Ca' Foscari University of Venice

Department of Economics

Working Paper

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ISSN: 1827-3580
No. 11/WP/2023

Working Papers
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Abstract
We describe a new Euro-stability bond that implies sovereign debt mutualization in the Eurozone without any significant short-term redistribution across countries or perverse incentives to fiscal profligacy. In a simple structural model of the economy, we theoretically show that the proposed Euro-stability bond is able to reproduce the market fiscal discipline while increasing the social welfare of all countries with respect to real market discipline. Relying on a GVAR model including the Eurozone countries, the U.S., Japan and China, we then analyze the future evolution of public debt (and other key macroeconomic variables) over time by comparing the predicted forecast in the baseline scenario and in a counterfactual scenario with the Euro-stability bond. We find no significant differences in the future path of interest expenditures and public debt-to-GDP ratios in the two scenarios, but a consistent reduction in the uncertainty of the estimates in the counterfactual scenario (around 68 % on average after 5 years). The reduced uncertainty of forecasts of public debt and other macroeconomic variables highlights the capacity of the Euro-stability bond to immunize the Eurozone from classical macroeconomic instability shocks that derive by the very existence of high sovereign debts and the related significant rollover risk in a framework of decentralized fiscal policies. To this extent, we finally exploit the results of the GVAR model to assess the capacity of the proposed scheme to reduce the probability of adverse macroeconomic events.

Keywords
Eurobonds, Fiscal stability, GVAR, Macroeconomic forecasts

JEL Codes
E02, E47, H63, H68

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May 2023

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We describe a new Euro-stability bond that implies sovereign debt mutualization in the Eurozone without any significant short-term redistribution across countries or perverse incentives to fiscal profligacy. In a simple structural model of the economy, we theoretically show that the proposed Euro-stability bond is able to reproduce the market fiscal discipline while increasing the social welfare of all countries with respect to real market discipline. Relying on a GVAR model including the Eurozone countries, the U.S., Japan and China, we then analyze the future evolution of public debt (and other key macroeconomic variables) over time by comparing the predicted forecast in the baseline scenario and in a counterfactual scenario with the Euro-stability bond. We find no significant differences in the future path of interest expenditures- and public debt-to-GDP ratios in the two scenarios, but a consistent reduction in the uncertainty of the estimates in the counterfactual scenario (around 68 % on average after 5 years). The reduced uncertainty of forecasts of public debt and other macroeconomic variables highlights the capacity of the Euro-stability bond to immunize the Eurozone from classical macroeconomic instability shocks that derive by the very existence of high sovereign debts and the related significant rollover risk in a framework of decentralized fiscal policies. To this extent, we finally exploit the results of the GVAR model to assess the capacity of the proposed scheme to reduce the probability of adverse macroeconomic events.

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1 Introduction

The reaction of the European Union (EU) to the COVID-19 crisis was unprecedented. The most pathbreaking decision was taken by the European Council on July 21st 2020 to finance part of the European Resilience and Recovery Fund (ERRF) by a temporary issuance of EU sovereign debt (European Council, 2020). Though this institutional experiment is a landmark in the EU history, it is likely to be just a temporary break in the long-lasting, fierce dispute on pros and cons of a common EU fiscal policy. In the post-COVID world, the debate on the reform of EU fiscal rules acknowledges the potential, future role of some *"central fiscal capacity"* (also relying on structural Eurobonds or similar debt mutualization schemes), though the assessment of such a reform continues to be driven by pre-pandemics principles (European Commission, 2022).[1]

The European sovereign debt crisis of early 2010s exposed the weaknesses of the European Monetary Union (EMU). The institutional design of the euro fostered fiscal risks in the pre-2008 crisis period and amplified perverse financial dynamics once the crisis occurred (Lane, 2012). The reforms of the EU fiscal governance adopted in the aftermath of the sovereign debt crisis were insufficient to provide reliable solutions to face future challenges. In this context, sovereign debt mutualization schemes were proposed to enhance the resilience of the EMU to macroeconomic shocks and contagion risks across the sovereign debt markets of the euro area. Several proposals put forward before and after the sovereign debt crisis aimed at improving the functioning of the EMU in three areas (Mody et al., 2012): 1) monetary policy transmission; 2) financial and banking stability; 3) fiscal risk-sharing. However, the mentioned proposals typically fail to satisfy the *"guiding principles for a euro area stabilization function"* spelled out in the 2015 Five Presidents'

[1]As highlighted by the European Commission (2022) (pp. 25-26): *"permanent central fiscal capacity [. . .] could address longer-term challenges through the provision of common public goods that would boost sustainable growth and help stem inflation and/or improve macroeconomic stabilisation. The Five Presidents report in 2015 identified sound guiding principles for its design, notably that such a capacity should not lead to permanent transfers between countries, it should maintain the incentives for sound fiscal policy-making at the national level, and it should be developed within the framework of the European Union."*

Report (Juncker et al., 2015). First, many of them would imply cross-country redistribution in the short run (e.g., Gros, 2011, Cioffi et al., 2019). Second, all Eurobond or debt mutualization schemes relying on a common interest rate pose a moral hazard problem by inducing fiscal profligacy, particularly in high-debt countries (e.g., Issing, 2009). Third, the participation of countries to the proposed schemes is often conceived as voluntary or conditional (on fiscal solvency) to be consistent with the existing EU fiscal coordination framework and, particularly, to avoid any potential interference with the functioning of the European Stabilization Mechanism. However, such provisions may foster self-selection problems, thus leading to ineffective (e.g., if no country joins fearful of stigma effects) or unsustainable schemes (e.g., if only insolvent countries join).

In this paper, we propose and assess – both theoretically and empirically – a new instrument, the *Euro-stability bond*, that aims at affording the usual benefits of debt mutualization mechanisms while complying with the main guiding principles of the 2015 Five Presidents' Report. The Euro-stability bond combines two features: 1) bonds are issued (and traded on the secondary market) at a unique, common interest rate; 2) individual Member States that finance themselves by such bonds pay an interest rate that is the sum of the common rate and a *fiscal discipline premium*. The latter would be politically determined. In the basic version of the Euro-stability bond on which we focus in this paper, the fiscal discipline premium aims at replicating the disciplining effect of sovereign debt markets on governments' fiscal policies; thus, it is a function of fiscal fundamentals that have historically determined the dynamics of sovereign spreads in the euro area. In a more encompassing version of the Euro-stability bond that we briefly discuss in a simplified theoretical model, the fiscal discipline premium may also be used as a fiscal coordination tool that substitutes the EU fiscal rules. In the latter, the fiscal discipline premium may depend on a larger set of economic and political determinants (e.g., macroeconomic imbalances, structural reform plans, etc.).

In the scenario with the Euro-stability bond, each Member State of the euro area would finance (part of) its government debt through a European debt agency that issues and manages the common sovereign bonds.[2] The same institution would supervise the fiscal behaviour of individual governments to charge Member States with differentiated fiscal discipline premia. Similar to what the European Council (2020) introduced to finance the ERRF, the common sovereign debt would be backed by EU own resources that include the revenues from fiscal discipline premia.[3] As highlighted in the literature, the market discipline – and thus the fiscal discipline premium that replicates it – may play an important role to keep price signals as an ex-ante disincentive to fiscal profligacy (e.g., Mody et al., 2012). In this perspective, the Euro-stability bond complements the existing EU fiscal coordination framework.

In this paper we focus on potential macroeconomic stabilization effects of a properly designed debt-mutualization scheme that complies with the currently accepted guiding principles leading to an EU fiscal policy. Our main contribution is to show the capacity of the Euro-stability bond to significantly reduce the variance of forecast estimates of fiscal variables and the probability of adverse macroeconomic events (e.g., recessions). The analysis relies on a suitable Global Vector Auto-Regressive (GVAR) representation of the Eurozone and its links to other large developed and emerging economies. For the sake of statistical tractability, we estimate a GVAR model with ten major Eurozone countries and three other key economies (China, Japan and USA) including five domestic variables that reflect the macroeconomic dynamics of each country over time (i.e., the real GDP growth, the long-term sovereign interest rate and three fiscal variables – the interest expenditure, the primary balance, and the public debt – considered as ratios to GDP). This model

[2]Other papers in the literature have analysed the potential functioning of a European debt agency (e.g., Amato et al., 2021). In our analysis, we assume that Eurozone countries are obliged to issue all their public debt in Euro-stability bonds. As for other Eurobond proposals, the implementation of the Euro-stability bond in the real world would require the solution of several, important institutional and financial issues (e.g., how to phase in the scheme, how to avoid wasteful arbitrage, in case of partial financing of countries' government debt, etc.) that we just assume away in this paper, for the sake of our main argument.

[3]Based on the estimations of our empirical model, the EU revenues from fiscal discipline premia would amount to around 0.66 % of the Eurozone GDP in the short -run after the introduction of the Euro-stability bond, with a general tendency to decrease in the medium run (0.11% of the Eurozone GDP after 5 years).

specification allows to perform a *baseline* (i.e., without the Euro-stability bond) and *counterfactual* (i.e., with the Euro-stability bond) analysis for Eurozone countries considering all potential spillovers among them (e.g., fiscal contagion, aggregate-demand externalities, etc.). Moreover, the GVAR methodology makes it possible to compute event probability forecasts (i.e., the out-of-sample probabilities associated with any possible positive or negative future events with respect to our variables of interest).

Four strands of the literature are related to our paper. First, we contribute to the Eurobond debate started by the Giovannini Group (2000).[4] The bulk of proposed schemes aim at providing the EMU with the fiscal capacity to increase the liquidity in government bond markets – thus controlling financing costs and keeping public debts on a sustainable path – while containing moral hazard of individual countries. The most controversial issues in such a debate have been the impact of such instruments on fiscal coordination within the euro area and, more broadly, the real costs and benefits of an EU permanent fiscal capacity. The first two decades of the euro have highlighted the limits of the EU fiscal framework as defined by the Maastricht Treaty and the Stability and Growth Pact (i.e., numerical thresholds for government debt and deficit ratios and monitoring procedures involving the European Commission and the European Council). The post-pandemics debate acknowledges such limits and suggests a revision of the EU fiscal rules with the objectives of *"improving national ownership, simplifying the framework and moving towards a greater medium-term focus, combined with stronger and more coherent enforcement"* (European Commission, 2022 (p.1); Blanchard et al., 2021; Gaspar, 2020; Beetsma and Larch, 2018). As above highlighted, the other (not necessarily alternative) solution – i.e., introducing EU, ordinary fiscal stabilization instruments – still relies on the political and institutional consensus that was forged before the pandemics. In our contribution, we show that a properly designed common debt instrument can be used to foster both fiscal discipline and stability under ordinary macroeconomic conditions.

[4]For a detailed and updated literature review of alternative Eurobond schemes that have been proposed in the last two decades, see Amato and Saraceno, 2022.

Second, we contribute to the GVAR forecast applications at country level. After GVAR models were firstly introduced by Pesaran et al. (2004), the number of contributions exploiting this approach in the academic literature has progressively grown, covering various fields and applications (e.g., financial markets and international business cycle, output gaps linkages, trade imbalances, credit risk and portfolio analysis).[5] Closer to our application, empirical exercises employing GVAR based counterfactual analysis are provided by Pesaran et al. (2007) and Dubois et al. (2009).

Third, the literature on the determinants of the sovereign spreads in the Eurozone is also relevant for our analysis, given their role in the theoretical and empirical calibration of the fiscal discipline premium, which is the cornerstone of the Euro-stability bond. Therefore, the second Section of the paper borrows from this literature to critically assess the performance of the market discipline within the euro area.

The empirical analysis on the macroeconomic effects of Eurobonds's introduction has, so far, not been systematically investigated.[6] To the best of our knowledge, the only exception is the contribution of Tielens et al. (2014) that relies on a VAR analysis to evaluate the effects of a Eurobond scheme on sovereign debt dynamics, particularly of Greece, Portugal, and Ireland. Our paper differs from Tielens et al. (2014) in two key methodological elements. First, while they estimate three country-specific VAR models, we combine several Eurozone countries in the same GVAR setup, which allows us to consider all sorts of economic links and externalities among countries. Therefore, our framework is more suitable to take into account potential financial contagion phenomena that play a crucial role in understanding the functioning of the Eurozone and in the assessment of the potential role of debt mutualization schemes. Second, while Tielens et al. (2014) measure the dynamics of public debt-over-GDP ex-post, combining the variables included in the VAR model in a specific law of motion, we directly include the debt ratio in our endogenous

[5] For a review on GVAR empirical applications, see Di Mauro and Pesaran (2013).

[6] In the recent debate on Eurobond, the contribution by Codogno and van den Noord (2021) comes close to ours, though they simulate a theoretical model to assess the macroeconomic stabilization effect of the Eurobond.

variables. Therefore, we can perform statistically meaningful counterfactual analyses.

Our results read as follows. First, we provide a clear foundation of the Euro-stability bond we propose, by a simple theoretical model of the Eurozone economies. Second, relying on our GVAR model, we show that the introduction of the Euro-stability bond – where the fiscal discipline premium is calibrated to replicate market discipline – is beneficial in terms of reduction in the overall volatility of expected future public debt-over-GDP ratio. Moreover, these latter results hold even if no significant differences in the path of interest expenditure over time is produced by the introduction of the Euro-stability bond, thus suggesting no cross-country fiscal redistribution in the short-run. By the same approach, we show that the probability of recessions decreases with the Euro-stability bond. Based on the theoretical analysis, we interpret our empirical results as the effect of the improved immunization of the public debt and the Eurozone economies with respect to different sources of macroeconomic instability and, particularly, by the suppression of the contagion effects that, in the baseline scenario, affect the long-run sovereign interest rates of Eurozone countries. The paper is organized as follows: Section 2 discusses the disciplining effect of sovereign bond markets analyzing the dynamics of the determinants of Eurozone sovereign spreads in the last two decades; Section 3 illustrates our proposal of Euro-stability bond relying on a simple, structural model of Eurozone economies; Section 4 reports our empirical evidence comparing baseline and counterfactual analyses; then, Section 5 draws conclusions.

2 The market discipline in the euro area: stylized facts

A crucial feature of our proposal is its capacity to replicate market discipline. In this Section, we analyze the determinants of Eurozone sovereign debt spreads to provide stylized facts about the efficiency of the market discipline within the euro area and to establish a benchmark to calibrate the counterfactual empirical model with the Euro-stability bond.

Starting from the adoption of the single currency in 1999, the evolution of sovereign interest spreads in the euro area – as represented by the difference between the 10-years interest rate of government bond of any Member State and the (safest) German bund – has drawn great attention among researchers and policy-makers. The motivation is straightforward: given the size of government debts and the degree of financial and economic integration of the euro-area countries, even a small variation in sovereign bond yields may push individual countries towards unsustainable fiscal dynamics and, in turn, affect the fiscal and monetary stability of the Eurozone.

There is a general consensus in the literature that the dynamics of interest rate spreads of euro area 10-years bonds may be modelled as function of three main determinants (Manganelli and Wolswijk, 2009; Favero et al., 2010; Arghyrou and Kontonikas, 2012; Afonso and Jalles, 2019): 1) the global risk, which conveys the systemic and time-varying international level of risk aversion and it is usually measured with the spread between corporate and government bonds or, alternatively, with standard global uncertainty indexes (e.g., VIX, EPU); 2) the credit risk, which internalizes the country's default risk and it is therefore related to country-specific fiscal variables and macroeconomic fundamentals (e.g., the expected fiscal position);[7] 3) the liquidity risk, which expresses the premium required by investors to bear the risk of obtaining a lower liquidation of the security with respect to the benchmark, and it is generally higher in case of a (temporary or structural) lower integration across sovereign bond markets. However, plenty of studies have documented that the contribution of each of the mentioned factors to the dynamics of sovereign spreads is non-linear and has structurally changed over time, both in a country-dependent and event-related way. Understanding reported non-linear and time-varying relations is key when it comes to assess the existence and causes of potential mispricing of sovereign bonds that have been documented before the 2008 financial crisis and during the sovereign debt

[7]The variables that have been more often used to measure countries' fiscal positions, as we do in this paper, are the government debt-over-GDP and the deficit-over-GDP ratios. Some authors also employed alternative measures that are more efficient to capture changes in the the magnitude of the default risk with high-frequency data such as credit ratings (Gómez-Puig, 2006; Manganelli and Wolswijk, 2009) and CDSs' differentials (Baber et al., 2009; Barrios et al., 2009).

crisis in the euro area (De Grauwe and Ji, 2012; Di Cesare et al., 2012)

Mispricing undermines the capacity of sovereign bond markets to reliably price the credit risk of individual countries, thus providing a rational market discipline for governments' fiscal policies without inducing financial and macroeconomic instability. A systematic review of the results of the literature on Eurozone sovereign spreads suggests widespread mispricing events.[8] From 1999 to the 2008 financial crisis, we observe a significant reduction of the euro-area government bond spreads of all Member States. During this *convergence phase*, the key driver of sovereign spreads is the global risk, especially in high-debt countries and during periods of worsening financial conditions (Codogno et al., 2003; Barrios et al., 2009). Macroeconomic fundamentals and fiscal variables (i.e., credit risk) were priced by the sovereign debt markets, though their impact on the dynamics of spreads was barely significant.[9] Why during this period the debt instruments of different Eurozone countries were perceived as almost equally safe? A common interpretation is that the suppression of the exchange rate risk and the (still untested) credibility of the EU fiscal framework *anchored the expectations* of investors towards the long-run convergence of economic and fiscal behaviors of different countries, thus curbing the perceived probability of sovereign default of weaker Eurozone Member States.

The 2008 financial crisis suddenly stopped the convergence phase. After the financial crisis and during the Eurozone sovereign debt crisis, we observe a growth in level and volatility of Eurozone sovereign spreads and, particularly, divergent dynamics between *core* countries (e.g., Netherlands, Belgium, Austria, etc.) and *periphery* countries (e.g., Greece, Ireland, Italy, Portugal, Spain), with France in between the two clusters. During this *divergence phase*, the weight of the mentioned determinants structurally changed (Caggiano and Greco, 2012; Aßmann and Boysen-Hogrefe, 2012). Fiscal and macroeconomics funda-

[8]For a detailed and updated literature review on spread determinants in the euro area, see Afonso and Jalles (2019).

[9]For example, in the years 2003-2006, we observe decreasing or stable spreads, while fiscal conditions of some countries clearly worsen. Moreover, the liquidity conditions of different sovereign debt markets were already heterogeneous and other economic variables (e.g., capital flows and the dynamics of total factor productivity) signalled a divergence between core and periphery countries of the Eurozone.

mentals that drive the credit risk became much more significant in the determination of the dynamics of sovereign spreads, while the impact of the liquidity risk became less significant and of uncertain sign. Moreover, a systematic under-pricing of sovereign bonds issued by periphery countries has been documented in this period.[10] The latter bias and, more generally, widespread evidence of contagion effects across countries suggests that markets over-reacted to credit risk during the divergence phase. In other terms, the contagion risk became a fourth, structural determinant of the Eurozone sovereign spreads (De Santis, 2012). The financial instability in one peripheral country triggers a downgrade in rating for bonds issued by other peripheral Members States with weak fiscal conditions, and then a flight-to-safety towards (core) Member States with sounder public finances. These dynamics characterized the Eurozone sovereign debt crisis that originated in Greece and led to an increase in the perceived probability of default (and, thus, in sovereign spreads) of other peripheral countries (i.e., Italy, Portugal, Spain, Ireland). Curbing mispricing driven by the contagion risk has been among the key objectives of the ECB unconventional monetary policies since late 2012. The interpretation of the divergence phase is specular to what we said about the convergence phase: the Eurozone sovereign debt crisis, by exposing the inadequacy of the EU fiscal framework, suddenly *de-anchored investors' expectations* about its capacity to prevent the default of weaker Member States.

To illustrate the described mispricing events in the euro-area sovereign debt markets, we run an intuitive empirical exercise. In a simple panel WLS (Weighted Least Square) framework, we regress the sovereign spreads of 10-years bonds of the nine larger euro-area economies[11] on two standard measures of countries' creditworthiness, namely the primary balance-over-GDP ratio and the public debt-over-GDP ratio. Formally, we estimate the

[10] Similar results have been found by different empirical models and techniques. For example, Caggiano and Greco (2012) estimate sub-sample regressions on different time spans – pre and post crisis – thus allowing for time variability in the parameters; while Aßmann and Boysen-Hogrefe (2012) explicitly model time-varying parameters.

[11] Given that Germany is the benchmark, these are Austria, Belgium, Finland, France, Ireland, Italy, Netherlands, Portugal, and Spain.

parameters α and β of the equation:

$$s_{it} = \alpha b_{it-1} + \beta p_{it-1} + \varepsilon_{it} \tag{1}$$

where for country i at time t, s_{it} is the 10-years sovereign spread, b_it is the public debt-over-GDP ratio and p_it is the primary balance-over-GDP ratio. Once estimated the parameters α and β, we compute the fitted sovereign spread $\hat{s_{it}}$ for each country and we sum this spread to the German bund 10-years rate. By this procedure, we obtain the *counterfactual 10-years bond rates* for each of the main European economies, where – by construction – the spread with respect to the benchmark rate of the German bund is driven by fiscal fundamentals only. Thus, a proxy of the realized mispricing of the country-specific creditworthiness is represented by the difference between the historically observed long-term rates (the blue line in Figure 1) and the counterfactual interest rate based on fiscal fundamentals (the red line in Figure 1). During the sovereign debt crisis (around 2011), sovereign debt markets were over-estimating the long-term interest rate of some European countries with respect to what should had been the interest rate according to fiscal imbalances and macroeconomic fundamentals. Before the 2008 financial crisis, a smaller mispricing event of opposite sign occurred (i.e., the red line is slightly above the blue line in Figure 1), that can be interpreted as the market over-pricing sovereign bonds of less creditworthy countries. The same argument can be also illustrated by looking at the association between the two time series. Countries which suffered for larger contagion effects show significantly lower values of correlation (with a minimum of 0.25 for Portugal) with respect to Members States where the market signal seemed to be more efficient along the selected period (e.g., Finland and Netherlands present a correlation of 0.99 between the two series). The above evidence highlights potential efficiency losses when relying on pure market signals as a mechanism to impose fiscal discipline on Eurozone countries. As we show in the next Section, the Euro-stability bond replicates the market discipline without incurring in the efficiency costs of contagion effects and mispricing.

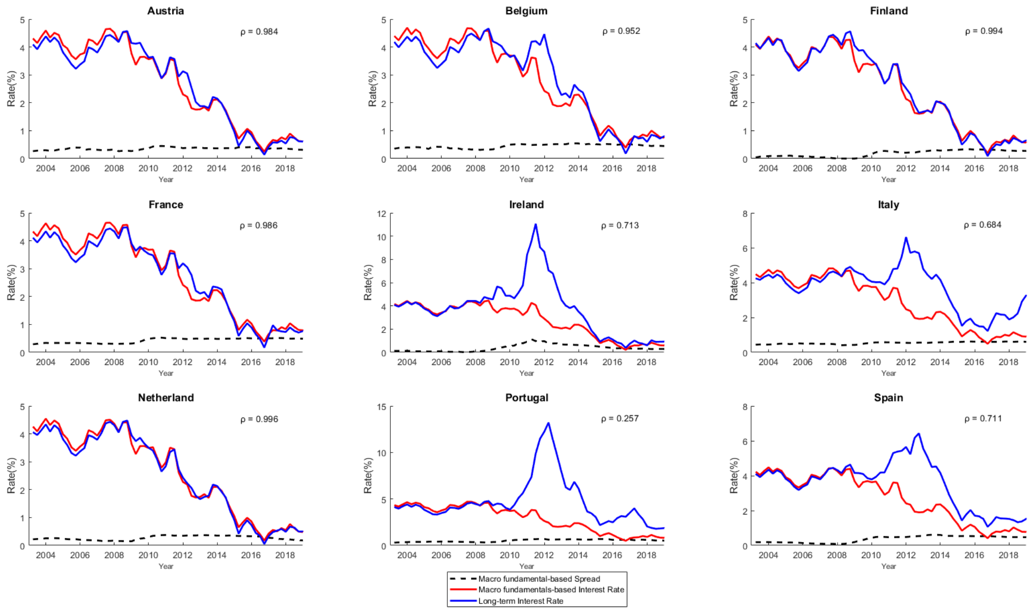

Figure 1: Long term interest rate and counterfactual macro fundamentals-based interest rate in the period 2004-2019 for the Eurozone countries in the sample.
Source: Authors' elaboration on OECD and ECB data.

3 The Euro-stability bond: theoretical background

To highlight the basic rationale underlying our proposal, we introduce a simple, structural model for N countries of the Eurozone. For each country $i \in \{0, ..., N\}$ at time t, we assume:

$$b_{it} = -p_{it} + e_{it} + (1 - g_{it})b_{it-1} + \varepsilon^b_{it} \tag{2}$$

$$e_{it} = \phi_i r_{it} b_{it-1} + \varepsilon^e_{it} \tag{3}$$

$$g_{it} = \bar{g}_i - \gamma_i r_{it} + \varepsilon^g_{it} \tag{4}$$

where, for the sake of simplicity, ε^z_{it} for all $z \in \{b, e, g\}$ are independently distributed as Normal random shocks with zero mean and variance ${\sigma^z_{it}}^2$. Equation (2) describes the dynamics of debt-over-GDP ratio (b_{it})[12] , which decreases in the primary balance-over-GDP ratio (p_{it}), increases in the interest expenditure-over-GDP ratio (e_{it}), and also depends on the level of past government debt (b_{it-1}). The dynamics of the interest expenditure-over-GDP ratio (e_{it}), in Equation (3), depends on the 10-years sovereign bond (or benchmark) interest rate (r_{it}) and the sensitivity of the interest expenditures to a change of the benchmark rate (ϕ_i) that is country-specific.[13] Finally, Equation (4) describes the determinants of the real growth rate of the country (g_{it}), which includes the potential long-run growth rate of country i ($\bar{g_i}$) and the sensitivity of the country's real growth to the benchmark rate (γ_i), that also influences and reflects the country's credit conditions.

In our model, we abstract from a refined modelling of the relationships between the real economy, the financial markets, and the monetary policy. We assume that the benchmark rate is:

$$r_{it} = r_{0t} + s_{it} \tag{5}$$

where r_{0t} is the benchmark rate of the core economy of the Eurozone (i.e., Germany) and s_{it} represents the sovereign spread of the non-core country i with respect to r_{0t}. For the sake of simplicity:

$$r_{0t} = \bar{r} + \sum_{j=1}^{N} \eta_i b_{jt-1} + \varepsilon_t \tag{6}$$

where $\bar{r}$ is the long run exogenous benchmark rate of the core economy, η_i is the sensitivity of such basic rate of the Eurozone to an increase of the stock of public debt-over-GDP ratio of the country i, ε_t is a Normal random variable – that is independently distributed with

[12]For the sake of analytical tractability, we use Equation (2) that approximates the exact dynamics of public debt-over-GDP ratio in discrete time, assuming away monetary financing of sovereign debt, i.e.:

$$b_{it} = -p_{it} + \frac{e_{it} - g_{it} b_{it-1}}{1 + g_{it}} + \varepsilon_{it}^{b}.$$

[13]This parameter is driven by the government debt structure (i.e., by type of security) and maturity. Though the latter are time-variant variables, the sensitivity of the cost of government debt to the benchmark rate is rather persistent in time. Thus, for the sake of analytical tractability, we assume it as time-invariant.

respect to random variables introduced in Equations (2)-(4) – with zero mean and variance ${\sigma_t}^2$. Following the discussion of Section 2, the sovereign spread of non-core country i is:

$$s_{it} = \alpha b_{it-1} + \beta p_{it-1} + \kappa_i \sum_{j \neq i, j=1}^{N} \varepsilon_{jt}^r + \varepsilon_{it}^r \qquad (7)$$

where $\alpha > 0$ and $\beta > 0$ are the sensitivities of the spread to past observed fiscal fundamentals, that in our simple model are represented by the government debt-over-GDP (b_{it-1}) and the primary balance-over-GDP (p_{it-1}) ratios; ε_{it}^r is a random shock to the sovereign spread of country i and κ_i is the sensitivity of country-i's sovereign spread to random shocks affecting other countries. The latter measures the magnitude of contagion (or spillover) effects among non-core countries. Again, to keep the model as simple as possible, all such shocks are independently and identically distributed as Normal random variables with zero mean and variance ${\sigma_i^r}^2$.

We introduce a simple objective function of the government of country i which embeds both a welfarist objective (e.g., a higher growth rate increases the social welfare) and, possibly, selfish interests of politicians (e.g., larger primary balances involve political costs):

$$W_{it} = v(g_{it}) - h(p_{it}) + \delta W_{it+1} \qquad (8)$$

where $v(g_{it})$ is a strictly increasing and concave utility function with constant risk aversion equal to ρ; $h(p_{it})$ is a strictly increasing and convex disutility function; and $\delta \in (0, 1)$ is the government's intertemporal discount rate.

3.1 The Euro-stability Bond v. the market discipline

Assuming that the government maximizes the objective function (8) and perfectly controls the level of primary balance p_{it}[14], we compare the government's optimal fiscal policy in

[14] All our results hold also even in a more realistic framework where the fiscal policy is also influenced by other macroeconomic variables (e.g., the growth rate, etc.).

three alternative scenarios: 1) the market discipline without any Eurobond; 2) the plain vanilla Eurobond, whereby all countries issue their debt with a common instrument and pay the same interest rate;[15]. 3) the Euro-stability bond.

Working with the algebra, we are able to retrieve the optimal primary balance that the government implements under the three scenarios.[16] Comparing the first two scenarios, we obtain the theoretical **Result 1**: *the optimal primary balance implemented by the government in case of plain-vanilla Eurobond* (p_i^{PVE}) *is always lower than the primary balance under pure market discipline* (p_i^*) *for all non-core countries.* The latter result highlights one of the main arguments against the introduction of a simple Eurobond: the suppression of the disciplining effect of the financial markets fosters fiscal profligacy.

Let us now consider the Euro-stability bond scenario in which government securities are issued and traded on the secondary market at a unique, basic interest rate; individual Member States – that finance themselves by such bonds – pay an interest rate that is the sum of the basic rate and a *fiscal discipline premium.*[17] The main objective of our proposal is to introduce a debt instrument mimicking the market discipline that sterilizes the contagion effects across Eurozone economies. In our theoretical model, the latter institutional and financial design is simulated by assuming that the euro area governments issue all their public debt in Euro-stability bond, and that for the country i the sovereign interest rate is given by $r_{it} = r_{0t} + \pi_{it}$. The latter is similar to Equation (5) with the difference that the market spread, s_{it}, is replaced by the following country-specific and

[15]This framework implies that the sovereign spread of each country is constrained to be equal to zero, therefore $r_{it} = r_{0t}$ for all $i \in \{1, \ldots, N\}$.

[16]See Appendix A for the analytical details.

[17]The Euro-stability bond is similar to Muellbauer (2013)'s *Euro-insurance bond*. Two important differences are the fact that we suggest EU own resources to back issued bonds and that the mechanism that drives the interest-rate spreads of individual countries is like what is suggested by Boonstra and Bruinshoofd (2013). The main differences between the Euro-stability bond and Boonstra and Bruinshoofd (2013)'s *Euro-Treasury Bills* is that in our proposal participation is mandatory and we do not focus on short-term instruments.

time-variant fiscal discipline premium:

$$\pi_{it} = \alpha b_{it-1} + \beta p_{it-1}, \tag{9}$$

where $\alpha > 0$ and $\beta < 0$ are the sensitivities of spreads to observed fiscal fundamentals, that are determined by a political agreement among the euro area countries and, in our empirical model, are assumed equal to the parameters estimated by Equation (1). In this simple theoretical setting, the only difference between the market spread and the fiscal discipline premium is that the former is also influenced by market shocks, notably the contagion effects (i.e., $\sum_{j \neq i} \varepsilon^r_{jt-1}$).

The Euro-stability bond replicates by construction the market incentive to fiscal discipline. Thus, the optimal fiscal policy of the generic country i is p^*_i also under this scenario. However, comparing the two scenarios from the perspective of the expected government welfare we obtain the theoretical **Result 2**: *the Euro-stability bond increases the expected government's welfare in all countries $E(W^{ES}_{it})$ with respect to pure market discipline $E(W^*_{it})$.* The intuition behind this result is that, by switching off all contagion components embedded in market spreads, the fiscal discipline premium reduces the sources of unnecessary macroeconomic and financial instability and increases expected economic growth. In turn, the Euro-stability bonds brings a welfare dividend to all countries because of the smaller risk premium associated to the suppression of contagion effects and, more generally, of smaller expected aggregate public debt-over-GDP ratio (hence, larger economic growth). It is worth to remark that the latter effect is relevant also for the core economy. Of course, also the plain vanilla Eurobond suppresses the negative welfare effects of contagion within the euro area, though it does it with the side effect of fostering fiscal profligacy.

3.2 The Euro-Stability Bond v. fiscal rules and market discipline

Our theoretical analysis allows to assess a more encompassing role of the Euro-stability bond, whereby this instrument could be used to substitute fiscal rules instead of complementing them. Assuming that the EU institutions maximize a weighted sum of all the Eurozone governments' objectives, we obtain the theoretical **Result 3**: *the optimal policy imposed by EU institutions on all countries* (p_i^{EU}) *always implies a larger primary balance than the optimal policy chosen by governments under market discipline* (p_i^*). The intuition is that the optimal policy designed at the euro area level for the country i fully internalizes the negative externalities of excessive fiscal expansion within the monetary union, and particularly the negative impact of excessive aggregate government debt on the common component of interest rates. Conversely, even when the market discipline operates, individual countries do not implement the optimal policies. The latter result represents the standard motivation for the existence of the EU fiscal rules.

The Euro-stability bond that aims at (just) mimicking the market discipline is unable to fully internalize fiscal externalities and, therefore, complements and does not substitute the EU fiscal rules. However, the mechanism of the fiscal discipline premium is very flexible and could be designed – by an appropriate choice of the weights α and β – to implement the optimal coordination of countries' fiscal policies.[18]

The conventional wisdom in the Eurobond debate is that market sovereign interest rates are the benchmark against which to test whether a debt mutualization scheme does (or does not) introduce any form of cross-country redistribution in the short run (e.g., Cioffi et al., 2019). The above theoretical discussion and the stylized facts about the dynamics of Eurozone sovereign spreads in Section 2 bring us to conclude that the EU fiscal rules – their credibility and, in turn, their impact on the dynamics of sovereign spreads – involve significant cross-country redistribution in the short run. The latter are unintended consequences of existing fiscal and financial externalities among countries that

[18] Further technical details can be found in the Appendix A.

share a common currency and monetary policy. However, the institutional debate within the EU still considers the no-redistribution clause as essential in the design of a common government debt within the euro area (Juncker et al., 2015). That is why, in the following, we analyze the simplest version of the Euro-stability bond that just replicates market incentives, though the same instrument could be used to implement more encompassing policies toward the optimal EU fiscal coordination. In any case, the main added value of the Euro-stability bond is its (theoretical) capacity to shut down unnecessary sources of macroeconomic and financial uncertainty within the Eurozone.

4 Empirical evidence: a GVAR counterfactual analysis

In the remaining part of the paper, we empirically assess the theoretical capacity of the Euro-stability bond to increase macroeconomic and financial stability. Specifically, we estimate the future dynamics of public debt-over-GDP ratio for the Eurozone countries with and without the Euro-stability bond and compare the obtained results in terms of future predicted uncertainty. Moreover, we check for the differential resilience of Eurozone economic systems against key negative events by estimating their conditional probability (i.e., event probability forecast) in the two scenarios.

To get rid of self-selection and arbitrage problems, we assume that, when the Euro-stability bond is introduced, the Eurozone countries issue all their sovereign debt through a European debt agency.[19] As discussed in Section 3, the Euro-stability bonds are issued and traded on the secondary market at a unique, basic interest rate that, in our empirical analysis, we approximate by the German bund rate. Then, Member States pay an interest rate that is the sum of the basic rate and the fiscal discipline premium. The European debt agency would also supervise the fiscal behavior of individual governments in order to charge differentiated fiscal discipline premia according to a country-specific fiscal rule.

[19] In the spirit ofAmato et al. (2021) and Amato and Saraceno (2022). Alternative decentralized mechanisms could be conceived to issue our Euro-stability bonds but the analysis of such institutional and financial technicalities is beyond the scope of this paper.

To adapt our theoretical model to the empirical analysis, we compute the fiscal discipline premium π_{it}, for the country i at time t, as follows:

$$\pi_{it} = max[0, \alpha b_{it-1} + \beta p_{it-1}] \tag{10}$$

where α and β have the same interpretation as in Sections 2 and 3. However, since also other countries besides Germany may be core (i.e., fiscally responsible), we do not allow for a negative fiscal discipline premium by imposing that $\pi_{it} \geq 0$. Therefore, as in the theoretical model of Section 3, a core country simply pays the basic interest rate on the issued debt.

Since the Euro-stability bond is designed to replicate the market discipline, in our empirical analysis, we estimate α and β from historical sovereign spreads data, by a simple panel WLS (Weighted Least Square) regression, using Equation (1). The estimation leads to $\alpha = 0.0047$ and $\beta = -0.0247$. These values are consistent with the intuition that the credit risk assessed by sovereign debt markets is increasing in the public debt-over-GDP ratio and decreasing in the primary balance-over-GDP ratio. As observed in Section 2, other determinants might play a role in the dynamics of sovereign spreads and, therefore, more refined estimations are possible. This is particularly true if we consider the intrinsic instability of parameters that characterized such dynamics. To keep the analysis as simple as possible, we choose to average out mis-pricing events occurring during the convergence (1999-2008) and divergence (2008-2019) phases highlighted in Section 2, especially in peripheral Eurozone countries. However, as shown in Section 3, the exact estimation (and political determination) of parameters α and β does not affect the quality of our main results.

4.1 Methodology and data

Once obtained the values for α and β, to empirically validate our proposal, we estimate a GVAR model employing data on the main Eurozone countries, the U.S., Japan and China and including five domestic variables reflecting the macroeconomic dynamics of each country over time. The main advantage of this framework is its ability to describe the connection between each country and the rest of the word, thus defining spillover effects based, for each country dynamics, on international variables that are considered weakly exogenous. In our context, this allows to jointly consider the macroeconomic dynamics of all Eurozone countries and to account for potential (in particular, fiscal) externalities among them in the whole EMU system. We exploit the parameters estimated to analyze the future evolution of public debt-over-GDP ratio by comparing the forecasts in the baseline scenario (without the Euro-stability bond) and the *conditional forecasts* in the counterfactual scenario (with the Euro-stability bond). The technical details concerning the econometric set-up and the estimation procedures of a GVAR model (Pesaran et al., 2004) are presented in Appendix B. To this extent, we provide a methodological novelty in the GVAR conditional forecasts estimation since our constraints are time-varying equation and are also a linear function of the variables included in the model, which dynamically changes according to their estimated values for the periods ahead.

The main sources of the data employed in our model are the OECD database and the ECB data warehouse. To improve the quality of our specification in terms of variability, we decided to collect data on quarterly basis, considering a total of 68 quarters spanning from 2002Q4 to 2019Q3.[20] Specifically, for all the Eurozone countries, at time t, we estimate a GVAR model with 5 different domestic variables:

- g_t, the real GDP growth rate; [21]

[20] Our estimates are therefore exempted from all the strong economic consequences of Covid-19 and the War in Ukraine.

[21] Growth rate is computed comparing one observation with the same observation of the previous year (i.e., same quarter, previous year).

- b_t, the debt-to-GDP ratio;
- r_t, the nominal interest rate on 10-years bond;
- e_t, the interest expenditure-to-GDP ratio;
- p_t, the primary balance-to-GDP ratio.

In the sample are included the ten major Eurozone countries[22], for which data are fully available on the entire period for all the domestic variables, and other three out-of-Europe countries (China, Japan and USA) for which only some of the variables considered are included in the analysis due to data availability.[23]

Concerning the weights that are used to build the country-specific foreign variables included in the GVAR model[24], we opt for a series of time-invariant weights $w_{i,j}$ computed according to the trade shares of the i country with respect to all the other j countries in the sample on worldwide basis. Specifically, we computed trade shares as the average direction of total trade statistics (exports plus import) over last five years (2015-2019) provided annually by the International Monetary Fund (IMF), as proposed by Pesaran et al. (2007). Our final matrix of time-invariant weights is reported in the Table 1. Data are scaled such that the columns, and not the rows, sum to one for each country.

[22] Austria, Belgium, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal and Spain.

[23] g_t and r_t for Japan and USA and only g_t for China.

[24] See Appendix 2 for a clear analytical explanation on how the weights are employed in the GVAR estimation procedure.

Countries	Aus	Bel	Fin	Fra	Ger	Ire	Ita	Net	Port	Spa	Chi	Jap	Usa
Aus	0,000	0,013	0,022	0,016	0,089	0,005	0,042	0,015	0,009	0,013	0,007	0,005	0,012
Bel	0,030	0,000	0,069	0,142	0,089	0,130	0,072	0,163	0,037	0,054	0,019	0,014	0,037
Fin	0,006	0,009	0,000	0,006	0,015	0,004	0,007	0,015	0,005	0,006	0,006	0,003	0,005
Fra	0,056	0,190	0,068	0,000	0,146	0,118	0,180	0,102	0,140	0,233	0,044	0,027	0,061
Ger	0,588	0,236	0,336	0,271	0,000	0,135	0,267	0,329	0,177	0,216	0,131	0,068	0,129
Ire	0,005	0,038	0,013	0,015	0,017	0,000	0,013	0,019	0,010	0,015	0,009	0,011	0,044
Ita	0,102	0,067	0,055	0,123	0,100	0,035	0,000	0,053	0,066	0,123	0,038	0,023	0,050
Net	0,050	0,226	0,165	0,096	0,190	0,077	0,073	0,000	0,065	0,075	0,059	0,024	0,049
Port	0,004	0,007	0,008	0,018	0,013	0,005	0,013	0,009	0,000	0,095	0,004	0,001	0,004
Spa	0,025	0,038	0,038	0,116	0,058	0,031	0,095	0,040	0,408	0,000	0,024	0,010	0,020
Chi	0,050	0,048	0,095	0,076	0,124	0,061	0,094	0,140	0,034	0,082	0,000	0,479	0,440
Jap	0,013	0,026	0,028	0,019	0,041	0,031	0,023	0,022	0,005	0,016	0,230	0,000	0,149
Usa	0,070	0,102	0,103	0,101	0,120	0,369	0,122	0,093	0,044	0,070	0,430	0,334	0,000

Table 1: Matrix of countries-specific weights employed in the GVAR estimation.
Source: Authors' elaboration on IMF data.

4.2 Results: regular and conditional forecasts

After estimating a GVAR (1,1) the model forecasts the future dynamics of public debt-over-GDP ratio for a 5-years horizon (20 quarters starting from 2019-Q4) for all Eurozone countries in the sample. Specifically, we estimate regular forecasts including in the GVAR model observable data for the variables considered (i.e., baseline scenario), and conditional forecasts in the counterfactual scenario (with the Euro-stability bond) by restricting the values of the long-term interest rate to the ones obtained with the application of the fiscal discipline premia described in Equation (10). As in Pesaran et al. (2007), in the counterfactual scenario interest rates are constrained and described as $r_{it} = r_{it}^{g}er + \pi_{it}$, where $\pi_{it} = \alpha b_{it-1} + \beta p_{it-1}$.

Differently with Pesaran et al. (2007), here the spreads depend on past endogenous variables and there is not commitment on the spread for the whole horizon.[25] The obtained forecasts are plotted in Figure 2 with shaded areas indicating the 95% confidence intervals of the estimates. As already argued, for the sake of simplicity, and to avoid the combination of macroeconomic dynamics and micro-financial issues into the same analysis, the conditional forecasts are built and estimated under the assumption that countries issue their whole

[25]The analytical details showing the algebra behind these conditional forecast schemes are provided in Appendix B.

public debt in Euro-stability bonds, starting from the first quarter of the forecast period. Our results show no significant differences in the future path of public debt-over-GDP ratio in the two scenarios, but a consistent reduction in the level of uncertainty of the estimates in the counterfactual analysis (with the Euro-stability bond) with respect to the regular forecasts for all countries in the sample (confidence intervals of the estimate are clearly narrower for the conditional forecasts estimated in the counterfactual scenario). The lower volatility of future estimates implies a higher stability of public debt dynamics in the next 5 years for all the euro area in the Euro-stability bond scenario. Our findings are in line with the idea that increasing public debt stability must be interpreted as an improvement in the predictability of future debt trajectories.

Concerning the magnitude of this predicted effects, in Table 2 we report the percentage reductions in the level of expected public debt volatility from the baseline to the Euro-stability bond scenario, at different time horizons. The estimated reduction in future uncertainty grows with the forecast horizon, signaling that the classical decline in the precision of the estimates (i.e., the longer is the horizon, the higher is the estimation error) is dampened by the introduction of the Euro-stability bond. Numerically, at the end of the forecast horizon (i.e., after 5 years), we observe an average volatility reduction across countries of 68%, ranging from a maximum of 77 % (Germany) to a minimum of 52% (Portugal). Even the latter evidence is consistent with our theoretical background and results: in particular, the reduction in uncertainty determined by the introduction of the Euro-stability bond is positively correlated with the initial level of fiscal discipline of a specific country. Indeed, high debt countries (e.g., Italy, Portugal, Spain) experience a percentage decrease in volatility relatively lower than the one we observe for virtuous Member States (e.g., Germany, Finland, Netherlands).

Moreover, the validity of these results is confirmed by noting that the forecasts (regular and conditional) estimated for the interest expenditure-over-GDP ratio (see Figure 3) behave similarly, showing no significant difference in the two scenarios. Consequently, the

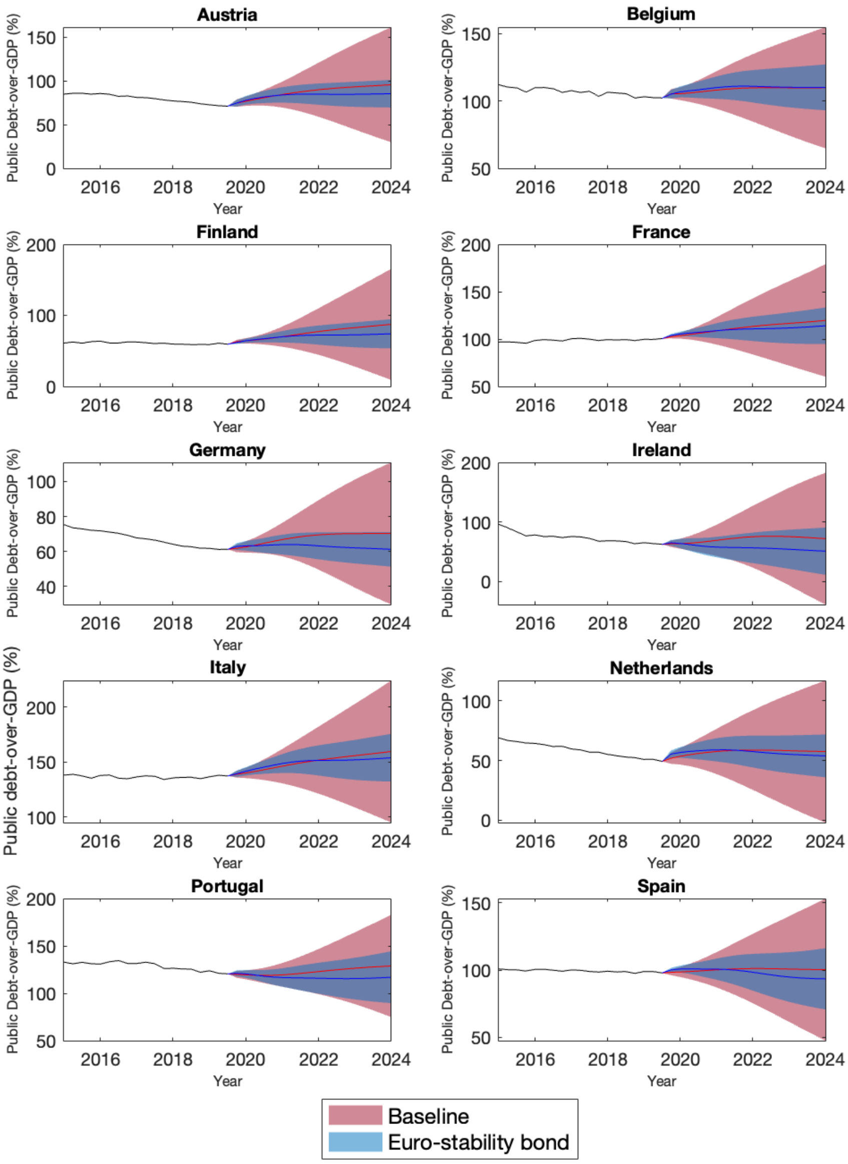

Figure 2: Regular and conditional forecasts for public debt-over-GDP ratio of the euro area countries in the sample for the period 2015-2024.
Source: Authors' elaboration.

	Horizon			
Countries	**1Q**	**1Y**	**3Y**	**5Y**
Austria	5%	24%	66%	78%
Belgium	9%	30%	55%	64%
Finland	12%	31%	64%	76%
France	14%	36%	60%	69%
Germany	12%	26%	67%	77%
Ireland	12%	21%	56%	65%
Italy	6%	36%	58%	68%
Netherlands	34%	41%	64%	71%
Portugal	11%	19%	37%	52%
Spain	30%	36%	50%	58%

Table 2: Reduction (%) in the level of expected public debt-over-GDP ratio volatility comparing the baseline and the counterfactual scenarios at different time horizons.
Source: Authors' elaboration

increase in future public-debt stability is reached without any significant redistribution across countries in the short-and-medium term, since the path of interest expenditures under the Euro-stability bond scenario over time reports no deviations with respect to the regular estimate for all countries in the sample.

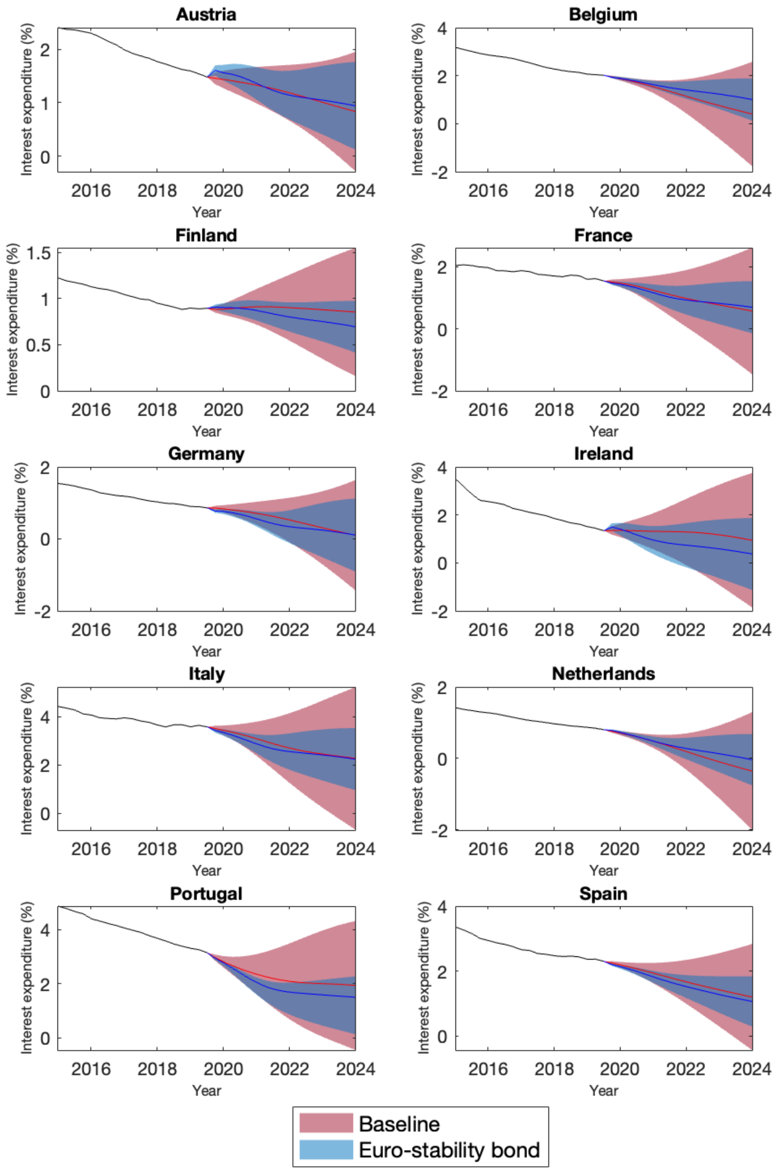

Figure 3: Regular and conditional forecasts for interest expenditure-over-GDP ratio of the euro area countries in the sample for the period 2015-2024.
Source: Authors' elaboration.

4.3 Results: event probability forecasts

The results presented in the fan charts are mainly focused on the differences between the expected level of future uncertainty in the macroeconomic variables of interest, rather than on central point forecast estimates in the two scenarios. However, more intuitive results of the positive effect of the Euro-stability bond can be based on probability forecasts, that aim at quantifying how likely some future specific events are, as already done by some previous papers (e.g., Greenwood-Nimmo et al., 2012). Technically, we estimate the probability that some events of interest might happen in the forecasting horizon. Probabilistic forecasts exploit the stochastic distribution of the GVAR predictions (employing Monte Carlo simulations) to simulate the out-of-sample trajectories of the variables and provide the time-varying probabilities of some specific economic episodes that might occur in the future.[26]

For each country i and for a given forecast horizon $T = 20$, we identify the following key events, that are function of the endogenous GVAR variables:

- Event 1: Running into a technical recession, defined as two following quarters of realized negative real GDP growth rate. Formally, we compute the probability at time $t + h$ of having:

$$g_{it+h} < 0 \ \wedge \ g_{it+h+1} < 0, \tag{11}$$

  for $h \in \{1, ..., 20\}$.

- Event 2: Reaching a specific debt-over-GDP target b^*, with $b^* \in \{60, 80, 100, 120\}$. Formally, we compute, the probability at time $t + h$ of having:

$$b_{it+h} \leq b^*, \tag{12}$$

  for $h \in \{1, ..., 20\}$.

[26] The analytical details and the assumptions behind our probability forecasts exercises are provided in the Appendix C.

- Event 3: Keeping the average interest expenditure-over-GDP ratio below the historically observed average level over time. Formally, given the historical average interest expenditure-over-GDP for the country i in our database $\bar{e_i}$ we compute the probability at time $t+h$ of having:

$$\frac{1}{h}\sum_{i=1}^{h} e_{t+i} \leq \bar{e_i}, \tag{13}$$

for $h \in \{1, ..., 20\}$.

- Event 4: Maintaining public debt-stability over time, where we interpret debt stability as smaller future fluctuations (both downwards and upwards) in the predicted level of the debt-over-GDP ratio. In statistical terms, we compute the probability of observing an expected future standard deviation of the public debt ratio in the four periods ahead lower or equal than the observed one in the past four quarters. Formally, we identify the trajectories of debt at time $t+h$ such that:

$$\sum_{n=1}^{4}\sqrt{\frac{1}{4}(b_{it+h+n} - \bar{b_i})} \leq \sum_{n=1}^{4}\sqrt{\frac{1}{4}(b_{it+h-n} - \tilde{b_i})} \tag{14}$$

where $\bar{b_i} = \frac{1}{4}\sum_{n=1}^{4}(b_{it+h+n})$ and $\tilde{b_i} = \frac{1}{4}\sum_{n=1}^{4}(b_{it+h-n})$, for $h \in \{1, ..., 20\}$.

Observing the results of the probability forecasts for the four designed events in the two scenarios of analysis (i.e., baseline v. Euro-stability bond) allows us to gain insights about the capacity of the Euro-stability bond to dampen the likelihood of negative events to occur (e.g., recessions) or to improve the ability of the macroeconomic system to stabilize fiscal dynamics over time.

Figure 4 shows the probability forecasts for the Event 1, namely, the technical recession. Results report a general tendency of the probability of recession to converge, in the medium term, to lower values in the Euro-stability bond scenario than in the baseline. Two caveats are important to interpret these results. First, the probabilities are in both cases small, moving from a minimum of 0 to a maximum of 3 % for Ireland. The latter is not surprising, our forecasts for real GDP are quite optimistic concerning future growth dynamics: being our last historical observation the third quarter of 2019 we are avoiding to account for the bad fiscal dynamics which affected the Eurozone from 2020 onwards due to extreme and exogenous shocks such as the Covid-19 pandemic and the Ukraine War. Therefore, a technical recession would have already been an unlikely event regardless to the scenario of analysis. Second, even for countries in which we observe an initial spike in the probability of recession in Euro-stability bond scenario above the baseline scenario (i.e., Belgium, Finland and Ireland), in the medium term they converge to smaller probabilities. We may interpret this behavior as the effect of the disciplining mechanism of the Euro-insurance bond, which initially exposes some countries to higher interest rates.

The probability forecasts for the Event 2 are illustrated in Figure 5 and 6. Specifically, the tri-dimensional plots report the probability of reaching a specific debt target as a function of both time (i.e., quarters) and the selected public debt-over-GDP ratio targets (i.e., 60, 80, 100, 120). The results show that these probabilities converge to medium-run values which are positively correlated with the target itself (i.e., the higher the target, the higher is the probability) regardless to the scenario of analysis considered. Moreover, comparing the Euro-stability bond scenario with the baseline scenario, in most of the countries the probability of reaching lower debt-over-GDP targets (i.e., 60 and 80) converges to higher values when the Euro-stability bond is introduced while it is larger in the baseline scenario once the threshold increases (i.e., 100 and 120). This latter conclusion is key and in line with our theoretical foundation: introducing a common debt instrument that embeds a fiscal discipline mechanism would increase the probability of more stable public debt-over-GDP trajectories with respect to exploding ones.

The results of probability forecast of the Event 3 are reported in Figure 7. In this exercise, as formally explained before, we are evaluating the probability, for each country, of maintaining a path of interest expenditure in line with (or better than) what it has been

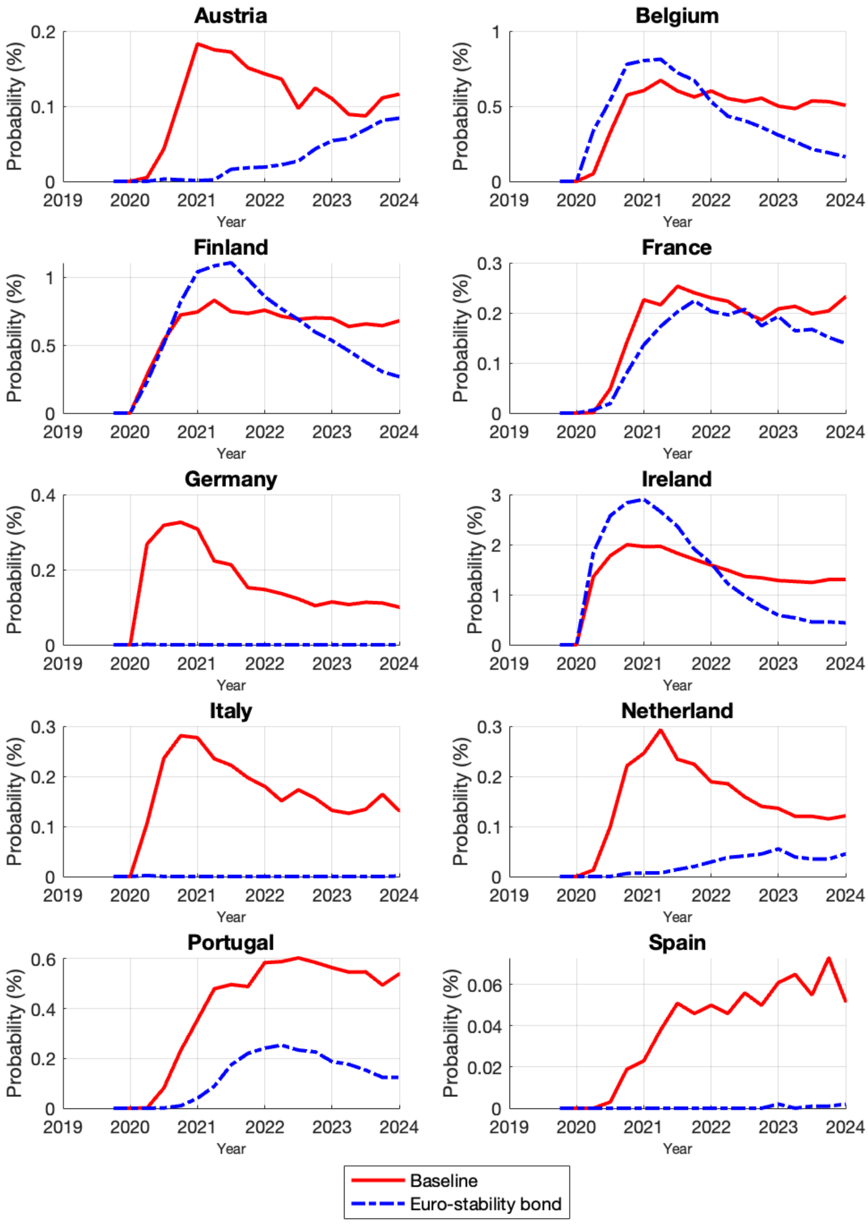

Figure 4: Event probability forecast for the Event 1 – Technical recession.
Source: Author's elaboration.

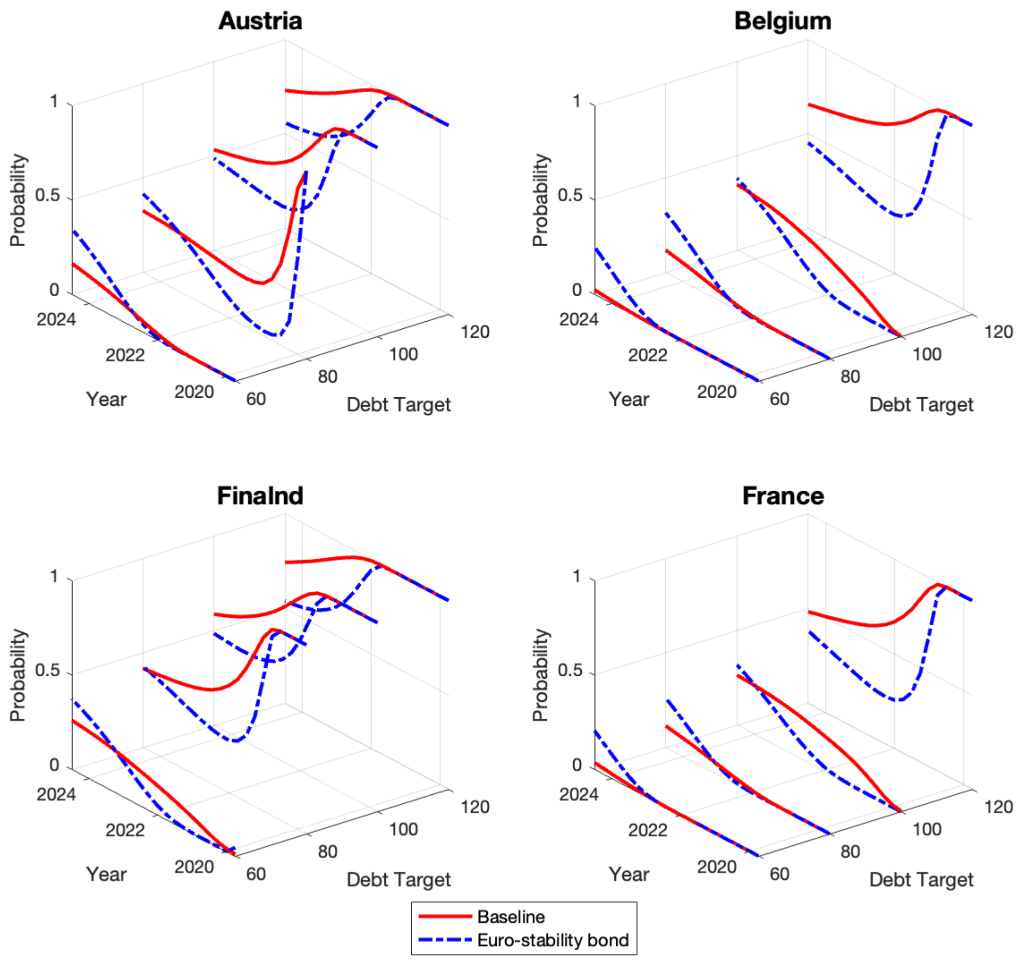

Figure 5: Event probability forecasts for the Event 2 – public debt-over-GDP targets. Source: Authors' elaboration.

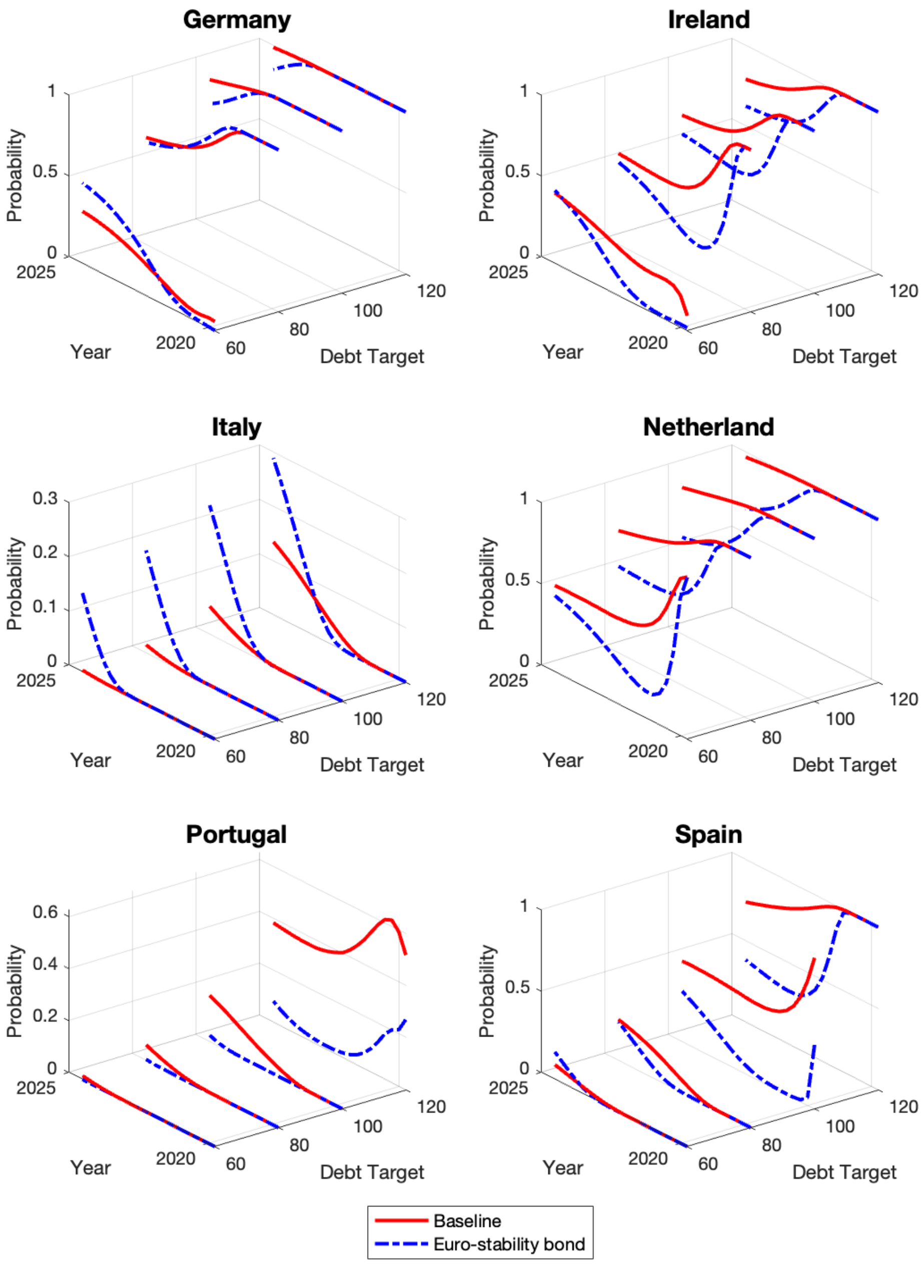

Figure 6: Event probability forecasts for the Event 2 – public debt-over-GDP targets.
Source: Authors' elaboration.

historically observed in the data. Specifically, the ones reported are the probabilities of keeping the level of the interest expenditure-over-GDP ratio below the average historical value, which is country-specific. We observe that the probabilities are really high (close to 1) and this is well explained by noting that the estimated forecasts (both for the baseline and the counterfactual scenarios) for interest expenditures are characterized by a marked negative trend (see Figure 3). Looking at these results, it is worth noting that the probabilities are substantially similar in the two scenarios for all the countries in the sample (except from a small deviation of the Euro-stability bond below the baseline scenario for Ireland). Keeping a similar path of the interest expenditure-over-GDP ratio also with the Euro-stability bond is a necessary condition to meet the principle of avoiding unacceptable cross-countries fiscal redistribution, which would pose problem of political feasibility of the proposed scheme. Observing similar paths in the probabilities of the described event pushes towards this direction, ensuring that no significant differences in terms of interest expenditure-over-GDP ratios would be induced by the adoption of the Euro-stability bond.

Finally, we report the probability forecast for the Event 4 in Figure 8. The results of the designed event for public debt stability show roughly similar paths over time in the two scenarios for all countries while converge to medium-run values that are generally higher in the Euro-stability bond scenario than in the baseline scenario (except for Portugal). Even in this framework, in the short run high-debt countries (e.g., Italy, Portugal, Spain) tend to report a higher probability of keeping public-debt stability in the baseline scenario, confirming that the fiscal discipline mechanism embedded in the Euro-stability bond provides a strong incentive to less "virtuous" countries to improve their fiscal position to face lower interest expenditures in the periods ahead.

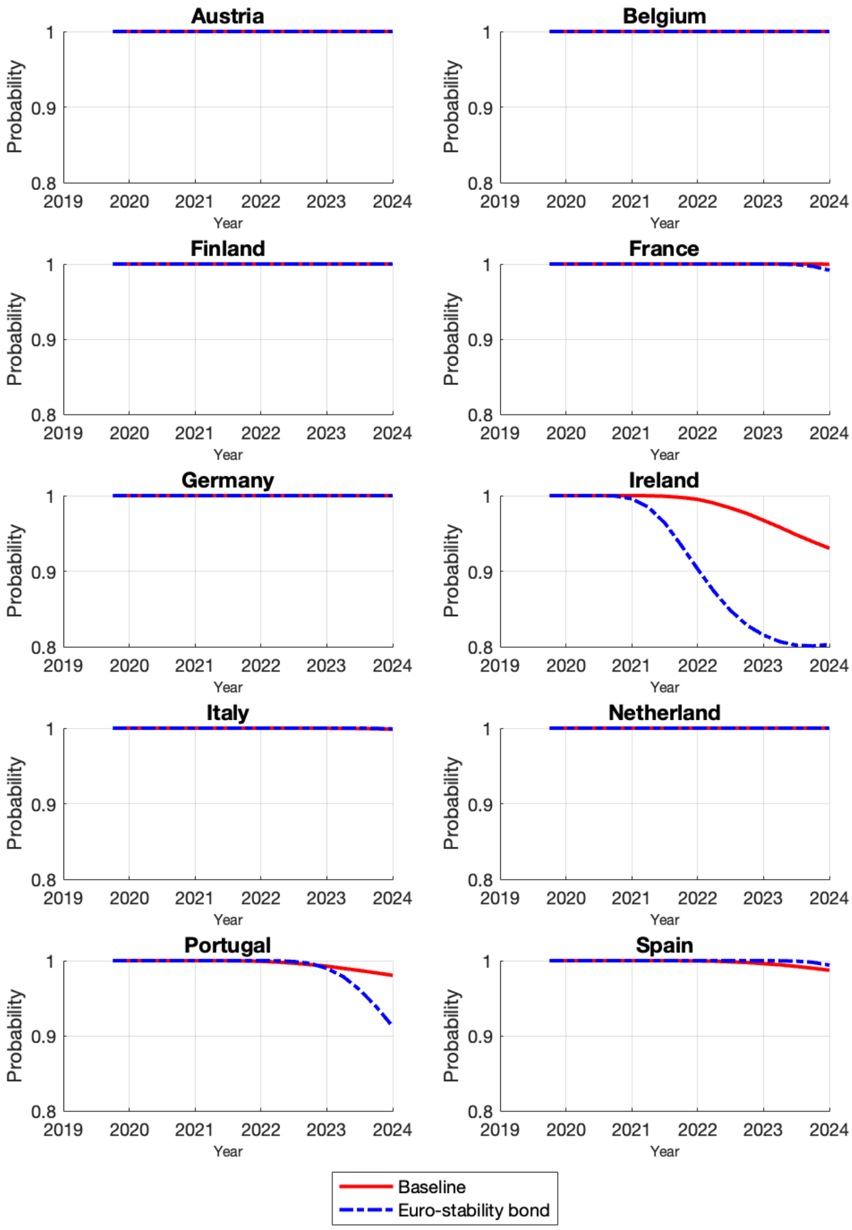

Figure 7: Event probability forecast for the Event 3 - interest expenditure-over-GDP path. Source: Authors' elaboration.

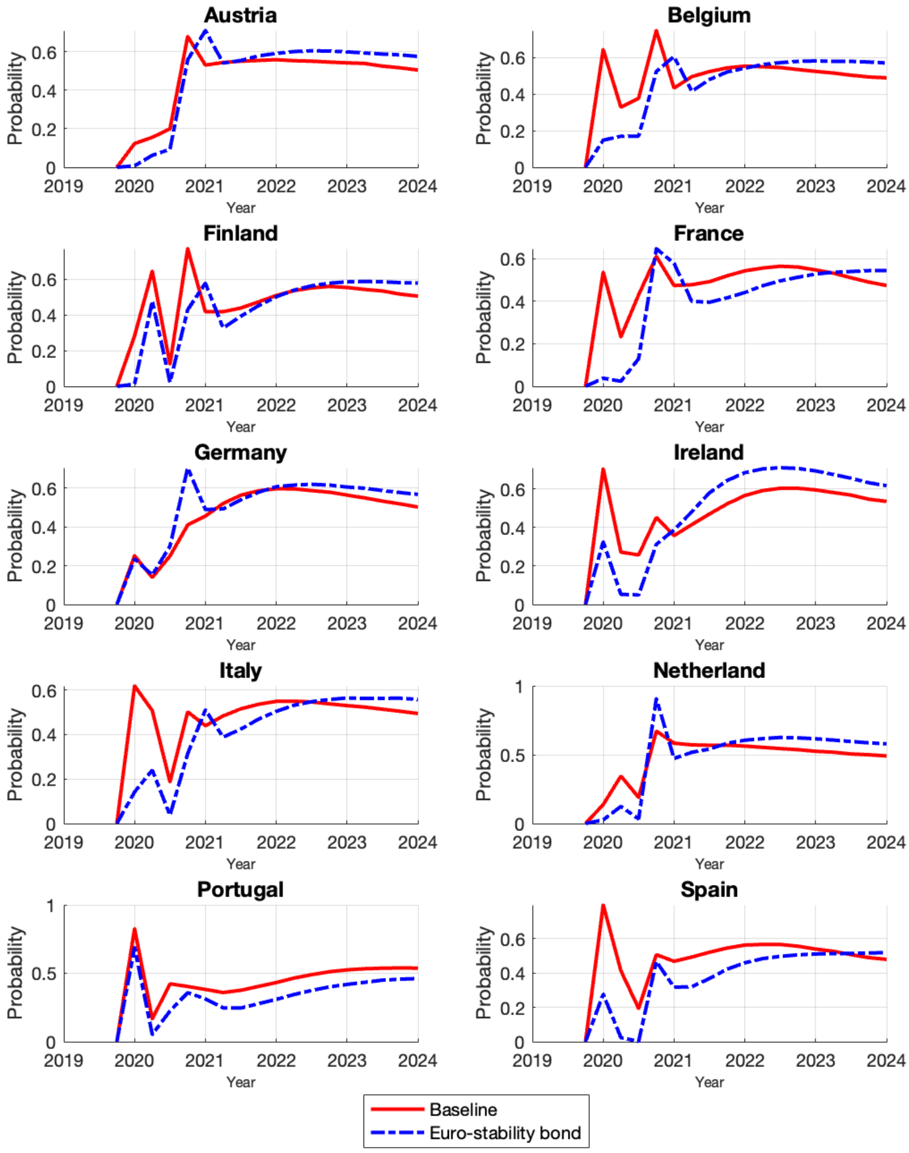

Figure 8: Event probability forecast for the Event 4 - public debt stability.
Source: Authors' elaboration.

5 Conclusions

In this paper, we propose a new scheme of sovereign debt mutualization in the Eurozone that complies with the main guiding principles to establish a central fiscal capacity in the

EU. Our Euro-stability bond does not involve significant short-term redistribution across countries nor perverse incentives to fiscal profligacy. Such bonds are issued and traded on the secondary market at a unique interest rate (which, in the empirical analysis, we proxy by the German bund rate), but Member States who finance themselves by them may pay an extra fiscal discipline premium that depends on their fiscal fundamentals. In our main analysis, the fiscal discipline premium replicates the market discipline without incurring in the contagion effects that caused mispricing of the European sovereign securities in the last two decades. The extra payments induced by the existence of country-specific spreads would be accumulated as EU own revenues. In the short run, such revenues would be significant (estimated, based on our empirical model, in 0.66 % of the Eurozone GDP), though – because of the very fiscal discipline the Euro-stability bond would induce – this amount would decrease in the medium-long run up to around 0.10 % of the Eurozone GDP after 5 years. A simple structural model of the economy helped us to illustrate the functioning of the proposed scheme. Our main theoretical results show that the Euro-stability bond can reproduce the market discipline while increasing the social welfare of all countries (including the core ones) with respect to real market discipline, because of the improvement in macroeconomic and fiscal stability. We also discuss how the Euro-stability bond, in a more encompassing version, could be used to substitute the EU fiscal rules. To assess our theoretical predictions, we estimate a GVAR à la Pesaran et al. (2007), that includes the Eurozone countries, the U.S., Japan and China, and we use this model to predict the future evolution of public debts and economies under two different scenarios: the baseline scenario, that employs observable macroeconomic data, and the Euro-stability bond scenario. Compared to Pesaran et al. (2007), we introduce the methodological novelty of a time-variant constraint featuring the conditional forecast in the Euro-stability bond scenario. In our empirical results we find no significant differences in the future evolution of the public debt-over-GDP ratios in the two scenarios, but a consistent reduction in the level of uncertainty of the estimates (around 68% on average across all countries after 5 years) in the conditional forecast with the Euro-stability bond. Moreover, the improvement in the stability of public debts is obtained without any significant difference in the path of interest expenditure-over-GDP ratios in the two scenarios, thus avoiding cross-country redistribution in the short run. We finally use our empirical model to assess (by event probability forecasts) the capacity of the Euro-stability bond to decrease the probability of specific adverse macroeconomic and fiscal events. With a horizon of 20 quarters, results suggest that the introduction of the Euro-stability bond, compared to the baseline scenario, would reduce the medium-run probability of recession in all countries. Furthermore, the probability of reaching lower public debt targets (i.e., 60 and 80 percent of the GDP) would sensibly improve, thus confirming the theoretical prediction that the proposed scheme would induce fiscal discipline and stable public debt-over-GDP trajectories.

References

A. Afonso and J. T. Jalles. Quantitative easing and sovereign yield spreads: Euro-area time-varying evidence. *Journal of International Financial Markets, Institutions and Money*, 58:208–224, 2019.

M. Amato and F. Saraceno. Squaring the circle: How to guarantee fiscal space and debt sustainability with a european debt agency'. *Bocconi Working Paper Series n.172.*, 2022.

M. Amato, E. Belloni, P. Falbo, and L. Gobbi. Europe, public debts, and safe assets: the scope for a european debt agency. *Economia Politica*, 38:823–861, 2021.

M. G. Arghyrou and A. Kontonikas. The emu sovereign-debt crisis: Fundamentals, expectations and contagion. *Journal of International Financial Markets, Institutions and Money*, 22(4):658–677, 2012.

C. Aßmann and J. Boysen-Hogrefe. Determinants of government bond spreads in the euro area: in good times as in bad. *Empirica*, 39, 2012.

A. Baber, M. Brandt, and K. Kavajecz. Flight-to-quality or flight-to-liquidity? evidence from the euro-area bond market. *Review of financial studies*, 22(3):925–957, 2009.

S. Barrios, P. Iversen, M. Lewandowska, and R. Setzer. Determinants of intra-euro area government bond spreads during the financial crisis. European Economy - Economic Papers 2008 - 2015 388, Directorate General Economic and Financial Affairs (DG ECFIN), European Commission, 2009.

R. Beetsma and M. Larch. Risk reduction and risk sharing in eu fiscal policymaking: The role of better fiscal rules. *Policy*, 14, 2018.

O. Blanchard, A. Leandro, and J. Zettelmeyer. Redesigning eu fiscal rules: from rules to standards. *Economic Policy*, 36(106):195–236, 2021.

W. Boonstra and A. Bruinshoofd. Conditional euro t-bills as a transitional regime. Technical report, Rabobank Economic Research Department, 2013.

G. Caggiano and L. Greco. Fiscal and financial determinants of eurozone sovereign spreads. *Economics Letters*, 117(3):774–776, 2012.

A. Chudik and M. H. Pesaran. Theory and practice of gvar modelling. *Journal of Economic Surveys*, 30(1):165–197, 2016.

M. Cioffi, P. Rizza, M. Romanelli, and P. Tommasino. Outline of a redistribution-free debt redemption fund for the euro area. Questioni di Economia e Finanza (Occasional Papers) 479, Bank of Italy, Economic Research and International Relations Area, 2019.

L. Codogno and P. van den Noord. Going fiscal? a stylised model with fiscal capacity and a safe asset in the eurozone. *Review of Economics and Finance*, 19:54–72, 2021.

L. Codogno, C. Favero, and A. Missale. Yield spreads on emu government bonds. *Economic Policy*, 18(37):503–532, 2003.

P. De Grauwe and Y. Ji. Mispricing of sovereign risk and macroeconomic stability in the eurozone. *Journal of Common Market Studies*, 50(6):866–880, 2012.

R. De Santis. The euro area sovereign debt crisis: safe haven, credit rating agencies and the spread of the fever from greece, ireland and portugal. Working Paper Series 1419, European Central Bank, 2012.

A. Di Cesare, G. Grande, M. Manna, and M. Taboga. Recent estimates of sovereign risk premia for euro-area countries. Questioni di Economia e Finanza (Occasional Papers) 128, Bank of Italy, Economic Research and International Relations Area, 2012.

F. Di Mauro and M. Pesaran, editors. *The GVAR Handbook: Structure and Applications of a Macro Model of the Global Economy for Policy Analysis*. Oxford University Press, 2013.

E. Dubois, J. Hericourt, and V. Mignon. What if the euro had never been launched? a counterfactual analysis of the macroeconomic impact of euro membership. *Economics Bulletin*, 29(3):2241–2255, 2009.

European Commission. Communication on orientations for a reform of the eu economic governance framework. Technical report, Communication from the Commission to the European Parliament, the Council, the European Central Bank, the European Economic and Social Committee and the Committee of the Regions, COM(2022) 583 final, Brussels, November 9., 2022.

European Council. Special meeting of the european council. Technical report, 17-21 July, Conclusions., 2020.

C. Favero, M. Pagano, and E.-L. von Thadden. How does liquidity affect government bond yields? *Journal of Financial and Quantitative Analysis*, 45(1):107–134, 2010.

V. Gaspar. Future of fiscal rules in europe. Technical report, 2020.

G. Giovannini Group. Co-ordinated public debt issuance in the euro area. 2000.

M. Greenwood-Nimmo, V. H. Nguyen, and Y. Shin. Probabilistic forecasting of output growth, inflation and the balance of trade in a gvar framework. *Journal of Applied Econometrics*, 27, 2012.

D. Gros. Eurobonds are the wrong solution. Technical report, 2011.

M. Gómez-Puig. Size matters for liquidity: Evidence from emu sovereign yield spreads. *Economics Letters*, 90(2):156–162, 2006.

O. Issing. Why a Common Eurozone Bond Isn't Such a Good Idea. Technical report, Centre for Financial Studies White Paper n° III, 2009.

J. Juncker, D. Tusk, J. Dijsselbloem, M. Draghi, and M. Schultz. The five president's report: Completing europe's economic and monetary union. Technical report, European Commission, Brussells, 2015.

P. Lane. The european sovereign debt crisis. *Journal of Economic Perspectives*, 26(3): 49–68, 2012.

S. Manganelli and G. Wolswijk. What drives spreads in the euro area government bond market? *Economic Policy*, 24(58):191–240, 2009.

M. A. Mody, M. S. Claessens, and M. S. Vallée. Paths to eurobonds. IMF Working Papers 2012/172, International Monetary Fund, 2012.

J. Muellbauer. Conditional eurobonds and the eurozone sovereign debt crisis. *Oxford Review of Economic Policy*, 29(3):610–645, 2013.

M. Pesaran, T. Schuermann, and S. Weiner. Modelling regional interdependencies using a global error-correction macroeconomic model. *Journal of Business and Economic Statistics*, 22:129–162, 2004.

M. Pesaran, L. Smith, and R. Smith. What if the uk or sweden had joined the euro in 1999? an empirical evalaution using a global var. *International Journal of Finance and Economics*, 12:55–87, 2007.

J. Tielens, B. V. Aarle, and J. V. Hove. Effects of eurobonds : A stochastic sovereign debt sustainability analysis for portugal, ireland and greece. *Journal of Macroeconomics*, 42: 156–173, 2014.

Appendix A: Theoretical results

Result 1: The market discipline v. the "plain vanilla" Eurobond

The optimal primary balance implemented by the government of the non-core country i that maximizes the expectation of the objective function (8) under plain-vanilla Eurobond (p_i^{PVE}) is always lower than the primary balance implemented by the government under pure market discipline (p_i^*).

Proof

We first consider the market discipline scenario. In period t, the government of the country i maximizes the expectation of the objective function (8). Exploiting the assumptions that $v(.)$ is a constant-absolute-risk-aversion (CARA) function, random variables are independently distributed, the government perfectly controls p_{it}, the government's objective function can be written as:

$$E_t(W_{it}) = E_t(g_{it}) - \frac{\rho}{2}Var_t(g_{it}) - h(p_{it}) + \delta E_t(W_{it+1}) \tag{15}$$

where $E_t(.)$ and $Var_t(.)$ are computed considering the realization of random variables up to $t-1$. Substituting Equations (6) and (7) in Equation (5) and the resulting expression in Equation (4), we have:

$$\bar{g}_i - \gamma_i[\bar{r} + \sum_{j\neq i}\eta_j b_{jt-1} + (\eta_j + \alpha)b_{it-1} + \beta p_{it-1} + \varepsilon_t + \kappa_i \sum_{j\neq i}\varepsilon^r_{jt} + \varepsilon^r_{it}] + \varepsilon^g_{it} \tag{16}$$

and substituting Equation (3) in Equation (2), we have:

$$b_{it-1} = -p_{it-1} + (\phi r_{it-1} + 1 - g_{it-1})b_{it-2} + \varepsilon^e_{it} + \varepsilon^b_{it} \tag{17}$$

It is easy to verify that $Var_t(g_{it})$ does not depend on p_{it}. Thus, by the first order condition of the objective function of Equation (15) with respect to p_{it}, we obtain the optimization condition of the government of (non-core) country i under market fiscal discipline:

$$h^{'}(p_i^*) = \delta\gamma_i(\eta_i + \alpha - \beta) \quad (18)$$

Let us remark that for the core country, the condition in Equation (18) becomes $h^{'}(p_0^*) = \delta\gamma_0\eta_0$. Under a "plain vanilla" Eurobond scenario, $r_{it} = r_{0t}$ (i.e., $s_{it} = 0$), which amounts to impose $\alpha = \beta = 0$ in Equation (18) for all non-core countries. Therefore, the optimal primary balance chosen by the government under the scenario with a "plain vanilla" Eurobond is p_i^{PVE} is:

$$h^{'}(p_i^{PVE}) = \delta\gamma_i\eta_i \quad (19)$$

Given the convexity and strictly increasing assumptions we made on function $h(.)$, Equations (18) and (19) imply that $p_i^{PVE} < p_i^*$ for all non-core countries, while the optimal policy is unchanged for the core country.

Result 2: The market discipline v. the market discipline

The Euro-stability bond that is introduced at time t and reproduces the market incentives to fiscal discipline increases the expected government's welfare of country i, $E_t(W_{it}^{ES})$, with respect to the expected government's welfare under pure market discipline, $E_t(W_{it}^*)$. This result holds also for the core country.

Proof

By Result 1, under both scenarios – i.e., the Euro-stability bond (denoted by the apex ES) and the market discipline (denoted by the apex *) – the optimal primary balance-over-GDP ratio is p_i^*. Substituting the expressions of $E_t(g_{it+\tau})$ and $Var_t(g_{it+\tau})$ into Equation (15) for all $\tau \geq 0$ in both scenarios, after some algebra, we can write:

$$\Delta E_t\left(W_{it}\right) = E_t\left(W_{it}^{ES}\right) - E_t\left(W_{it}^*\right) = \Pi_{\mathrm{i}} + \Upsilon_{\mathrm{i}} \quad (20)$$

where:

$$\Pi_{\mathrm{i}} = \frac{\delta}{1-\delta}\frac{\rho}{2}\gamma_i^2\left(\kappa_i^2\sum_{j\neq i,j=1}^{N}\sigma_j^{r2}+\sigma_i^{r2}\right) > 0 \tag{21}$$

is the discounted welfare gain determined by the reduction of the risk premium because of the suppression of contagion effects under the Euro-stability bond; and:

$$\Upsilon_i = \gamma_i\sum_{\tau=0}^{\infty}\delta^{\tau}\left\{\sum_{j\neq i,j=1}^{N}\eta_j\left[E_t\left(b^*_{jt+\tau-1}\right)-E_t\left(b^{ES}_{jt+\tau-1}\right)\right]+(\eta_i+\alpha)\left[E_t\left(b^*_{it+\tau-1}\right)-E_t\left(b^{ES}_{it+\tau-1}\right)\right]\right\} \tag{22}$$

is the discounted welfare gain determined by the larger GDP growth because of smaller expected public debt-over-GDP ratios. Remark that Equation (22) is positive under the sufficient condition that $E_t\left(b^*_{it+\tau-1}\right) > E_t\left(b^{ES}_{it+\tau-1}\right)$ for all countries i and for all $\tau \geq 0$. By appropriate substitutions of Equations (2)-(7), we can write:

$$E_{t+\tau-2}\left(b_{it+\tau-1}\right) = A_iE_{t+\tau-2}\left(b^2_{it+\tau-2}\right)+B_iE_{t+\tau-2}\left(b_{it+\tau-2}\right)+\sum_{j\neq i,j=1}^{N}C_{ji}E_{t+\tau-2}\left(b_{jt+\tau-2}b_{it+\tau-2}\right)-p^*_i \tag{23}$$

with $A_i > 0$, $B_i > 0$, and $C_{ji} > 0$ that depends on the model's parameters but are independent on the relevant scenario. Using Equation (23) recursively starting from $\tau = 0$, we can show that the variance of $b_{it+\tau-2}$ and the covariance between $b_{it+\tau-2}$ and $b_{jt+\tau-2}$ are larger under the market discipline than under the Euro-stability bond scenario for all i and j, and then that the expectation of public debt is larger under the first than under the second scenario.

Result 3: The Euro-stability bond v. fiscal rules and market discipline

The optimal policy imposed by an EU fiscal institution (that maximizes a weighted sum of governments' objectives) on the non-core country i (p_i^{EU}) always implies a larger primary balance than the optimal policy chosen by the government of the same country under market discipline (p_i^*). Moreover, the optimal EU fiscal coordination policy can be implemented by the Euro-stability bond with an appropriate choice of parameters α and β.

Proof

Let us consider the optimal fiscal coordination policy that is defined by a common fiscal authority that maximizes the expectation of the weighted sum of individual governments' objectives $E_t\left(W_{EU}\right) = \sum_{j=0}^{N} \omega_j E_t\left(W_{jt}\right)$, with $\omega_i \geq 0$ the weight of the individual country i which possibly embed political considerations. The optimization condition of the objective function of the common fiscal authority with respect to the primary balance of the non-core country i is:

$$h'\left(p_i^{EU}\right) = \delta\left[\gamma_i\left(\eta_i + \alpha - \beta\right) + \sum_{j\neq i} \frac{\omega_j}{\omega_i}\gamma_j\eta_i\right] \tag{24}$$

Remark that in the case of the core country Equation (24) becomes:

$$h'\left(p_0^{EU}\right) = \delta\left[\gamma_0\eta_0 + \sum_{j\neq 0} \frac{\omega_j}{\omega_0}\gamma_j\eta_0\right]$$

By the assumption of convexity of $h(.)$, the comparison of Equations (24) and (19) – and similar equations for the core country – imply for all countries $p_i^{EU} > p_i^*$. Let us finally remark that the condition in Equation (22) can be implemented through the Euro-stability bond if the weight of the government debt-over-GDP ratio in the fiscal discipline premium is country-specific and defined as follows:

$$\alpha_i^{FB} = \alpha + \sum_{j\neq i} \frac{\omega_j}{\omega_i}\gamma_j\eta_i \tag{25}$$

for all non-core countries; and $\alpha_0^{FB} = \alpha + \sum_{j\neq i} \frac{\omega_j}{\omega_0}\gamma_j\eta_0$ for the core country.

Appendix B: GVAR

The GVAR model is built in two steps: first, a VARX (VAR model with further regressors) dynamics is considered and estimated for each country; second, all the individual VARX are combined and solved contemporaneously, to obtain a unique VARX dynamics to describe global macroeconomic fluctuations, namely the GVAR.

In the first step, each country $i = 1, \ldots, 13$ is described by a VARX(1,1) model:

$$\boldsymbol{x}_{it} = \boldsymbol{\alpha}_i + \boldsymbol{\beta}_i t + \Phi_{i1}\boldsymbol{x}_{it-1} + \Lambda_{i0}\boldsymbol{x}^*_{it} + \Lambda_{i1}\boldsymbol{x}^*_{it-1} + \epsilon_{it} \tag{26}$$

where ϵ_{it} is an exogenous and gaussian vector of shocks, $\boldsymbol{x}_{it}$ is a vector of country specific variables, whereas $\boldsymbol{x}^*_{it}$ is a vector of foreign variables, obtained by a linear combination of the corresponding variables for the other countries with given weights $w_{ij},\ i, j = 1, \ldots, N$, that is:

$$\boldsymbol{x}^*_{it} = \sum_{j=1, j \neq i}^{N} w_{ij}\boldsymbol{x}_{jt}. \tag{27}$$

As a second step, all the individual VARX are stacked and solved. Specifically, $\boldsymbol{x}_t = (\boldsymbol{x}_{1t}, \ldots, \boldsymbol{x}_{Nt})$ is the stacked vector of all the endogenous variables, that can be proved obeys the following dynamics (Chudik and Pesaran, 2016):

$$\boldsymbol{x}_t = \boldsymbol{a} + \boldsymbol{b}t + \boldsymbol{F}\boldsymbol{x}_{t-1} + \boldsymbol{u}_t \tag{28}$$

where $\boldsymbol{a}$, $\boldsymbol{b}$ and $\boldsymbol{F}$ are parameter's matrices that can be obtained form the parameters of the individual VARX models and the weights matrix W. The error term $\boldsymbol{u}_t$ is a linear combination of $\epsilon_t = (\epsilon_{1t}, \ldots, \epsilon_{Nt})$. From a practical point of view, GVAR allows to describe in a unified framework the global economy, avoiding the course of dimensionality issue, caused by the large dimension of $\boldsymbol{x}_t$. In fact, each individual VARX is estimated independently from the others even though is solved globally.

We use the GVAR to implement a counterfactual analysis, in order to evaluate the impact of the Euro-insurance bond introduction. We base our exercise on Pesaran et al. (2007), by comparing the conditional probability distributions of forecasted macroeconomic variables in case of the introduction of the common debt instrument (counterfactual), compared with the regular predictions. The counterfactual is thus based on a conditional forecast, in which we assume interest rates for each country are determined by a benchmark rate (here, we consider the German rate) plus a fiscal discipline premium as defined in Section 3. This corresponds to imposing a constraint on future predictions as follows:

$$\Psi \boldsymbol{x}_{T+h} = \boldsymbol{d}_{T+h} \tag{29}$$

for $h = 1, \ldots, H$, where Ψ is a selection matrix, $\boldsymbol{d}_{T+h}$ is a vector of spreads that is predetermined whereas H is the forecasting horizon. Here, we deviate from Pesaran et al. (2007), by assuming the spread is not fixed at T and kept constant all over the forecasting horizon, but is rather updated on the basis of past (and predicted) macroeconomic fundamentals. Implicitly, we do not assume a long term commitment for all the euro countries, but a deal that is renewed at each time (or for a limited amount of time). Provided the prediction based on the past I_T for $\boldsymbol{x}$ under the *regular* scenario, is $\hat{\boldsymbol{x}}_{T+h} = \mathrm{E}[x_{T+h}|I_T]$ with forecasting error Ω_{hh}, it can be easily proved that the *counterfactual* predictions are:

$$\begin{aligned} \hat{\boldsymbol{x}}^c_{T+h} &= \mathrm{E}[x_{T+h}|I_T, \Psi \boldsymbol{x}_{T+h} = \boldsymbol{d}_{T+h}] && (30) \\ &= \hat{\boldsymbol{x}}_{T+h|T} + \Omega_{hh}\Psi'(\Psi\Omega_{hh}\Psi')^{-1}(\boldsymbol{d}_{T+h} - \Psi\hat{\boldsymbol{x}}_{T+h}) && (31) \end{aligned}$$

for $h = 1, \ldots, H$, and prediction accuracy given by:

$$\Omega^c_{hh} = \Omega_{hh} - (\Omega_{hh}\Psi')(\Psi\Omega_{hh}\Psi')^{-1}(\Psi\Omega_{hh}) \tag{32}$$

It can be also proved that the forecast differential $\delta_{t+H} = \hat{\boldsymbol{x}}_{T+h} - \hat{\boldsymbol{x}}^c_{T+h}$ is Gaussian

$$\delta_{T+h|T} \sim \mathcal{N}\left(\hat{\boldsymbol{x}}_{T+h|T} - \hat{\boldsymbol{x}}^c_{T+h|T},\ \Omega_{hh} - \Omega^c_{hh}\right), \quad h = 1, \ldots, H. \tag{33}$$

for $h = 1, \ldots, H$.

Appendix C: Event Probability forecasts

Probability forecasts refers to the estimation of the probability assigned to some future event. In the GVAR setup, since the model is completely parametric, and the error term is assumed to be a multivariate Normal, in principle it is possible to derive an analytical expression for these probabilities. However, the complexity of the events considered might require simulations to avoid cumbersome algebraic computations. This is the case of probability forecasts on multiple events, such as the occurrence of a sequence of episodes over time, as a technical recession.

In this paper, probability forecasts have been obtained through Monte Carlo, where a number S of out-of-sample trajectories from the GVAR model has been drawn. To compute the Monte Carlo simulation, we assume absence of uncertainty on parameters, that are set at their point estimates. GVAR shock are assumed Gaussian with null average and known variance/covariance set as the estimated one. Following Greenwood-Nimmo et al. (2012), the probabilities of such events are estimated as:

$$\frac{1}{S}\sum_{s=1}^{S} I[event^s_{it}] \tag{34}$$

where $I[event^s_{it}]$ is just an indicator function that takes value 1 if the event at time t for country i is observed in the simulated s-trajectory and 0 otherwise.

For instance, to check if a recession, defined as a sequence of two negative GDP growth rate values, is observed, we first simulated the model out-of-sample for a horizon of 20 quarters, and then we evaluated if, for each t=1,...,20, two contiguous negative GDP growth for each country ($event_{it}$) are observed. If so, $I[event^s_{it}] = 1$. We thus iterated this procedure S=100,000 times and averaged to obtain an estimate for the probabilities.