi_t \tag{10}$$

$$X_t^{'} = [g_t, \pi_t, i_t^L, i_t^S]$$

$$E(\xi_t \xi_t^{'}) = \Omega$$

$$\xi_t \overset{i.i.d.}{\sim} N(0, \Omega)$$

Where, as before, g_t denotes real growth of GDP, π_t equals inflation, i_t^L and i_t^S denote long and short term nominal interest rates, respectively. A_0 is a column vector of constants [order 4x1], A_1 to A_3 represent matrices of autoregressive coefficients [order 4x4]. ξ_t denotes a vector of well-behaved error terms with a time-invariant positive semidefinite variance covariance matrix $E(\xi_t \xi_t^{'}) = \Omega$. Observe that the off-diagonal elements of Ω are potentially non-zero. Dickey-Fuller tests reveal that all variables entering (10) are stationary [I(0)]. The AIC criterion was used in lag length selection. In keeping with the literature, we do not report the estimated coefficients of (10) as they do not easily lend themselves to a useful interpretation.

We estimate the VAR based on quarterly data going from 2002Q1 to 2012Q4. Longer time series, however, are available (going back to 1995), but including pre-euro years makes the VAR sensitive to model specification; the slope coefficients in the VAR are in all likelihood altered when the sovereign adopts the euro [e.g. for inflation see Hartmann and Herwartz (2009); for real growth see Barrell et al. (2008)]. To estimate Ω for Ireland and Portugal, we use residuals spanning the time period 2002Q1-2012Q4 (thus including crisis years). Leaving out crisis years produces a comparable $\hat{\Omega}$. For Greece, we estimate Ω based on 2002Q1-2007Q4 (thus excluding crisis years). Including 2008Q1-2012Q4 produces roughly the same covariances (off-diagonal elements), but increases the variance (diagonal elements) to an unwarranted degree. We suspect the time frame 2002Q1-2007Q4 to be better suited for our analysis.

With a given set of coefficients of the VAR, we can simulate (10) forward in time. Each quarter, we add shocks $\xi_t, \xi_{t+1}, ..., \xi_T$ to the model $(\forall t \in [t, T])$ – see notes [2] for details regarding the derivation of ξ_t. We repeat this procedure N times (number of simulations, $N = 25.000$) to obtain N time series (with length 2013Q1-2020Q4) for each of the four endogenous variables. We annualise the VAR variables as the analysis is on an annual basis - see notes [3] for details. Note that this approach produces time series of $\langle g_t, \pi_t, i_t^L, i_t^S \rangle$ that reflect realistic features of macroeconomic data: (i) *persistence*, due to the inclusion of the lagged values of the endogenous variable. (ii) *Volatility*, due to the diagonal elements in $\hat{\Omega}$ and (iii) *correlation*, as quantified by the off-diagonal elements in $\hat{\Omega}$ (Ferrucci and Penalver, 2003).

3.3. Projecting fiscal policy

Equation (9) contains pb_t, which reflects fiscal policy behaviour. To model the latter, one could follow three distinct routes. Somewhat rudimental, one could assume a pre-specified fiscal policy rule (e.g. a balanced budget rule). The drawback is that such a fiscal rule is deterministic, preventing flexibility whenever specific economic circumstances call for it. For our purpose, to unequivocally tie the hands of the sovereign by a single policy rule lacks credibility. Recall that we model a large number of macroeconomic scenarios, many in which one single fiscal rule would end up being either too lax or too restrictive. On these grounds, we discard the exogenous policy rule approach. Two alternatives are more auspicious. A first is to include the quarterly primary balance (% of GDP) in the VAR as an endogenous variable (Garcia and Rigobon, 2004). A second is to estimate a separate panel fiscal reaction function (FRF) in which fiscal behaviour (pb_t) responds to the economic environment produced by the VAR.

Including the primary balance in the VAR has the benefit of yielding a fully endogenous fiscal policy consistent with prevailing macroeconomic conditions. In addition, the VAR is allowed to produce a variance-covariance matrix of error terms (Ω) containing non-zero off-diagonal elements (non-orthogonality). Accordingly, innovations (i.e. shocks) to the primary balance are mutually consistent with shocks in other endogenous variables (an appealing feature regarding growth shocks to capture automatic stabilization). This approach would, to a large extent, circumvent the endogeneity issue to which we are vulnerable were we to estimate a FRF. On the downside of these two advantages, some complications arise (Celasun et al., 2006). One being economic in nature, the other data-oriented. First, by construction, the VAR only includes lagged endogenous variables. The drawback here is that fiscal policy is more likely to react to current events (or expectations of current events) in lieu of past economic conditions. The magnitude of this error is possibly small (as all variables in the VAR are persistent), but it would be erroneous nonetheless. Second, one would require the quarterly seasonally unadjusted primary balance. However, this time series has an outspoken seasonal component which one could only capture using a sufficiently long lag length. This strong data requirement is not met by sufficient data availability. In addition, quarterly fiscal data series have a low signal-to-noise ratio (as quarterly fiscal data is often measured inaccurately). Both these considerations deter us from including pb_t in the VAR.

Alternatively one could estimate a panel Fiscal Reaction Function (FRF) based on annual data.[8] Given the limitations of the VAR, this is the approach taken below. Following seminal work by Galí and Perotti (2003), we estimate a FRF of the form:

$$pb_{i,t} = \psi_0 + \psi_1 pb_{i,t-1} + \psi_2 E_{i,t-1}[gap_{i,t}] + \psi_3 d_{i,t-1} + \eta_i + \varepsilon_{i,t} \tag{11}$$

$$t = 2000, ..., 2012; i = 1, ..., 12$$

$$\varepsilon_{i,t} \sim i.i.d.(0, \sigma_\epsilon^2)$$

Where pb_t is the cyclically unadjusted primary balance (fraction of GDP). pb_{t-1} captures persistence in fiscal policy. $d_{i,t-1}$(debt-to-GDP) accounts for a debt correction strategy (Bohn, 1995). $gap_{i,t}$ represents the output gap and η_i captures unobserved country fixed effects. Following the lead of Galí and Perotti (2003) we include $E_{i,t-1}[gap_{i,t}]$ to recognize the fact that fiscal policy decisions are typically implemented only after a time lag. However, to estimate (11) we will substitute $gap_{i,t}$ for $E_{i,t-1}[gap_{i,t}]$ and instrument the former (infra). We derive $gap_{i,t}$ using the Hodrick-Prescott (HP) filter with a smoothing parameter of 100 (Backus and Kehoe, 1992). ψ_2 reflects both automatic stabilizers as well as endogenous discretionary fiscal policy. (11) is estimated based on annual data from the 12 first-wave Eurozone countries. Data sources and technicalities are detailed in appendix A.1.

When estimating a FRF, specific endogeneity issues come to the fore (Celasun et al., 2006). A first concern is the correlation between $gap_{i,t}$ and $\varepsilon_{i,t}$. Hence, we instrument $gap_{i,t}$ using the following instruments: Oil price (Oil_{t-1}), US Output gap (GAP^{US}_{t-1}), Inflation (π_{t-1}) and Openess ($Openess_{i,t-1} = [Export_{i,t-1} + Import_{i,t-1}]/GDP_{i,t-1}$). Medeiros (2012) and Galí and Perotti (2003) and references therein provide a comprehensive discussion regarding the validity and relevance of these instruments. Next, some member states have a historic track record of high primary balances, which in turn causes a lower $d_{i,t-1}$. Inclusion of η_i (country fixed effects) will prevent a bias of ψ_3. Third, there is a possibility of persistence of the error terms $\varepsilon_{i,t}$. The latter is overcome by including $pb_{i,t-1}$.

The functional we will use in our simulation analysis takes the form – [4]:

$$pb_{i,t} = \psi_0 + \psi_1 pb_{i,t-1} + \psi_2 gap_{i,t}|X_{i,t-1} + \psi_3 d_{i,t-1} + \eta_i + \varepsilon_{i,t} \tag{12}$$

To enhance the fit of (12), we included several additional exogenous variables to our base specification: (i) a fiscal rule index (measuring stringency) as published by the EC[9] and (ii) the German output gap (to account for the foreign business cycle). The latter turns out to be significant but does not materially alter the coefficients in (12) (besides gap_t). However, we abstain from including the German output gap in our FRF since our analysis would require ad hoc assumptions regarding its future values. Table 1 summarises these main regression results. We note that our regression coefficients accord with those in the literature. For brevity, we do not report the country fixed effects here (see appendix A.2 for the full-blown regression table). In our simulation analysis, we will use regression specification (4) from table 1.

[8] A FRF characterises the systematic budgetary response to the economic environment.

[9] See fiscal rule database European Commission.

One note of caution is in order. Ideally one would like to estimate a FRF for each of the sovereigns independently. Due to data constraints, however, this is not a viable alternative. The panel approach solves this issue at the cost that the estimated parameters might not truly reflect fiscal behaviour of each sovereign (ECB, 2012) – although the fixed effects absorb some of the cross-country variation in fiscal policy. However, there is no getting away from this issue and we found the panel estimation to be the dominant approach in the literature [see e.g. Eller and Urvová (2012); Medeiros (2012)].

Table 1: Estimation results FRF Euro area countries (2000-2012)

	(1) No IV/No FE	(2) IV/FE	(3) IV/FE	(4) IV/FE	(5) IV/FE
pb_{t-1}	0.764***	0.695***	0.699***	0.699***	0.682***
	(13.62)	(10.34)	(10.40)	(10.43)	(9.85)
d_{t-1}	0.00434	0.0672**	0.0628**	0.0623**	0.0589*
	(0.72)	(3.03)	(2.75)	(2.80)	(2.19)
gap_t	0.162*	0.420***	0.381***	0.376***	-0.100
	(2.30)	(4.12)	(3.39)	(3.64)	(-0.63)
Fiscal Index					-0.00181
					(-0.31)
Gap Germany					0.718***
					(4.36)
ψ_0	-0.00710	-0.0435**	-0.0406*	-0.0403*	-0.0353
	(-1.59)	(-2.72)	(-2.48)	(-2.51)	(-1.86)
N	140	140	140	140	130
Countries	12	12	12	12	11
R^2	0.6197	0.6791	0.6806	0.6807	0.7315
F-test	0.000	0.000	0.000	0.000	0.000

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

IV: instrumental variables. FE: country fixed effects.

We drop Germany from specification (5). Specifications (2)-(4) use different sets of instruments.

Given (i) the debt framework, (ii) the VAR and (iii) the FRF we now briefly comment on the iteration process that underlies the empirical distribution functions of future d_t. Starting from $t = 2012$, the VAR yields projections for $g_{2013}, \pi_{2013}, i^L_{2013}, i^S_{2013}$. The output gap in (12), which is derived from g_{2013} (and past GDP data), is inserted into the FRF (12). The latter returns pb_{2013}. This yields all the variables required for the debt framework at $t = 2013$, of which the key output variable is d_{2013} (which enters the FRF in the next period). This process iterates forward $\forall t \in [2013, 2020]$. We repeat this algorithm N times (number of VAR simulations). The stochastic nature of the VAR therefore spills over to the FRF and debt framework, thus generating probability profiles for $\langle g_t, \pi_t, i^L_t, i^S_t, pb_t, d_t \rangle$ which we depict using fan charts.

The fan charts we construct in this way are labelled Baseline scenarios. Before we proceed, it is important to stress what these baseline scenarios represent – and what they do not. First, they do *not* represent a forecast of sovereign debt we expect to truly prevail in the future. They are, in this respect, different from the debt sustainability exercises typically found in reports by the EC, IMF, ECB, etc. who aspire just that. The main reason is that our approach does not account for the sizeable structural reforms (e.g. labor markets reforms, considerable privatizations, tax reforms, etc.) and fiscal consolidation efforts such as detailed in the latest Economic Adjustment Programmes (EC, 2013a,b,c) and IMF country reports (IMF, 2012a,b, 2011). Therefore, our debt baseline scenarios reveal what debt dynamics would have looked like absent such interventions (a "no policy change" scenario). Neglecting these structural reforms and measures in our debt projections allows us to later assess the impact of Eurobonds on sovereign debt dynamics without their effect being confounded with policy measures with budgetary relevance. In addition, the omission of these aspects from our analysis does suggest a direction in which our baseline scenario is "biased" vis-à-vis the baseline scenarios set out in the Economic Adjustment Programmes or IMF country reports. We revisit this issue below when discussing our results.

3.4. Tailoring the Baseline scenario to Eurobonds

The above vector autoregression (10) and FRF (12) reflect the baseline - no Eurobonds - scenario. We now tailor both to reflect the FULL-FLEDGED EUROBOND scenario. In the Eurobond scenario we assume an introduction scheme, kin to Delpla (2010), where the sovereign starts issuing Eurobonds after a date of introduction. Old debt remains under national guarantee. New (Eurobond) debt is fully backed by participating member states.

Recall that the VAR contains two equations that determine the domestic nominal long and short term interest rate. Under a Eurobond scenario, these interest rates are substituted by i_t^{LEU} and i_t^{SEU} (EU superscript refers to Eurobond). This approach is similar to Stock and Watson (2001), who - in their application - swap an interest equation in the VAR with a Taylor rule. We define i_t^{LEU} and i_t^{SEU} as:

$$\begin{cases} i_t^{LEU} = \overline{i_{GER}^L} + \varepsilon_{i^{LEU}} \\ i_t^{SEU} = \overline{i_{GER}^S} + \varepsilon_{i^{SEU}} \end{cases} \tag{13}$$

where $\overline{i_{GER}^L}$ and $\overline{i_{GER}^S}$ are average yields on the ten and one year German bund respectively. This is in keeping with the Eurobond literature that argues that the Eurobond rate will likely be close to the German interest rate (see EC, 2011). $\langle \varepsilon_{i^{LEU}}, \varepsilon_{i^{SEU}} \rangle$ are stochastic error terms, to be interpreted as shocks to the Eurobond rates (and are compatible with the uncertainty that currently exists in the Eurobond literature w.r.t. the expected interest rate). They have the following variance-covariance matrix[10]:

$$\Sigma_\varepsilon = \begin{bmatrix} Var(\varepsilon_{i^{LEU}}) & Cov(\varepsilon_{i^{LEU}}, \varepsilon_{i^{SEU}}) \\ Cov(\varepsilon_{i^{SEU}}, \varepsilon_{i^{LEU}}) & Var(\varepsilon_{i^{SEU}}) \end{bmatrix} \tag{14}$$

We also define a new $\hat{\Omega}'$ which updates $\hat{\Omega}$ as follows:

$$\hat{\Omega} = \left[\begin{array}{c|c} A & B' \\ \hline B & C \end{array} \right] \Rightarrow \hat{\Omega}' = \left[\begin{array}{c|c} A & B' \\ \hline B & \Sigma_\varepsilon \end{array} \right]$$

The original C block is replaced with its Eurobond counterpart Σ_ε. There are no economic priors which suggest that the elements in B (B') will alter in a Eurobond scenario. With respect to the A block, one could argue that lower variances in the errors of $\langle g_t, \pi_t \rangle$ will ensue under a Eurobond scenario (see e.g. Matziorinis, 2012).[11] Recognizing the possible validity of this argument, we nonetheless preserve the original variances. In doing so, we shut down one channel through which Eurobonds could lower volatility in sovereign debt trajectories. Observe that this leads our analysis to provide a lower bound when assessing the impact on debt trajectory volatility.

Eurobond time series of $\langle g_t, \pi_t, i_t^{LEU}, i_t^{SEU} \rangle$ are obtained from the VAR (10) – with the interest rate process swapped with (13). New periodic shocks $\xi_t^{'}$ (4x1 vectors) are obtained as before – with $\hat{\Omega}$ replaced with $\hat{\Omega}'$. Note that our approach implies that domestic fundamentals (i.e. g_t, π_t) do not impact Eurobond rates (see 13)[12]. This assumption does not sacrifice any realism given the small weight in the Eurozone of the member states under consideration. Somewhat more restrictive is that domestic fundamentals are not influenced by spillovers from core Eurozone countries. Should a lower growth in the VAR be interpreted as a signpost of a downturn in Germany, it is unlikely that Eurobond rates would stay constant. Hence, at this point, it is key to stress that our analysis ignores those spillovers.

Note that this SUBSTITUTION APPROACH (13)-(14) is subject to the Lucas Critique (Lucas, 1976). It is paramount for our analysis to ponder if the introduction of Eurobonds would impact the estimated parameters in our VAR or FRF. First, reconsider the FRF (12)[13]. Will Eurobonds alter fiscal behaviour summarised in our FRF? The answer is: *it depends*. It depends on whether the design of the Eurobond succeeds in containing moral hazard. To see this, consider the parameter ψ_3, which reflects austerity measures taken to reduce the debt position of the sovereign. At present, the rationale of these austerity measures is, inter alia, to counter an increase in the debt position. Ultimately, the aim is

[10] All parameters in (13) and (14) are estimated from quarterly historical post Euro entrance data.

[11] There are no economic priors which suggest an alteration of the autoregressive coefficients pertaining to $\langle g_t, \pi_t \rangle$ contained in $A_1 - A_3$ in (10).

[12] Note that there is no causality present in $\xi_t^{'}$.

[13] For the VAR we could not identify any economic priors to which the Lucas Critique would apply.

to prevent an elevated debt position to raise solvency doubts which in turn would trigger higher borrowing rates. When Eurobonds are introduced, the latter channel is null and void. An unwarranted increase in the debt position no longer incentivises sovereigns to pursue a debt correction strategy as it will not affect their borrowing terms. This is exactly the moral hazard argument we encountered before. Below, we will vary ψ_3 to illustrate what the effect of moral hazard (lower ψ_3) will be on our results.

We have now tailored the baseline framework we developed earlier to the Full-Fledged Eurobond scenario. Hence, we repeat the previous analysis with this adapted framework. The same ζ_t vectors are used, but they will necessarily produce different $\xi_t^{'}$ than those used in the baseline scenario. In sum, any difference between the two scenarios will ensue due to (i) a different interest rate process (level effect) and (ii) a different constellation of shocks (volatility effect).

4. Sovereign debt projections

As stated, the sovereigns subject to our analysis are (i) Greece, (ii) Ireland and (iii) Portugal. The reason of choice is threefold. First, as detailed above, our model hinges on the presumption that the Eurobond rate is not influenced by domestic fundamentals. This is valid for GIP since their GDP represents a mere 1.5%, 1.3% and 1.3% of European GDP respectively (a similar claim can be made regarding their debt positions). This constancy of the Eurobond rate would be unlikely to hold for EU heavyweights (such as Italy or Spain), where an increase in debt or a downturn in growth could plausibly deteriorate the Eurobond rate. Second, the economic structure of GIP is diverse; the Irish economic structure is distinct from that of Greece and Portugal (e.g. relatively labour intensive production process, lack of innovation, large public sector, inefficient state-owned companies, etc.). Third, the debt-interest rate relationship varies considerably for these three sovereigns. Greece has a large debt position coupled with elevated borrowing rates. Ireland and Portugal have had comparable debt positions over time, but Irish interest rates have tended to be lower than those observed for Portugal. These interest-debt differentials allow us to probe the impact of different starting positions of debt/interest on debt dynamics.

At each future moment in time, we obtain an empirical distribution of d_t. An appealing way to present our results is by drawing fan charts for d_t, kin to the inflation charts drawn by the BoE. Fan charts depict the empirical probability distribution function of variables over time.

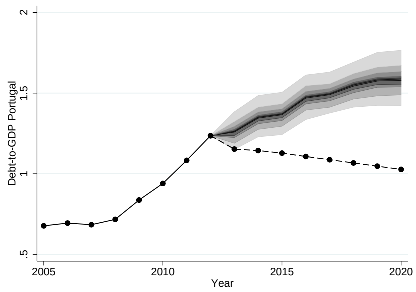
4.1. The baseline scenario.

Figure 1 (Panel a, c and e) plots the baseline fan charts of debt-to-GDP for GIP. Figure 1 (Panel b, d and f) plots fan charts for the applicable long term interest rate process. For Portugal and Ireland, the starting year of our debt projections is 2013Q1. As a result of data constraints, our starting date is one year earlier (2012Q1) for Greece. We project debt positions up until (and including) 2020Q4 for all three member states. The outer bounds in Figure 1, 2 and 3 represent the 10% and 90% deciles (including the 5% and 95% percentiles clouds the quality of the fan charts). Similar to the historically observed debt pattern, the debt process is not smooth (and at times non monotonously decreasing) but characterised by *"kinks"*. The reasons are, inter alia, that (i) we do not assume a constant repayment rate, (ii) nor do we assume a constant growth rate of nominal GDP, (iii) allow for discrete shifts in the interest burden

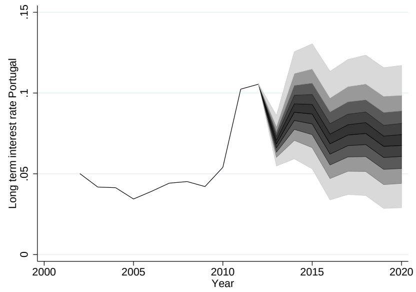
When evaluating debt sustainability, we follow Hamilton and Flavin (1986): if d_t spirals upward (i.e. non-stationairity of d_t) it is unsustainable. (i) We observe that debt tends to remain unsustainable in Greece. After a small decline, brought about through the stock flow adjustment[14], Greek debt continues to rise. (ii) Portuguese debt is monotonously on the rise (but at a decreasing rate), reaching a median debt projection of 158.21% by 2020. (iii) Irish debt is slowly recovering, reaching 112.25% in 2020. Observe that for GIP, the top 10% decile is quite large (when compared to the bottom 10% decile), suggesting upside risk in debt dynamics.

In Figure 2 we compare our baseline scenarios with those included in the corresponding

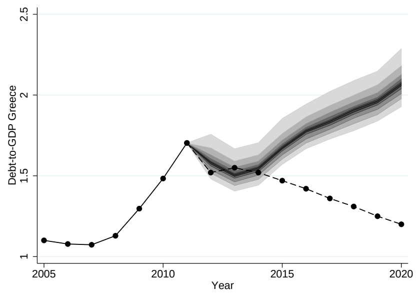
[14]Due to its sheer size, we account for a restructuring of Greek sovereign debt of -36.4% of GDP in 2012 [i.e. a stock flow adjustment due to private sector involvement, see EC (2013d)]. No stock flow adjustments are made hereafter for Greece and none at all for Ireland and Portugal.



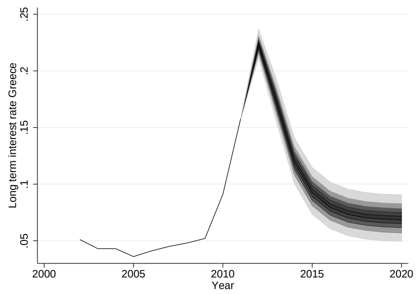
(a) Baseline debt chart Portugal. Dashed line: IMF country report (p. 47, IMF 2012b).



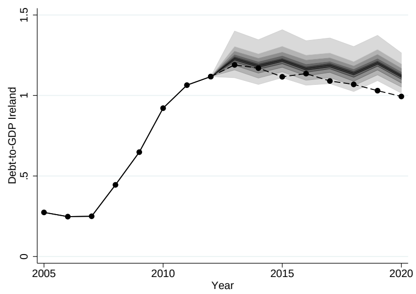
(b) Baseline interest chart Portugal.



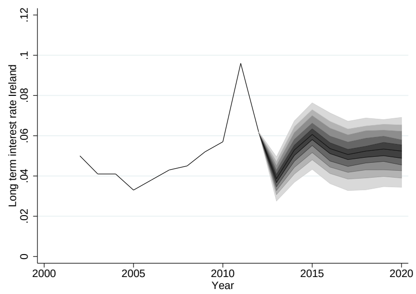
(c) Baseline debt chart Greece. Dashed line: IMF country report (p.71, IMF 2011).



(d) Baseline interest chart Greece.



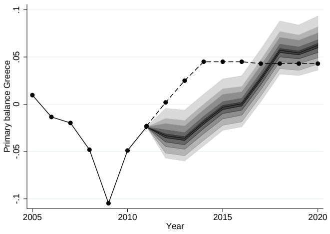
(e) Baseline debt chart Ireland. Dashed line: IMF country report (p. 48, IMF 2012a).



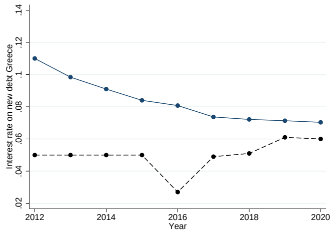
(f) Baseline interest chart Ireland.

Figure 1: Baseline scenario debt-to-GDP and LT interest.

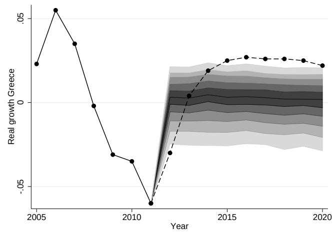
IMF country reports. For GIP, we observe that our pb_t is lower than IMF projections in early years (due to smaller fiscal consolidation efforts and no structural reforms). Our interest rates on new debt lie above those in the IMF country reports. This is to be expected as the projected borrowing rates in the IMF baselines accounts for the EU/IMF & bilateral facilities whereas our borrowing rates are purely market rates. Moreover, our interest rate process converges back to stationary values at a slower pace than anticipated in IMF/EC reports. Our convergence process reflects the dynamics that would prevail absent structural reforms. In reality, these reforms spur market confidence which leads to lower yields. Our VAR reflects future dynamics of i_t^L, i_t^S based on historic dynamics (reflected by $A_1 - A_3$ in (10)) – which fully accords with what we aim to capture with our baseline scenario. With respect to growth, we note that IMF projections are at the upper bound of our fan charts. Figure 1 also contains the baseline debt projections of the IMF (which is a deterministic debt path). In view of all the above, we observe that our debt fan charts are biased upwards vis-á-vis IMF baselines for GIP – as expected ex ante. The difference is the largest for Greece and the smallest for Ireland.



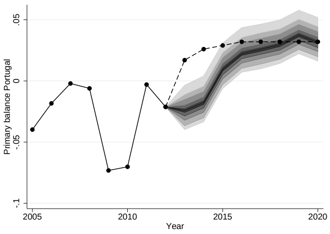
(a) **Greece.** Primary balance. Dashed black line: IMF country report (p. 71, IMF 2011). Fan chart: our analysis.



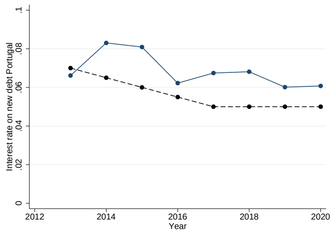
(b) **Greece.** Average interest rate on newly issued debt. Dashed black line: IMF country report (p. 71, IMF 2011). Solid blue line: our analysis.



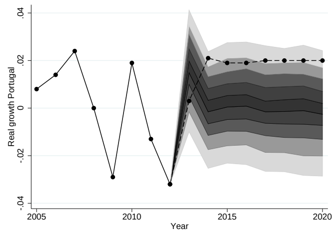
(c) **Greece.** Real growth. Dashed black line: IMF country reports (p. 71, IMF 2011). Fan chart: our analysis.



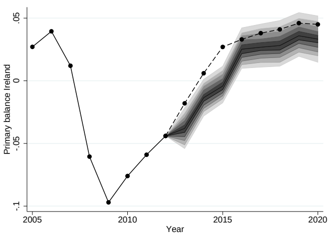
(d) **Portugal.** Primary balance. Dashed black line: IMF country report (p. 47, IMF 2012b – missing values interpolated). Fan chart: our analysis.



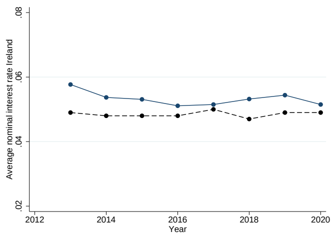
(e) **Portugal.** Average interest rate on newly issued debt. Dashed black line: IMF country report (p. 52, IMF 2012b). Solid blue line: our analysis.



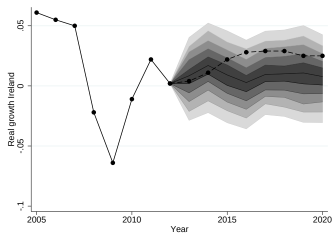
(f) **Portugal.** Real growth. Dashed black line: IMF country report (p. 47, IMF 2012b – missing values interpolated). Fan chart: our analysis.



(g) **Ireland.** Primary balance. Dashed black line: IMF country report (p. 48, IMF 2012a – missing values interpolated). Fan chart: our analysis.



(h) **Ireland.** Average nominal interest rate on public debt [$INT_{t+1}/Debt_t$]. Dashed black line: IMF country report (p. 48, IMF 2012a). Solid blue line: our analysis.



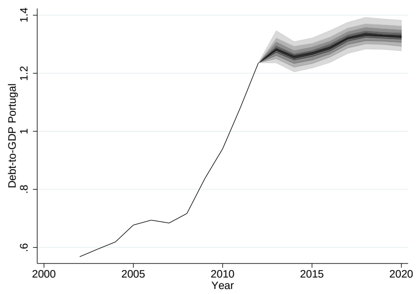
(i) **Ireland.** Real growth. Dashed black line: IMF country report (p. 48, IMF 2012a). Fan chart: our analysis.

Figure 2: Comparing Baseline scenarios with IMF Baseline scenarios. We use IMF country reports because they are (i) more explicit in the underlying assumptions and (ii) more standardised across countries than the EC Economic Adjustment Programmes. For each country we use the country report available at or near the starting date of our projections (such that IMF projections make use of the same data as we do).

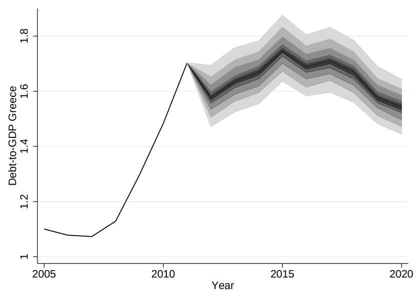
4.2. The Full-Fledged Eurobond scenario.

Next, Figure 3 (Panel a, b and c) plots the projected debt path under a Eurobond scenario. Figure 3 (Panel d) plots the new Portuguese long term interest rate process, which is similar for Greece and Ireland (the same holds true for the short term rate). (i) For Portugal, we observe that Eurobonds have the potential to quickly neutralise the previously observed rise in sovereign debt. It yields a median debt position of 132.85%, which is 20 percentage points lower than the baseline scenario in 2020. (ii) Whereas Greek debt was rising before, we observe that Eurobonds have the potential to revert the adverse debt dynamics downward, reaching 153.94% by 2020 (median projection). (iii) For Ireland we observe that median debt-to-GDP is 94.43%, roughly 20% lower vis-à-vis that observed under the baseline scenario.

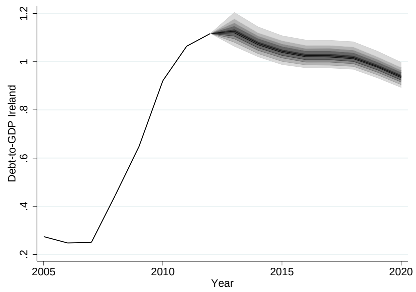
A comparison of Figure 1 [Baseline] and Figure 3 [Eurobond] suggests what an introduction of Eurobonds could have achieved instead of the structural reforms/bailout packages/large fiscal consolidation efforts. We observe the effects from Eurobonds to be material. For Greece and Portugal, we see that Eurobond debt dynamics leads to sustainability, but



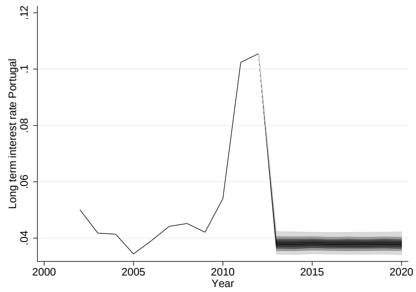
(a) Portugal



(b) Greece



(c) Ireland



(d) Eurobond long term interest rate

Figure 3: Full-Fledged Eurobond design for GIP.

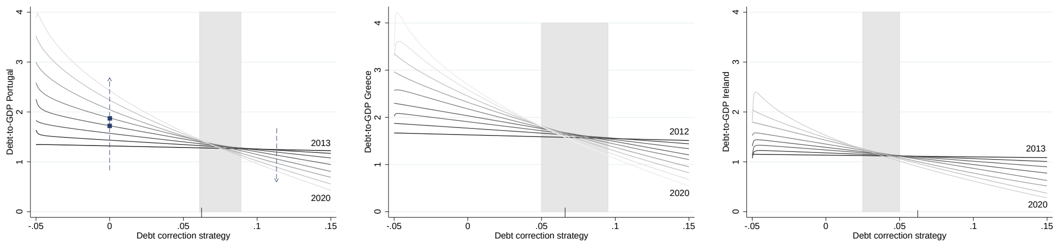
debt would still be materially higher than what is projected in the IMF country reports, suggesting the importance of structural reforms in these countries. For Ireland, debt dynamics now resembles the scenarios put forward in the IMF country report, which incorporates all structural reforms (tax reforms, health sector reforms, etc.). In no case do we argue that Eurobonds would have been an equally worthy substitute to these (necessary) structural reforms, but the comparison does bring normative significance to the table.

In appendix A.3 we present the Eurobond counterpart of Figure 2. We observe that our Eurobond rate (which is identical for GIP) to be lower than that projected in the IMF reports. When compared to our Baseline scenario, we observe that both g_t and pb_t are higher in the Eurobond scenario.

4.3. Further analysis

4.3.1. Moral hazard in the fiscal reaction function

We now investigate the sensitivity of our Eurobond results with respect to ψ_3, the debt correction parameter that embodies a potential moral hazard problem. We analyse only the impact of moral hazard - not its likelihood of occurrence. In Figure 4, each curve plots the median debt position at the end of year t $\in$ [2013, 2020] when ψ_3 is unilaterally allowed to vary. E.g., if one were to start on the curve for t = 2016 on the lower square (d_{2016} = 171.4%) in panel a, with $\psi_3 = 0$ during t = 2017, we would arrive at the upper square (d_{2017} = 184.5%) at the end of 2017. The crossing of two time adjacent curves identifies a year-on-year steady state (STST) debt correction strategy (ψ_3). These year-on-year STST strategies are situated very close to each other, thereby identifying a "range of STST debt correction strategies" (the shaded grey area). In the case of Portugal and Greece, the debt correction parameter from table Table 1, column 4 (which point estimate equalled 0.0623) falls in the zone of STST debt correction strategies, whereas it surpasses it in Ireland. The implication of this observation is that, under a Eurobond scenario, if Greece or Portugal are to lower their debt correction (ψ_3) due to moral hazard, debt would quickly become unsustainable. In Ireland, however, some slack in fiscal policy is possible. Concisely, our results suggest that the "margin of moral hazard" is small (if not absent); moral hazard immediately has repercussions on debt sustainability. The policy implication is that a Eurobond design should at worst allow only a very small margin of moral hazard.

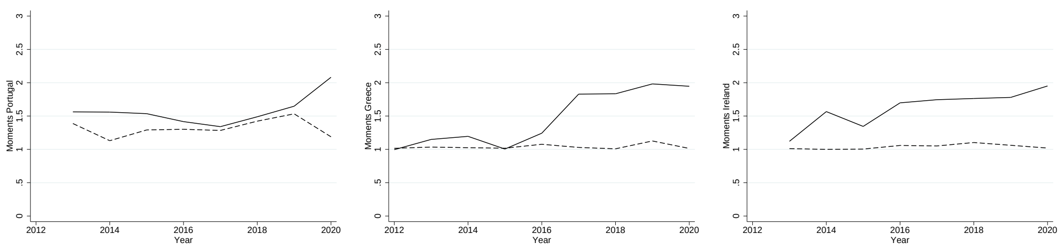


(a) Portugal (b) Greece (c) Ireland

Figure 4: Moral hazard allowance. Median d_t vs. ψ_3.

4.3.2. Depressing volatility in debt forecasts

Figure 5 plots the ratio of the second central moment (variance, solid line) and the third standardised moment (skewness, dashed line) of our annual debt-to-GDP forecasts under the baseline and Full-Fledged scenario.[15] We observe that the variance is lower in the Full-Fledged Eurobonds scenario ($V_t > 1$), enabling policy-makers to narrow the uncertainty of debt forecasts (as the interest volatility is - to large degree - taken out of the equation). This benefit increases over time and is quite large. We observe that the variance of our debt projections are reduced more than half when Eurobonds are issued. The skewness is, in both scenarios, positive (indicating long right tails). This positive skewness can be interpreted as the upside risk in debt dynamics and is found to be of lower magnitude in the Eurobond scenario ($S_t > 1$). The average skewness in the baseline (Eurobond) scenario was 0.11 (0.083) in Portugal; 0.19 (0.18) in Greece; 0.22 (0.18) in Ireland. Note that the non-smooth behaviour of these ratios is, due to confounding of many determinants, difficult to interpret.



(a) Portugal (b) Greece (c) Ireland

Figure 5: Moments Portugal, Greece, Ireland. Solid line: V_t. Dashed line: S_t.

5. Conclusion

Europe finds itself at a crossroads: *more or less unification*. This paper assesses the effect on debt dynamics of more unification through the issue of a common debt instrument: a Eurobond. The countries under consideration were Greece, Ireland and Portugal, i.e. peripheral member states currently under stress. We briefly summarise the main results and infer three policy implications from the analysis.

A first insight is the normative significance of Eurobonds on sovereign debt, a benefit which before has only been claimed but not really formally assessed. Our fan charts of the Full-Fledged Eurobond design reveal that the median debt projection of 2020 declines with roughly 20 percentage points (Portugal and Ireland) and 50 percentage points (Greece) vis-à-vis a baseline scenario. This level effect on sovereign debt is non-negligible and certainly underscores the economic rationale of Eurobonds as claimed in paragraph 1.2.1. of the relevant Green Paper EC (2011).

15

$$V_t = \frac{\sigma_t^{Baseline}(\frac{Debt}{GDP})}{\sigma_t^{Full-Fledged}(\frac{Debt}{GDP})}; S_t = \frac{Skewness_t^{Baseline}(\frac{Debt}{GDP})}{Skewness_t^{Full-Fledged}(\frac{Debt}{GDP})} \quad (15)$$

A second implication is the depressed debt volatility brought about by the stable interest environment. We found the moments of sovereign debt distributions to be more favourable under Eurobond scenarios, halving the variance and lowering the upside risk in debt dynamics through a lower skewness. These results allow for a more efficient sovereign debt management as claimed in paragraph 1.2.1. EC (2011).

The last implication concerns potential pitfalls concerning Eurobonds. The successful introduction of Eurobonds requires that asymmetric information problems - leading to moral hazard and adverse selection - are tackled successfully in its design.

– Notes

[1] We note that Cherif and Hasanov (2012) recommend including lagged debt (d_{t-1}) as an exogenous variable in the VAR to account for possible feedback on the interest rates. In effect, as argued by Di Cesare et al. (2013), sovereign debt has become an important determinant of market interest rates. Although we recognize the possible benefit of including (d_{t-1}), careful considerations deter us from doing so. (i) For the member states under consideration, (d_{t-1}) was found to be non-stationary [I(1)] (cf. van Aarle and Van Hove (2012) for Ireland; van Aarle and Kappler (2011) for Greece; Contreras (2011) for Portugal). (ii) De Grauwe and Ji (2012) show that the relationship between the interest rates and d_t was significantly altered throughout the crisis. Accounting for this shift in market behaviour using structural breaks requires too much degrees of freedom. (iii) Currently, the VAR framework is a distinct building block in our analysis; simulating the VAR forward in time to obtain time series of $\langle g_t, \pi_t, i_t^L, i_t^S \rangle$ does not require the debt framework (1)-(9) nor the FRF (11). However, including d_{t-1} would tie the VAR to both the debt framework and the FRF as d_{t-1} is required to be periodically updated (using the debt framework and the FRF) and re-entered in the VAR. This requires us to, period by period, derive the quarterly output-gap (as it is included in the FRF). As shown by Hodrick and Prescott (1997), estimates of the output gap at the end of the time series are typically noisy, which therefore threatens the quality of the estimated output gap included in our FRF. Due to all the above, we abstain from including d_{t-1} in the VAR specification.

[2] Deriving quarterly shocks ξ_t (4x1 vectors). The procedure described below originates from the work by Sims (1980) and is the standard approach in the stochastic debt literature – see e.g. Celasun et al. (2006); Tanner and Samake (2008); Cherif and Hasanov (2012); Medeiros (2012); Penalver and Thwaites (2006); Eller and Urvová (2012); Garcia and Rigobon (2004). The variance-covariance matrix of the residuals $\hat{\Omega}$ characterizes the joint statistical properties of the contemporaneous disturbances of the endogenous variables in the VAR. As the errors are contemporaneously correlated, we first orthogonalize the errors through a Cholesky decomposition of $\hat{\Omega}$: $\hat{\Omega} = B'B$. B [order 4x4] is an upper triangular matrix (i.e. all entries below the main diagonal are zero). The entries on the main diagonal of B are the standard deviations of all structural shocks. Using B, quarterly shocks for the Monte Carlo simulation (ξ_t) are obtained as follows: $\xi_t = B\zeta_t$ where $\zeta_t \sim N(0,1)$, where ζ_t is a 4x1 vector. For a discussion concerning the importance of the the ordering of the variables in our application, see Garcia and Rigobon (2004). We repeat this procedure N times (i.e. the number of simulations is 25.000) for a time horizon of 8 years (i.e. $T = 32$ quarters) to arrive at NT vectors of ξ_t.

[3] The debt accounting framework [subsection 3.1] is based on annual variables whereas the VAR framework projects quarterly values of g_t, π_t, i_t^L and i_t^S. We annualise the VAR predictions of the endogenous variables before they enter the debt accounting framework (and fiscal reaction function). For i_t^L and i_t^S we take the arithmetic mean of the four quarters. For g_t and π_t we annualise using $\prod(1+g_t)-1$ and $\prod(1+\pi_t)-1$ respectively. This process is identical to the annualisation procedure which underlies these variables in the AMECO database.

[4] Observe that using (12) in our simulation model requires us to obtain future values of $gap_{i,t}$. $gap_{i,t}$ (for t=2013,...,T) is obtained using the VAR in which we include $g_{i,t}$ (real growth). Starting from real $GDP_{i,2012}$ we obtain a time series of real $GDP_{i,t}$ of arbitrary length. The latter is appealing as the calculation of the output gap using the HP filter is typically noisy at the end of the time series. Our approach allows us to lengthen the time series of future real $GDP_{i,t}$ by enough to overcome this drawback.

Appendix A. Appendix

Appendix A.1. Data sources

Table A.2: Data sources VAR

Variable	Source
Quarterly long term interest	AMECO Database
Quarterly short term interest	Datastream
Quarterly inflation	EUROSTAT
Quarterly real growth (seasonally unadjusted)	EUROSTAT

Table A.3: Data sources FRF

Variable	Source
Annual debt-to-GDP	EUROSTAT
Annual nominal GDP	EUROSTAT
Annual real GDP	EUROSTAT
Annual inflation	EUROSTAT
Annual oil price	ECB Statistical Data Warehouse
Annual primary balance (seasonally unadjusted)	ECB Statistical Data Warehouse
US output gap	World Economic Outlook Database
Openess	ECB Statistical Data Warehouse
Fiscal rule index	European Commission, Fiscal Rule Database

Table A.4: Debt framework

Variable	Source
Repayment Schedule Ireland	EC, 2013a & NTMA year reports
Repayment Schedule Greece	EC, 2013b
Repayment Schedule Portugal	EC, 2013c
Annual Long Term Interest	AMECO Database
Annual Short Term Interest	AMECO Database

Table A.5: Other

Variable	Source
Historic German bund yields (10 year maturity)	AMECO Database
Historic German bund yields (1 year maturity)	Datastream

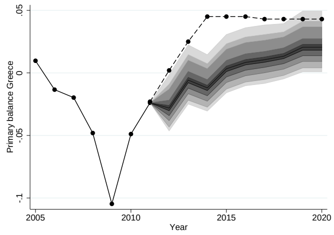
Appendix A.2. Estimates FRF

Table A.6: Estimation results FRF

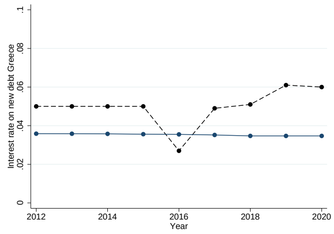
	(1) No IV/No FE	(2) IV/FE	(3) IV/FE	(4) IV/FE	(5) IV/FE
pb_{t-1}	0.764***	0.695***	0.699***	0.699***	0.682***
	(13.62)	(10.34)	(10.40)	(10.43)	(9.85)
d_{t-1}	0.00434	0.0672**	0.0628**	0.0623**	0.0589*
	(0.72)	(3.03)	(2.75)	(2.80)	(2.19)
gap_t	0.162*	0.420***	0.381***	0.376***	-0.100
	(2.30)	(4.12)	(3.39)	(3.64)	(-0.63)
Belgium		-0.0176	-0.0163	-0.0162	-0.0150
		(-1.59)	(-1.47)	(-1.47)	(-1.21)
Finland		0.0174	0.0164	0.0163	0.0203*
		(1.79)	(1.67)	(1.68)	(2.00)
France		-0.00313	-0.00348	-0.00352	-0.00932
		(-0.36)	(-0.40)	(-0.41)	(-1.11)
Germany		-0.00127	-0.00124	-0.00124	-0.00255
		(-0.15)	(-0.15)	(-0.15)	(-0.31)
Greece		-0.0570***	-0.0538***	-0.0535***	-0.0387*
		(-3.89)	(-3.56)	(-3.64)	(-2.05)
Ireland		0.00203	0.000901	0.000775	0.00224
		(0.18)	(0.08)	(0.07)	(0.17)
Italy		-0.0274*	-0.0255*	-0.0253*	-0.0255
		(-2.14)	(-1.96)	(-1.97)	(-1.67)
Luxembourg		0.0372*	0.0346*	0.0343*	0.0345
		(2.49)	(2.27)	(2.30)	(1.90)
Netherlands		0.00415	0.00350	0.00343	0.00318
		(0.47)	(0.40)	(0.39)	(0.33)
Portugal		-0.0109	-0.0108	-0.0107	-0.0118
		(-1.27)	(-1.26)	(-1.25)	(-1.14)
Spain		-0.0000998	-0.000773	-0.000848	0.00277
		(-0.01)	(-0.08)	(-0.09)	(0.24)
Fiscal Index					-0.00181
					(-0.31)
Gap Germany					0.718***
					(4.36)
ψ_0	-0.00710	-0.0435**	-0.0406*	-0.0403*	-0.0353
	(-1.59)	(-2.72)	(-2.48)	(-2.51)	(-1.86)
N	140	140	140	140	130
Countries	12	12	12	12	11
R^2	0.6197	0.6791	0.6806	0.6807	0.7315
F-test	0.000	0.000	0.000	0.000	0.000

t statistics in parentheses

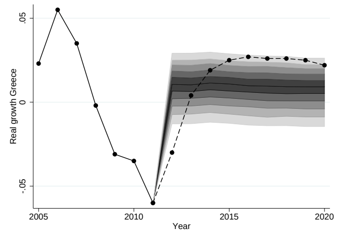
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$



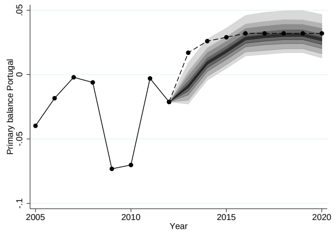
(a) **Greece.** Primary balance. Black dashed line: IMF country report (p.71, IMF 2011). Fan chart: our Eurobond scenario.



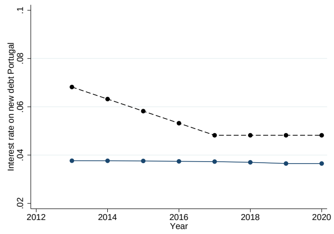
(b) **Greece.** Average interest rate on newly issued debt. Dashed black line: IMF country report (p.71, IMF 2011). Solid blue line: our Eurobond scenario.



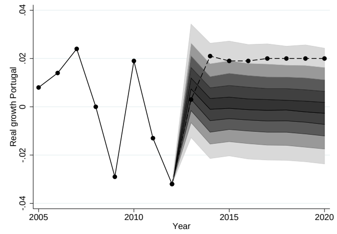
(c) **Greece.** Real growth. Dashed black line: IMF country reports (p.71, IMF 2011). Fan chart: our Eurobond scenario.



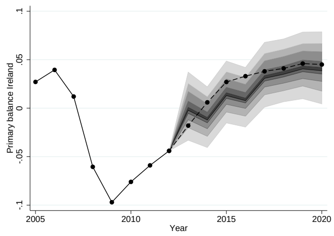
(d) **Portugal.** Primary balance. Dashed black line: IMF country report (p. 47, IMF 2012b – missing values interpolated). Fan chart: our Eurobond scenario.



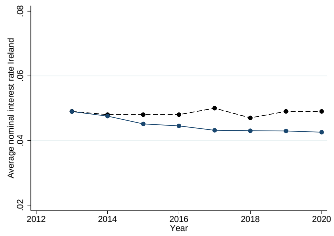
(e) **Portugal.** Average interest rate on newly issued debt. Dashed black line: IMF country report (p.52, IMF 2012b). Solid blue line: our Eurobond scenario.



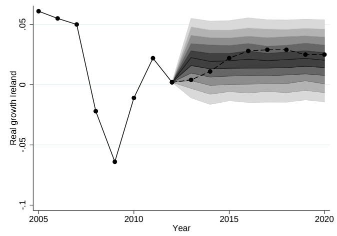
(f) **Portugal.** Real growth. Dashed black line: IMF country report (p. 47, IMF 2012b – missing values interpolated). Fan chart: our Eurobond scenario.



(g) **Ireland.** Primary balance. Dashed black line: IMF country report (p. 48, IMF 2012a – missing values interpolated). Fan chart: our Eurobond scenario.



(h) **Ireland.** Average nominal interest rate on public debt $[INT_{t+1}/Debt_t]$. Dashed black line: IMF country report (p. 48, IMF 2012a). Solid blue line: our Eurobond scenario.



(i) **Ireland.** Real growth. Dashed black line: IMF country report (p. 48, IMF 2012a). Fan chart: our Eurobond scenario.

Figure A.6: Comparing Eurobond scenarios with IMF Baseline scenarios.

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