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Abstract
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Keywords
Eurobonds, Fiscal Stability, GVAR, Macroeconomic Forecasts

JEL Codes
E02, E47, H63, H68

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When Fiscal Discipline Meets Macroeconomic Stability: The Euro-Stability Bond

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Abstract

We study the consequences of introducing a Euro-stability bond mechanism that involves sovereign debt mutualization in the Eurozone without causing significant short-term redistribution across countries or creating perverse incentives for fiscal irresponsibility. Using a simple structural economic model, we theoretically demonstrate that this mechanism can replicate market-driven fiscal discipline while enhancing social welfare compared to real market discipline. Employing a GVAR model that includes 10 Eurozone countries, the U.S., Japan, and China, we analyze the projected evolution of public debt and other macroeconomic indicators by comparing baseline forecasts with a counterfactual scenario incorporating the Euro-stability bond. Our findings suggest no significant differences in future public debt-to-GDP ratios between the two cases. However, we observe a consistent reduction in forecast uncertainty under the Euro-stability bond scenario. The reduced uncertainty in macroeconomic forecasts highlights the potential of the Euro-stability bond to shield the Eurozone from macroeconomic instability arising from high sovereign debt and associated rollover and contagion risks under decentralized fiscal policies. Finally, leveraging the results of the GVAR model, we assess the ability of the proposed scheme to mitigate the likelihood 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 extraordinary decision, made by the European Council on July 21st 2020, was to finance part of the European Resilience and Recovery Fund (ERRF) by issuing EU sovereign debt (European Council, 2020). Although this institutional experiment is a landmark in the EU history, it is likely to be just a temporary break in the 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 EU fiscal governance reforms that were adopted in the aftermath of the sovereign debt crisis were insufficient to providing reliable solutions for future challenges. In this context, sovereign debt mutualization schemes were proposed to enhance the EMU's resilience 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 sought to improve the EMU's functioning in three areas (Mody et al., 2012): monetary policy transmission, financial and banking stability, and 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' Report (Juncker et al., 2015), as many of them would imply cross-country redistribution in the short run [e.g., Gros, 2011, Cioffi et al., 2019]. In addition, all Eurobond or debt mutualization schemes that rely on a common interest rate pose a moral hazard problem by inducing fiscal profligacy, particularly in high-debt countries [e.g., Issing, 2009]. What's more, countries' participation in the proposed schemes was often conceived as voluntary or conditional on fiscal solvency so as to be consistent with the existing EU fiscal coordination framework and to avoid interference with the functioning of the European Stabilization Mechanism. However, such provisions could lead to the schemes' being ineffective (e.g., if no country joins to avoid stigma effects) or unsustainable (e.g., if only insolvent countries join).

In this paper, we study from a theoretical and empirical point of view an *Euro-stability bond* mechanism that affords the usual benefits of debt mutualization mechanisms while complying with the main guiding principles of the 2015 Five Presidents' Report. This Euro-stability bond combines two features: bonds are issued and traded on the secondary market at a unique common interest rate and individual Member States, that finance themselves using such bonds, pay an interest rate that is the

[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."*

sum of the common rate and a politically determined *fiscal discipline premium*. Specifically, the fiscal discipline premium seeks to replicate the disciplining effect of sovereign debt markets on governments' fiscal policies, so it is a function of fiscal fundamentals that have historically determined the dynamics of sovereign spreads in the euro area. From a theoretical perspective, the fiscal discipline premium may also be used as a fiscal coordination tool that substitutes for the EU fiscal rules. In this respect, the fiscal discipline premium may depend on a larger set of economic and political determinants (e.g., macroeconomic imbalances, structural reform plans).

In the Euro-stability bond scenario, 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, which include the revenues from fiscal discipline premia.[3] As highlighted in the literature, the market discipline – and 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]. From 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 a EU fiscal policy. Our main contribution is to show the capacity of the Euro-stability bond to reduce significantly the variance in the 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 U.S.) using five domestic variables that reflect each country's macroeconomic dynamics over time: the real GDP growth, the long-term sovereign interest rate and three fiscal variables – the interest expenditure, the primary balance, and the public debt – as ratios to GDP. This model specification allows us to perform a *baseline* analysis (i.e., without the Euro-stability bond) and a *counterfactual* analysis (i.e., with the Euro-stability bond) for Eurozone countries that consider all potential spillovers among them (e.g., fiscal contagion, aggregate-demand externalities). Moreover, the GVAR methodology makes it possible to compute *event probability forecasts* (i.e., the out-of-sample time-varying probabilities that are associated with possible positive or negative future events with respect to our variables of interest).

Our paper contributes to three strands of the literature. First, we contribute to the Eurobond

[2]Other papers in the literature analyse the potential functioning of a European debt agency [e.g., Amato et al., 2021]. Our analysis assumes that Eurozone countries are obliged to issue all their public debt in Euro-stability bonds. Other Eurobond proposals for the implementation of the Euro-stability bond would require several important institutional and financial issues to be solved (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 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).

debate that was begun by the Giovannini Group (2000).[4] The bulk of proposed schemes seek to provide 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 this debate are the effect of such instruments on fiscal coordination within the euro area and, more broadly, the real costs and benefits of a permanent EU 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"* [Beetsma and Larch, 2018; Gaspar, 2020; Blanchard et al., 2021; European Commission, 2022, p.1]. As highlighted above, the other (not necessarily alternative) solution, introducing EU ordinary fiscal stabilization instruments, still relies on the political and institutional consensus that was forged before the pandemic. Our contribution shows that a properly designed common debt instrument can be used to foster both fiscal discipline and stability under ordinary macroeconomic conditions.

Second, we provide a new empirical contribution which exploits a GVAR estimation to produce forecasts at a country level, while jointly considering potential spillover effects. Since the seminal work of Pesaran et al. (2004), a number of applications in different fields has been proposed, e.g., financial markets and international business cycle, output gaps linkages, trade imbalances and credit risk and portfolio analysis.[5] Counterfactual analysis based on GVAR have been proposed in Pesaran et al. (2007) and Dubois et al. (2009), while Hebous and Zimmermann (2013) is one of the few contributions estimating these models on euro area data, to assess the magnitude of fiscal spillovers on macroeconomic outcome variables.

Third, our analysis contributes to the literature on the determinants of the sovereign spreads in the Eurozone, given these determinants' 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 our paper borrows from this literature to assess the performance of the market discipline within the euro area.

The macroeconomic effects of the Eurobond's introduction has, so far, not been systematically investigated. One of the few notable exceptions refers to Pallara and Renne (2024), where a common debt instrument in the Euro area associated with a post-issuance redistribution scheme to alleviate the moral hazard problem has been recently proposed. They develop a multi-country credit risk model in order to price both national and common sovereign bond in the main Euro area economies performing a counterfactual exercise. Their results are analysed in the case of totally joint or not joint guarantees and considering the probability of default as function of each country's fiscal space (i.e., distance from

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

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

a specific fiscal limit). The authors highlight how, in absence of an exogenous issuance limit on the Eurobond (as in our model), an ex-post redistribution scheme of the yield gains which depends on the country-specific fiscal positions should be introduced to counter moral hazard, though they do not elaborate this point. Our contribution focuses on such an issue by the introduction of a fiscal discipline premium, hence it is complementary to Pallara and Renne (2024). Related to this literature, it is also worth highlighting the research by Jarociński and Maćkowiak (2018), that simulate the impacts of a monetary and fiscal policy configuration which introduces a non-defaultable Eurobond on output, and the contribution of Codogno and van den Noord (2021), that assesses a specific Eurobond's macroeconomic stabilization effect together with a central fiscal capacity. However, the latter couple of works relies on simulations from calibrated theoretical models without any econometric application. Moreover, their counterfactual exercises are based on ex-post output projections of past adverse economic events (e.g., Great Recession), while our focus is to generate forward looking scenarios, both for macroeconomic fundamentals and probability of adverse macroeconomic events. To the best of our knowledge, the closest contribution to our empirical exercise is Tielens et al. (2014), based on a VAR analysis to evaluate the effects of a Eurobond scheme on sovereign debt dynamics, particularly those of Greece, Portugal, and Ireland. Our paper differs from Tielens et al. (2014) in two key methodological elements: while Tielens et al. (2014) estimate three country-specific VAR models, we combine several Eurozone economies in the same GVAR setup, which allows us to consider all sorts of economic links and externalities among countries. Therefore, our framework takes into account the potential financial contagion that plays a crucial role in understanding the functioning of the Eurozone and in the assessment of the possible role of debt mutualization schemes. Second, while Tielens et al. (2014) measure the dynamics of public debt-to-GDP ex-post, combining the forecasts of the variables included in the VAR model in a specific law of motion, we include the debt ratio directly in the set of our endogenous variables. This aspect is key, since allows to straightforwardly produce forecasts for the public debt in for different scenarios, without any need for predicting other endogenous or exogenous variables and then combine them possibly in a nonlinear way.

Our results read as follows. First, we provide a clear foundation of the proposed Euro-stability bond mechanism by means of a simple theoretical model of the Eurozone economies. Second, relying on a GVAR model, we show that the introduction of the Euro-stability bond, where the fiscal discipline premium is calibrated to replicate market discipline, might have beneficial effects in terms of reduction in the overall volatility of expected future public debt-over-GDP ratio. Moreover, we find that introducing an Eurobond scheme does not significantly alter the predicted dynamics of the interest expenditure for all the countries considered, thus suggesting no cross-country fiscal redistribution in the short-run. Using event probability forecasts, we show that the probability of recessions may decrease in the medium term with the Euro-stability bond introduction. 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 contagion risk that, in the baseline scenario, affects the long-run sovereign interest rates of Eurozone countries.

The remainder of the paper is organized as follows. Section 2 discusses the disciplining effect of sovereign bond markets by analyzing the dynamics of the determinants of Eurozone's sovereign spreads over the last two decades. Section 3 presents 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, and Section 5 draws conclusions.

2 The market discipline in the euro area: stylized facts

A central feature of our proposal is its capacity to replicate market discipline. In this section, our analysis of the determinants of Eurozone sovereign debt spreads provides stylized facts about the efficiency of the market discipline within the euro area and establishes a benchmark for calibrating 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 government bond of any Member State's 10-years interest rate and the (safest) German bund, has drawn the attention of researchers and policy-makers. The motivation for this attention is straightforward. Given the size of government debts and the the euro-area countries' degree of financial and economic integration, even a small variation in sovereign bond yields may push individual countries toward unsustainable fiscal dynamics, thus affecting the Eurozone's fiscal and monetary stability.

The consensus in the literature is 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): the global risk, which conveys the systemic and time-varying international level of risk aversion and is usually measured as the spread between corporate and government bonds or using standard global uncertainty indexes (e.g., VIX, EPU); 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)[6]; and the liquidity risk, which expresses the premium investors require to bear the risk of liquidating the security at a lower price than the benchmark, a risk that is generally greater when the sovereign bond markets are (temporarily or structurally) less integrated. However, plenty of studies have documented that each of these factors' contribution to the dynamics of sovereign spreads is non-linear and has structurally changed over time, both in country-dependent (Costantini et al., 2014) and event-related ways. Understanding reported non-linear and time-varying relations is key to assess the presence and causes of sovereign bonds' mispricing that have been documented before the 2008 financial crisis and during the sovereign debt crisis in the euro area (De Grauwe and Ji, 2012; Di Cesare et al., 2012).

Mispricing undermines the capacity of sovereign bond markets to price individual countries' credit risk reliably, which provides a rational market discipline for governments' fiscal policies without inducing financial and macroeconomic instability. A systematic review of the results of the literature on

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

Eurozone sovereign spreads suggests widespread mispricing events.[7] From 1999 to the 2008 financial crisis, the euro-area government bond spreads of all Member States declined significantly. During this *convergence phase*, the key driver of sovereign spreads was 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, although their impact on the dynamics of spreads was barely significant.[8] Why, then, were debt instruments of different Eurozone countries perceived as almost equally safe? A common answer is that the suppression of the exchange rate risk and the still untested credibility of the EU fiscal framework *anchored the expectations* of investors to the long-run convergence of countries' economic and fiscal behaviors, thus curbing perceptions that weaker Eurozone Member States would default.

The 2008 financial crisis stopped the convergence phase. After the financial crisis and during the Eurozone sovereign debt crisis, the levels and volatility of Eurozone sovereign spreads grew, and the dynamics between *core* countries (e.g., Netherlands, Belgium, Austria, etc.) and *periphery* countries (e.g., Greece, Ireland, Italy, Portugal, Spain) diverged, with France in between the two clusters. During this *divergence phase*, the weights of the determinants changed structurally (Aßmann and Boysen-Hogrefe, 2012; Caggiano and Greco, 2012). The fiscal and macroeconomic fundamentals that drive the credit risk became much more significant in determining sovereign spreads' dynamics, 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 occurred in this period.[9] 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 words, the contagion risk became a fourth structural determinant of the Eurozone sovereign spreads (De Santis, 2012). Financial instability in one peripheral country triggers a downgrade in rating for bonds issued by other peripheral countries that have weak fiscal conditions, and then a flight-to-safety toward (core) Member States whose public finances are more sound. These dynamics characterized the Eurozone sovereign debt crisis that originated in Greece and led to an increase in the perceived probability of other peripheral countries' default and, thus, in their sovereign spreads (i.e., Ireland, Italy, Portugal, Spain). 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 mirrors what we said about the convergence phase: by exposing the inadequacy of the EU fiscal framework, the Eurozone sovereign debt crisis suddenly *de-anchored investors' expectations* about its capacity to prevent weaker Member States from defaulting.

To illustrate the described mispricing events in the euro-area sovereign debt markets, we run an

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

[8] For example, in the years 2003-2006, we observe decreasing or stable spreads, while fiscal conditions of some countries were clearly worsening. 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.

[9] Several empirical models and techniques reveal similar results. 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.

intuitive empirical exercise. In a simple panel WLS (Weighted Least Square) framework, we regress the sovereign spreads of the nine largest euro-area economies' 10-years bonds[10] on two standard measures of countries' creditworthiness, namely the primary balance-to-GDP ratio and the public debt-to-GDP ratio. Formally, we estimate the 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-to-GDP ratio and p_{it} is the primary balance-to-GDP ratio. Once the parameters α and β are estimated, 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 rate* for each of the main European economies, where, by construction, the spread with respect to the benchmark rate of the German bund is driven only by fiscal fundamentals. Thus, a proxy of the realized mispricing of the country-specific creditworthiness is represented by the difference between the historically observed long-term rates and the counterfactual interest rate based on fiscal fundamentals (Figure 1). During the sovereign debt crisis (around 2011), sovereign debt markets were over-estimating some European countries' long-term interest rate with respect to what should had been their interest rate according to fiscal imbalances and macroeconomic fundamentals. Before the 2008 financial crisis, a smaller mispricing event of opposite sign occurred (Figure 1), that can be interpreted as the market over-pricing less creditworthy countries' sovereign bonds. The same argument can be also illustrated by looking at the association between the two time series. Countries that suffered larger contagion effects show significantly lower correlation (with a minimum of 0.25 for Portugal) with respect to Members States for which 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). This evidence highlights potential efficiency losses when one relies 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.

3 The Euro-stability bond: theoretical background

To highlight the basic rationale that underlies 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:

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

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

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

where, for the sake of simplicity, ε_{it}^{z} for all $z \in \{b, e, g\}$ are independently distributed as Normal random shocks with zero mean and variance ${\sigma_{it}^{z}}^2$. Equation (2) describes the dynamics of debt-

[10]Given that Germany is the benchmark, the nine largest euro-area economies are Austria, Belgium, Finland, France, Ireland, Italy, Netherlands, Portugal, and Spain.

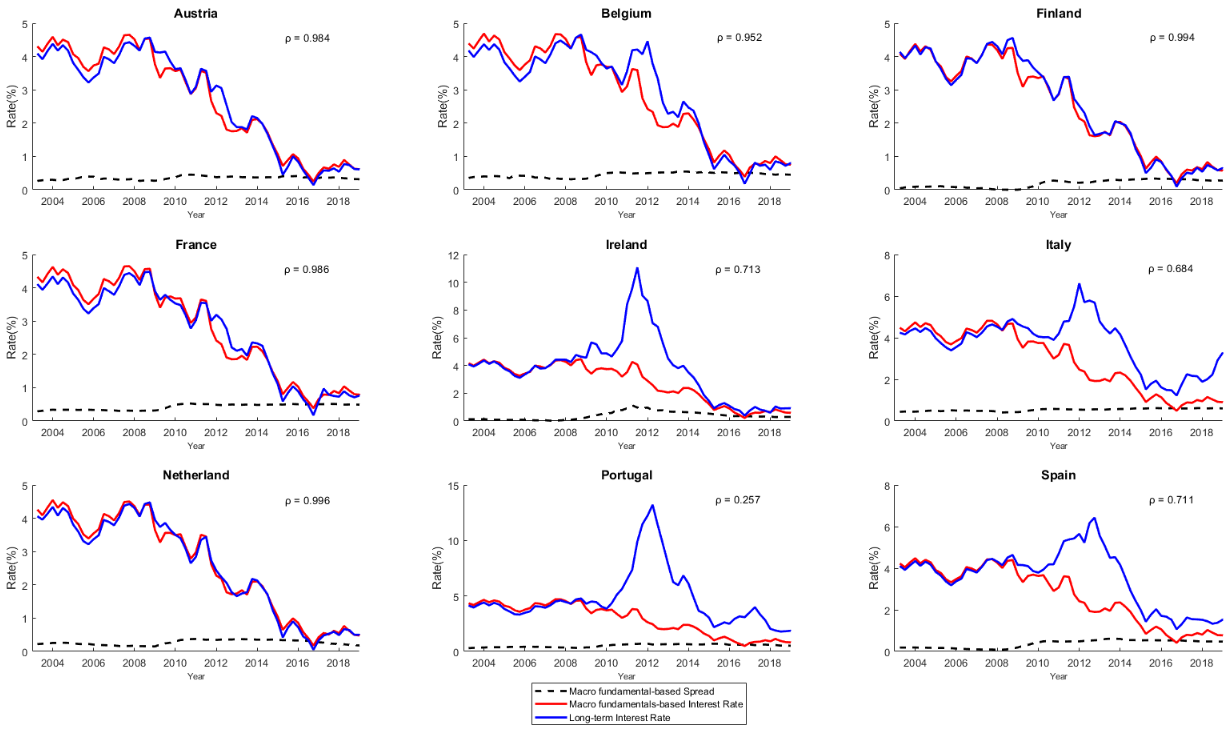

Figure 1: Long term interest rate, counterfactual macro fundamentals-based interest rate and macro fundamentals-based spread in the period 2004-2019 for the Eurozone countries in the sample.

to-GDP ratio (b_{it})[11], which decreases in the primary balance-to-GDP ratio (p_{it}), increases in the interest expenditure-to-GDP ratio (e_{it}), and depends on the level of past government debt (b_{it-1}). The dynamics of the interest expenditure-to-GDP ratio (e_{it}) in Equation (3) depends on the 10-years sovereign bond interest rate (r_{it}) and the interest expenditure's sensitivity to such a rate (ϕ_i), given the level of the public debt in $t-1$.[12] Finally, Equation (4) describes the determinants of the country's real growth rate (g_{it}), which includes country i's potential long-run growth rate $(\bar{g}_i)$ and its sensitivity to the benchmark rate (γ_i), which also influences and reflects the country's credit conditions.

Our model abstracts from a refined modelling of the relationships among 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 interest rate of the core economy of the Eurozone (i.e., Germany) and s_{it}

[11] For the sake of analytical tractability, we use Equation (2) to approximate the dynamics of public debt-to-GDP ratio in discrete time, assuming away monetary financing of sovereign debt, that is:

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

[12] The 10-years sovereign bond interest rate is the benchmark rate of a country's sovereign debt as it represents the level of interest rates on other government securities. The parameter ϕ_i is driven by the government debt structure (i.e., by type of security) and maturity that are time-variant variables. However, the cost of government debt's sensitivity to the benchmark rate tends to be persistent over time. Thus, for the sake of analytical tractability, we assume that it is time-invariant.

is the sovereign spread of the non-core country i with respect to r_{0t}. For the sake of simplicity:

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

where $\bar{r}$ is the exogenous component of the benchmark rate of the core economy, η_i is the sensitivity of r_{0t} to an increase in country i's stock of public debt-to-GDP ratio, ε_t is a Normal random variable – that is independently distributed with 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 a non-core country i is:

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

where $\alpha > 0$ and $\beta < 0$ are the sensitivities of the spread to past fiscal fundamentals, which our simple model represents as the government debt-to-GDP (b_{it-1}) and the primary balance-to-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 that affect other countries. Again, to keep the model as simple as possible, all these shocks are assumed to be independently and identically distributed as Normal random variables with zero mean and variance ${\sigma_{it}^r}^2$. Equation (6) and Equation (7) provide useful measures to capture the magnitude of contagion (or spillover) effects both from non-core countries to the core economy and among non-core countries. Specifically, the component $\sum_{j=1}^{N} \eta_j b_{jt-1}$ in Equation (6) represents the negative impact of a larger average debt within the Eurozone on the basic interest rate level of the monetary union (e.g., because of larger demand of capital, higher inflation expectations). It is valuable to note that, in the real world (and in our model), this transmission channel motivates the very existence of fiscal rules within monetary unions with decentralized fiscal policies. Potentially different weights η_i aim at representing country-specific effects of this relationship. First, larger countries are likely to have a larger influence on r_{0t}. Second, the increase of sovereign debt issued by an historically profligate country may have a larger negative impact on the benchmark rate of core countries with respect to the same increase of an historically frugal country, even if the two countries are similar in size. Similarly, the κ_i terms in Equation (7) measure, for each non-core country, the sensitivity of the sovereign spread to unexpected shocks affecting other non-core countries (i.e., credit risk contagion).[13]

We introduce a simple objective function of the government of country i at time t that 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):

$$W_{it} = E_{t-1}[v(g_{it}) - h(p_{it}) + \delta W_{it+1}] \tag{8}$$

where $E_{t-1}(.)$ is computed considering the realization of random variables up to $t-1$, $v(g_{it})$ is a strictly increasing and concave utility function with constant absolute risk aversion (CARA) equal to ρ; $h(p_{it})$ is a strictly increasing and convex disutility function; and $\delta \in (0, 1)$ is the government's intertemporal

[13] A clear example of this mechanism is the negative rate linkage which characterized the high-debt European countries during the sovereign-debt crisis starting from Greece's financial distress.

discount rate. Exploiting the assumptions that the utility is a CARA function and random shocks are normally distributed, we can represent the expected utility of growth at time t in mean-variance terms:

$$E_{t-1}[v(g_{it})] = E_{t-1}(g_{it}) - \frac{\rho}{2}Var_{t-1}(g_{it}) \tag{9}$$

where $Var_{t-1}(.)$ is 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:

$$g_{it} = \bar{g}_i - \gamma_i[\bar{r} + \sum_{j \neq i} \eta_j b_{jt-1} + (\eta_j + \alpha)b_{it-1} + \beta p_{it-1} + \kappa_i \sum_{j \neq i} \varepsilon^r_{jt} + \varepsilon^r_{it} + \varepsilon_t] + \varepsilon^g_{it} \tag{10}$$

hence

$$E_{t-1}(g_{it}) = \bar{g}_i - \gamma_i[\bar{r} + \sum_{j=1, j \neq i}^{N} \eta_j E_{t-1}(b_{jt-1})] - \gamma_i[(\eta_i + \alpha)E_{t-1}(b_{it-1}) + \beta p_{it-1}] \tag{11}$$

$$Var_{t-1}(g_{it}) = E_{t-1}\{[g_{it} - E_{t-1}(g_{it})]^2\} = \gamma_i\Big(\kappa_i \sum_{j \neq i, j=1}^{N} \sigma^{r2}_{jt} + \sigma^{r2}_{it} + \sigma^2_t\Big) + \sigma^{g2}_{it}, \tag{12}$$

for all t, where we exploited the assumption that random shocks are independently distributed. Let us remark that, for all t and $T > 0$, $E_{t-1}[E_{t+T-1}(g_{t+T})] = E_{t-1}(g_{t+T})$ and $E_{t-1}[Var_{t+T-1}(g_{t+T})] = Var_{t+T-1}(g_{t+T})$. Assuming that the government perfectly controls the primary balance in all periods[14], we can substitute the mean-variance utility (9) into government's objective function (8) and then substitute recursively W_{it+T} into W_{it} for all $T \geq 1$. Thus, the government's objective function at time t can also be written as:

$$W_{it} = \sum_{\tau=0}^{\infty} \delta^\tau [E_{t-1}(g_{it+\tau}) - \frac{\rho}{2}Var_{t+\tau-1}(g_{it+\tau}) - h(p_{it+\tau})]. \tag{13}$$

Assuming that the government maximizes the objective function (13) in all periods, we compare the government's optimal fiscal policy in three alternative scenarios: the market discipline without any Eurobond; the *plain vanilla* Eurobond, where all countries issue their debt with a common instrument and pay the same interest rate[15]; and the Euro-stability bond scenario.

3.1 The plain vanilla Eurobond v. the market discipline

Our first theoretical result arises from the comparison of the maximization of the government's objective function (13) under the first two scenarios, assuming that the plain vanilla Eurobond is introduced from time t on.

Proposition 1. *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 is always lower than the primary balance implemented by the government under pure market discipline.*

[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).

[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 $i \in \{1, \ldots, N\}$.

Proof. As highlighted by Equation (12), $Var_{t+T-1}(g_{it+T})$ does not depend on p_{it}, for any $T \geq 0$. Thus, the first order condition of the maximization of the government's objective function (13) with respect to p_{it} is:

$$\sum_{\tau=1}^{\infty} \delta^{\tau} \frac{\partial E_{t-1}(g_{it+\tau})}{\partial p_{it}} - h'(p_{it}) = 0 \tag{14}$$

By Equation (11):

$$\frac{\partial E_{t-1}(g_{it})}{\partial p_{it}} = 0 \tag{15}$$

$$\frac{\partial E_{t-1}(g_{it+1})}{\partial p_{it}} = -\gamma_i \Big[(\eta_i + \alpha)\frac{\partial E_{t-1}(b_{it})}{\partial p_{it}} + \beta\Big] \tag{16}$$

$$\frac{\partial E_{t-1}(g_{it+T+1})}{\partial p_{it}} = -\gamma_i(\eta_i + \alpha)\frac{\partial E_{t-1}(b_{it+T})}{\partial p_{it}}, \tag{17}$$

for all t and $T \geq 1$. Substituting Equations (6) and (7) into (5) and, then, the resulting expression and Equations (3) and (10) into (2), we obtain the dynamic equation of debt-to-GDP ratio in t:

$$\begin{aligned} b_{it} = (\phi_i + \gamma_i)(\eta_i + \alpha)b_{it-1}^2 + (\phi_i + \gamma_i) \sum_{j=1, j\neq i}^{N} \eta_j b_{jt-1} b_{it-1} + (\phi_i + \gamma_i)\beta p_{it-1} b_{it-1} + \\ + [(\phi_i + \gamma_i)\bar{r} + 1 - \bar{g}_i] b_{it-1} - p_{it} + \\ + [(\phi_i + \gamma_i)(\kappa_i \sum_{j\neq i, j=1}^{N} \varepsilon_{jt}^r + \varepsilon_{it}^r + \varepsilon_t) + \varepsilon_{it}^g] b_{it-1} + \varepsilon_{it}^b + \varepsilon_{it}^e \end{aligned} \tag{18}$$

which depends only on the parameters, the current shocks, the level of debt-to-GDP ratios of all countries in t, and the primary balance-to-GDP ratio in t and $t-1$. Substituting Equations (15), (16) and (17), for all $T \geq 1$, into (14), the optimization condition that characterizes the primary balance-to-GDP ratio at time t can be written as:

$$h'(p_{it}) = \delta\gamma_i(\eta_i + \alpha - \beta) - \gamma_i(\eta_i + \alpha)\sum_{\tau=2}^{\infty} \delta^{\tau} \frac{\partial E_{t-1}(b_{it+\tau-1})}{\partial p_{it}}. \tag{19}$$

where we used $\frac{\partial E_{t-1}(b_{it})}{\partial p_{it}} = \frac{\partial b_{it}}{\partial p_{it}} = -1$, which follows by Equation (18). Also, by Equation (18), for for any $\tau \geq 2$, we have:

$$\frac{\partial E_{t-1}(b_{it+\tau})}{\partial p_{it}} = E_{t-1}\Big(\prod_{s=1}^{\tau} \frac{\partial b_{it+s}}{\partial b_{it+s-1}} \frac{\partial b_{it}}{\partial p_{it}}\Big) = -E_{t-1}\Big(\prod_{s=1}^{\tau} \frac{\partial b_{it+s}}{\partial b_{it+s-1}}\Big) \tag{20}$$

where we used $\frac{\partial b_{it}}{\partial p_{it}} = -1$, and

$$\frac{\partial b_{it+s}}{\partial b_{it+s-1}} = \theta_{is} + \phi_i\Big(\kappa_i \sum_{j\neq i, j=1}^{N} \varepsilon_{jt+s}^r + \varepsilon_{it+s}^r + \varepsilon_{t+s}\Big) \tag{21}$$

with

$$\theta_{is} = (\phi_i + \gamma_i)\Big[2(\eta_i + \alpha)b_{it+s-1} + \sum_{j=1, j\neq i}^{N} \eta_j b_{jt+s-1} + \beta p_{it+s-1} + \bar{r}\Big] + 1 - \bar{g}_i. \tag{22}$$

Let us remark that, for reasonable values of future debt-to-GPD and primary balance-to-GDP ratios and exogenous parameters (particularly, $\alpha \geq 0$ and $\beta \leq 0$), $\theta_{is} > 0$. Also, given that shocks are independently distributed and have zero mean, by Equation (21), we can write Equation (20) as:

$$\frac{\partial E_{t-1}(b_{it+\tau})}{\partial p_{it}} = -E_{t-1}\Big(\prod_{s=1}^{\tau}\theta_{is}\Big) < 0. \tag{23}$$

Thus, the optimization condition (19) becomes:

$$h'(p_{it}) = \delta\gamma_i(\eta_i + \alpha - \beta) + \gamma_i(\eta_i + \alpha)\sum_{\tau=2}^{\infty}\delta^{\tau}E_{t-1}\Big(\prod_{s=1}^{\tau}\theta_{is}\Big), \tag{24}$$

which is positive for $\alpha \geq 0$ and $\beta \leq 0$. Let us remark that $E_{t-1}\Big(\prod_{s=1}^{\tau}\theta_s\Big)$ depends on p_{it} for all $\tau \geq 2$. Particularly, by Equation (22), for $s = 1$

$$\frac{\partial\theta_{i1}}{\partial p_{it}} = (\phi_i + \gamma_i)\Big[2(\eta_i + \alpha)\frac{\partial b_{it}}{\partial p_{it}} + \beta\Big] = -(\phi_i + \gamma_i)[2(\eta_i + \alpha) - \beta] < 0, \tag{25}$$

and for $s \geq 2$

$$\frac{\partial\theta_{is}}{\partial p_{it}} = (\phi_i + \gamma_i)2(\eta_i + \alpha)\prod_{z=2}^{s}\frac{\partial b_{it+z-1}}{\partial b_{it+z-2}}\frac{\partial b_{it}}{\partial p_{it}} = \tag{26}$$

$$= -(\phi_i + \gamma_i)2(\eta_i + \alpha)\prod_{z=2}^{s}\Big[\theta_{iz-1} + \phi_i\Big(\kappa_i\sum_{j\neq i, j=1}^{N}\varepsilon^r_{jt+z-1} + \varepsilon^r_{it+z-1} + \varepsilon_{t+z-1}\Big)\Big],$$

where, in both expressions, we used $\frac{\partial b_{it}}{\partial p_i t} = -1$ and in the second one we substituted Equation (21). Again, exploiting the assumptions that shocks are independently distributed and with zero mean, we can write:

$$\frac{\partial E_{t-1}\Big(\prod_{s=1}^{\tau}\theta_{is}\Big)}{\partial p_{it}} = E_{t-1}\Big(\sum_{z=1}^{\tau}\frac{\partial\theta_{iz}}{\partial p_{it}}\prod_{s=1, s\neq z}^{\tau}\theta_{is}\Big) = \tag{27}$$

$$= -(\phi_i + \gamma_i)E_{t-1}\Big\{[2(\eta_i + \alpha) - \beta]\prod_{s=2}^{\tau}\theta_{is} + \sum_{z=2}^{\tau}2(\eta_i + \alpha)\prod_{m=2}^{z}\theta_{im-1}\prod_{s=1, s\neq z}^{\tau}\theta_{is}\Big\} < 0$$

where we also used Equations (25) and (26). We are now able to compare the paths of the optimal primary balance-to-GDP ratios chosen by governments from time t on in the two scenarios: under pure market discipline (i.e., with $\alpha > 0$ and $\beta < 0$), which we denote by $\{p^*_{it+T}\}_{T=0}^{\infty}$; under a plain-vanilla Eurobond (i.e., with $\alpha = \beta = 0$), which we denote by $\{p^{PVE}_{it+T}\}_{T=0}^{\infty}$. Assume, by contradiction, that $p^*_{it+T} \leq p^{PVE}_{it+T}$ for all $T \geq 0$. By derivative (27), the latter implies that $E_{t-1}\Big(\prod_{s=1}^{\tau}\theta^*_{is}\Big) \geq E_{t-1}\Big(\prod_{s=1}^{\tau}\theta^{PVE}_{is}\Big)$ for all $\tau \geq 0$ (where apexes * and ^{PVE} denote the considered functions under market discipline and plain-vanilla Eurobond, respectively). Also, by expression (24) and the convexity of $h(.)$, we necessarily have that:

$$h'(p^*_{it}) = \delta\gamma_i(\eta_i + \alpha - \beta) + \gamma_i(\eta_i + \alpha)\sum_{\tau=2}^{\infty}\delta^{\tau}E_{t-1}\Big(\prod_{s=1}^{\tau}\theta^*_{is}\Big) \leq$$

$$\leq \delta\gamma_i\eta_i + \gamma_i\eta_i\sum_{\tau=2}^{\infty}\delta^{\tau}E_{t-1}\Big(\prod_{s=1}^{\tau}\theta^{PVE}_{is}\Big) = h'(p^{PVE}_{it})$$

which implies the following contradiction:

$$0 < \gamma_i\eta_i\Big[\sum_{\tau=2}^{\infty}\delta^{\tau}E_{t-1}\Big(\prod_{s=1}^{\tau}\theta^{*}_{is}\Big) - \sum_{\tau=2}^{\infty}\delta^{\tau}E_{t-1}\Big(\prod_{s=1}^{\tau}\theta^{PVE}_{is}\Big)\Big] \leq$$
$$-\delta\gamma_i(\alpha-\beta) - \gamma_i\alpha\sum_{\tau=2}^{\infty}\delta^{\tau}E_{t-1}\Big(\prod_{s=1}^{\tau}\theta^{*}_{is}\Big) < 0.$$

Thus the proof follows, for any t and $T \geq 0$.

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.

3.2 The Euro-stability bond v. the market discipline

The second theoretical result is retrieved from the comparison of the market discipline scenario with our Eurobond proposal. Let us 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*.[16] The main objective of our proposal is to introduce a debt instrument that mimics the market discipline but also immunizes Eurozone economies from the contagion effects.[17] In our theoretical model, the 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 time-variant fiscal discipline premium:

$$\pi_{it} = \alpha b_{it-1} + \beta p_{it-1}, \tag{28}$$

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. 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., $\sum_{j\neq i,j=1}^{N}\varepsilon^{r}_{jt}$ in Equation 7). By Proposition 1, under both scenarios – i.e., the Euro-stability bond (denoted by the apex ES) and the

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

[17]Our Euro-Stability Bond proposal embodies, somehow, the spirit of the Transmission Protection Instrument (TPI) approved by the ECB's Governing Council in July 2022. TPI's objective is, indeed, to guarantee the effectiveness of the monetary policy transmission mechanism by purchasing public sector securities of countries whose financing conditions are worsening in a way which is not warranted by fiscal fundamentals. However, while inducing fiscal discipline in high-debt countries is the main goal of our common debt scheme, a high level of fiscal sustainability is an ex-ante necessary condition to exploit the TPI.

market discipline (denoted by the apex *) – the optimal primary balance-to-GDP ratio is p^*_{it} for any t.

Proposition 2. *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 with respect to the expected government's welfare under pure market discipline. This result holds also for the core country.*

Proof. Considering that under both scenarios the flow of primary balances is $\{p^*_{it+T}\}^{\infty}_{T=0}$, by Equation (13), the welfare differential between the two scenarios is:

$$\Delta E_{t-1}\left(W_{it}\right) = E_{t-1}\left(W^{ES}_{it}\right) - E_{t-1}\left(W^*_{it}\right) = \tag{29}$$
$$= \sum_{\tau=0}^{\infty} \delta^{\tau}[E_{t-1}(g^{ES}_{it+\tau}) - E_{t-1}(g^*_{it+\tau})] + \frac{\rho}{2}\sum_{\tau=0}^{\infty} \delta^{\tau}[Var_{t+\tau-1}(g^*_{it+\tau}) - Var_{t+\tau-1}(g^{ES}_{it+\tau})].$$

The second term of Equation (29) 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, which by Equation (12) is:

$$\frac{\rho}{2}\sum_{\tau=0}^{\infty} \delta^{\tau}[Var_{t+\tau-1}(g^*_{it+\tau}) - Var_{t+\tau-1}(g^{ES}_{it+\tau})] = \frac{\rho}{2}\gamma_i^2 \sum_{\tau=0}^{\infty} \delta^{\tau}\left(\kappa_i^2 \sum_{j\neq i, j=1}^{N} \sigma^{r2}_{jt+\tau} + \sigma^{r2}_{it+\tau}\right) \geq 0,$$

with strict inequality for non-core countries $i \neq 0$, which are affected by contagion risk through Equation (7). The first term of Equation (29), which by Equation (11) can we written as

$$\sum_{\tau=0}^{\infty} \delta^{\tau}[E_{t-1}(g^{ES}_{it+\tau}) - E_{t-1}(g^*_{it+\tau})] = \gamma_i \sum_{\tau=0}^{\infty} \delta^{\tau}\left\{ \sum_{j\neq i, j=1}^{N} \eta_j \left[E_{t-1}\left(b^*_{jt+\tau-1}\right) - E_{t-1}\left(b^{ES}_{jt+\tau-1}\right)\right] + \right. \tag{30}$$
$$\left. + \left(\eta_i + \alpha\right)\left[E_{t-1}\left(b^*_{it+\tau-1}\right) - E_{t-1}\left(b^{ES}_{it+\tau-1}\right)\right] \right\},$$

is the discounted welfare gain determined by the larger GDP growth because of smaller expected public debt-to-GDP ratios under the Euro-stability bond scenario. By Equation (18), we work out the following useful results:

$$E_{t-1}(b^*_{it}) = E_{t-1}(b^{ES}_{it}) \tag{31}$$

$$Var_{t-1}(b^*_{it}) = \left[(\phi_i + \gamma_i)^2 \left(\kappa_i^2 \sum_{j\neq i, j=1}^{N} \sigma^{r2}_{jt} + \sigma^{r2}_{it} + \sigma^2_t\right) + \sigma^{g2}_{it}\right] b^2_{it-1} + \sigma^{b2}_{it} + \sigma^{e2}_{it} \geq \tag{32}$$
$$\geq [(\phi_i + \gamma_i)^2 \sigma^2_t + \sigma^{g2}_{it}] b^2_{it-1} + \sigma^{b2}_{it} + \sigma^{e2}_{it} = Var_{t-1}(b^{ES}_{it}),$$

$$Cov_{t-1}(b^*_{jt}, b^*_{it}) = (\phi_i + \gamma_i)(\phi_j + \gamma_j)\left(\kappa_i \kappa_j \sum_{s=1, s\notin\{i,j\}}^{N} \sigma^{r2}_{st} + \kappa_i \sigma^{r2}_{jt} + \kappa_j \sigma^{r2}_{it} + \sigma^2_t\right) b_{it-1} b_{jt-1} > \tag{33}$$
$$> (\phi_i + \gamma_i)(\phi_j + \gamma_j)\sigma^2_t b_{it-1} b_{jt-1} = Cov_{t-1}(b^{ES}_{jt}, b^{ES}_{it}),$$

with strict inequality in Equation (32) for $i \neq 0$, given that the b_{it-1} is the same in both regimes.

Consider now the expectation in $t-1$ of Equation (18) at time $t+1$:

$$E_{t-1}(b_{it+1}) = (\phi_i+\gamma_i)(\eta_i+\alpha)E_{t-1}(b_{it}^2) + (\phi_i+\gamma_i)\sum_{j=1,j\neq i}^{N}\eta_j E_{t-1}(b_{jt}b_{it}) + \\ +[(\phi_i+\gamma_i)(\beta E_{t-1}(p_{it})+\bar{r})+1-\bar{g}_i]E_{t-1}(b_{it}) - E_{t-1}(p_{it+1}). \quad (34)$$

Given that $E_{t-1}(b_{it}^2) = Var_{t-1}(b_{it}) + E_{t-1}(b_{it})^2$ and $E_{t-1}(b_{jt}b_{it}) = Cov_{t-1}(b_{jt}b_{it}) + E_{t-1}(b_{jt})E_{t-1}(b_{it})$, by Equations (31), (32), and (33), we obtain $E_{t-1}(b_{it}^{*2}) \geq E_{t-1}(b_{it}^{ES2})$, with strict inequality (equality) sign for $i \neq 0$ $(i=0)$, and $E_{t-1}(b_{jt}^* b_{it}^*) > E_{t-1}(b_{jt}^{ES} b_{it}^{ES})$. Considering that the path of the optimal primary balance-to-GDP ratios is the same in the two scenarios, by Equations (34), we obtain $E_{t-1}(b_{it+1}^*) > E_{t-1}(b_{it+1}^{ES})$, for all i. Consider now the expectation in $t-1$ of Equation (34) at time $t+2$:

$$E_{t-1}(b_{it+2}) = (\phi_i+\gamma_i)(\eta_i+\alpha)E_{t-1}(b_{it+1}^2) + (\phi_i+\gamma_i)\sum_{j=1,j\neq i}^{N}\eta_j E_{t-1}(b_{jt+1}b_{it+1}) + \\ +[(\phi_i+\gamma_i)(\beta E_{t-1}(p_{it+1})+\bar{r})+1-\bar{g}_i]E_{t-1}(b_{it+1}) - E_{t-1}(p_{it+2}). \quad (35)$$

Let us remark that

$$E_{t-1}(b_{it+1}^2) = Var_{t-1}(b_{it+1}) + E_{t-1}(b_{it+1})^2 \quad (36)$$

$$E_{t-1}(b_{jt+1}b_{it+1}) = Cov_{t-1}(b_{jt+1}b_{it+1}) + E_{t-1}(b_{jt+1})E_{t-1}(b_{it+1}). \quad (37)$$

By the assumption that shocks are independently distributed, we can write:

$$Var_{t-1}(b_{it+1}) = E_{t-1}\{[b_{it+1} - E_{t-1}(b_{it+1})]^2\} = E_{t-1}\{[b_{it+1} - E_t(b_{it+1}) + E_t(b_{it+1}) - E_{t-1}(b_{it+1})]^2\} = \\ = E_{t-1}\{[b_{it+1} - E_t(b_{it+1})]^2\} + E_{t-1}\{[E_t(b_{it+1}) - E_{t-1}(b_{it+1})]^2\},$$

Thus, by $E_{t-1}(b_{it}^{*2}) \geq E_{t-1}(b_{it}^{ES2})$,

$$E_{t-1}\{[b_{t+1}^* - E_t(b_{t+1}^*)]^2\} = \\ = [(\phi_i+\gamma_i)(\kappa_i \sum_{j\neq i,j=1}^{N} \sigma_{jt+1}^{r2} + \sigma_{it+1}^{r2} + \sigma_{t+1}^2) + \sigma_{it+1}^{g2}]E_{t-1}(b_{it}^{*2}) + \sigma_{it+1}^{b2} + \sigma_{it+1}^{e2} > \\ > [(\phi_i+\gamma_i)\sigma_{t+1}^2 + \sigma_{it+1}^{g2}]E_{t-1}(b_{it}^{ES2}) + \sigma_{it+1}^{b2} + \sigma_{it+1}^{e2} = E_{t-1}\{[b_{t+1}^{ES} - E_t(b_{t+1}^{ES})]^2\}.$$

Moreover, let us remark that, for all i, the expectation in t of Equation (18) in $t+1$ is a quadratic function of the vector of public debt-to-GDP ratios at time t, that is:

$$B_i(\mathbf{b}_t) \equiv E_t(b_{it+1}) = (\phi_i+\gamma_i)(\eta_i+\alpha)b_{it}^2 + (\phi_i+\gamma_i)\sum_{j=1,j\neq i}^{N}\eta_j b_{jt}b_{it} + \\ +[(\phi_i+\gamma_i)(\beta p_{it}+\bar{r})+1-\bar{g}_i]b_{it} - E_t(p_{it+1}), \quad (38)$$

where $\mathbf{b}_t \equiv \langle b_{1t}, ..., b_{it}, ..., b_{Nt}\rangle$. The second-order Taylor polynomial that approximates the quadratic function (38) around the vector of the expectation in $t-1$ of public debt-to-GDP ratios $E_{t-1}(\mathbf{b}_t) \equiv$

$\langle E_{t-1}(b_{1t}), ..., E_{t-1}(b_{it}), ..., E_{t-1}(b_{Nt})\rangle$ is

$$B_i(\mathbf{b}_t) \approx B_i(E_{t-1}(\mathbf{b}_t)) + \sum_{j=1}^{N} \frac{\partial B_i(E_{t-1}(\mathbf{b}_t))}{\partial b_{jt}}[b_{jt} - E_{t-1}(b_{jt})] +$$

$$+\frac{\partial^2 B_i(E_{t-1}(\mathbf{b}_t))}{\partial b_{it}^2}\frac{[b_{it} - E_{t-1}(b_{it})]^2}{2} + \sum_{j=1,j\neq i}^{N} \frac{\partial^2 B_i(E_{t-1}(\mathbf{b}_t))}{\partial b_{it}\partial b_{jt}}[b_{it} - E_{t-1}(b_{it})][b_{jt} - E_{t-1}(b_{jt})],$$

where we considered that, by Equation (38), all the second order derivative with respect to b_{jt}, with $j \neq i$, are equal to zero. In turn, taking the expectation in $t-1$ of the approximation of $B_i(\mathbf{b}_t)$,

$$E_{t-1}[B_i(\mathbf{b}_t)] \approx B_i(E_{t-1}(\mathbf{b}_t)) + \frac{\partial^2 B_i(E_{t-1}(\mathbf{b}_t))}{\partial b_{it}^2}\frac{Var_{t-1}(b_{it})}{2} + \sum_{j=1,j\neq i}^{N} \frac{\partial B_i(E_{t-1}(\mathbf{b}_t))}{\partial b_{jt}} Cov_{t-1}(b_{it}, b_{jt}),$$

we can write:

$$E_t(b_{t+1}) - E_{t-1}(b_{t+1}) = B_i(\mathbf{b}_t) - E_{t-1}[B_i(\mathbf{b}_t)] \approx \sum_{j=1}^{N} \frac{\partial B_i(E_{t-1}(\mathbf{b}_t))}{\partial b_{jt}}[b_{jt} - E_{t-1}(b_{jt})] +$$

$$+\frac{\partial^2 B_i(E_{t-1}(\mathbf{b}_t))}{\partial b_{it}^2}\frac{[b_{it} - E_{t-1}(b_{it})]^2}{2} + \sum_{j=1,j\neq i}^{N} \frac{\partial^2 B_i(E_{t-1}(\mathbf{b}_t))}{\partial b_{it}\partial b_{jt}}[b_{it} - E_{t-1}(b_{it})][b_{jt} - E_{t-1}(b_{jt})] +$$

$$-\frac{\partial^2 B_i(E_{t-1}(\mathbf{b}_t))}{\partial b_{it}^2}\frac{Var_{t-1}(b_{it})}{2} - \sum_{j=1,j\neq i}^{N} \frac{\partial^2 B_i(E_{t-1}(\mathbf{b}_t))}{\partial b_{it}\partial b_{jt}}\frac{Cov_{t-1}(b_{it}, b_{jt})}{2}.$$

Thus, we are able to check that $E_{t-1}\{[E_t(b_{it+1}) - E_{t-1}(b_{it+1})]^2\}$ is increasing in $Var_{t-1}(b_{it})$, $Var_{t-1}(b_{jt})$, $Cov_{t-1}(b_{it}, b_{jt})$ and higher order moments for all j. Thus, by Equations (32) and (33), $E_{t-1}\{[E_t(b^*_{t+1}) - E_{t-1}(b^*_{t+1})]^2\} > E_{t-1}\{[E_t(b^{ES}_{t+1}) - E_{t-1}(b^{ES}_{t+1})]^2\}$. In turn, $Var_{t-1}(b^*_{it+1}) > Var_{t-1}(b^{ES}_{it+1})$. Following the same procedure that we described in detail for variance, we can show that $Cov_{t-1}(b^*_{it+1}, b^*_{jt+1}) > Cov_{t-1}(b^{ES}_{it+1}, b^{ES}_{jt+1})$. Thus, by Equations (36) and (37), we obtain that $E_{t-1}(b^{*2}_{it+1}) > E_{t-1}(b^{ES2}_{it+1})$ and $E_{t-1}(b^*_{jt+1}b^*_{it+1}) > E_{t-1}(b^{ES}_{jt+1}b^{ES}_{it+1})$, which by Equation (35) implies that $E_{t-1}(b^*_{it+2}) > E_{t-1}(b^{ES}_{it+2})$. Iterating the same recursive procedure for $t+\tau$, with $\tau > 3$, it follows that $E_{t-1}(b^*_{it+\tau-1}) > E_{t-1}(b^{ES}_{it+\tau-1})$ for all countries i and for all $\tau \geq 0$, hence Equation (30) is positive for all countries, including the core economy.

The intuition behind this result is that, by switching off all contagion components that are 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 bond brings a welfare dividend to all countries because of the smaller risk premium associated with suppressing contagion effects and, more generally, with a smaller expected aggregate public debt-to-GDP ratio (hence, larger economic growth). This effect is relevant also for the core economy. Of course, the plain vanilla Eurobond also suppresses the negative welfare effects of contagion within the euro area, although it also fosters fiscal profligacy.

3.3 The Euro-stability bond v. fiscal rules and market discipline

Our theoretical analysis allows us to assess a more encompassing role of the Euro-stability bond, as this instrument could be used to substitute for fiscal rules instead of complementing them. This leads us to the third theoretical result of the model. Let us consider the optimal fiscal coordination policy which we denote by the apex EU and is defined by a common fiscal authority that maximizes the expectation of the weighted sum of individual governments' objectives

$$\sum_{j=0}^{N} \omega_j E_{t-1}\left(W_{jt}\right) \tag{39}$$

with $\omega_i \geq 0$ the weight of the individual country i which possibly embeds political considerations.

Proposition 3. *The optimal policy chosen by the EU common fiscal authority for the country i always implies a larger primary balance than the optimal policy chosen by government of country i under market discipline. Moreover, the optimal EU fiscal coordination policy can be implemented by the Euro-stability bond with an appropriate choice of country-specific, time-varying parameters $\{\alpha_{jt}, \beta_{jt}\}_{j=0}^{N}$.*

Proof. Considering Equation (23), the optimization condition of the objective function (39) with respect to the primary balance-to-GDP ratio of the non-core country i in t can be written as:

$$\begin{aligned} h'(p_{it}) = \delta\gamma_i(\eta_i + \alpha - \beta) + \gamma_i(\eta_i + \alpha)\sum_{\tau=2}^{\infty} \delta^{\tau} E_{t-1}\Big(\prod_{s=1}^{\tau} \theta_{is}\Big) + \\ + \sum_{j\neq i, i=0}^{N} \frac{\omega_j}{\omega_i}\gamma_j\eta_i\Big[1 + \sum_{\tau=2}^{\infty}\delta^{\tau} E_{t-1}\Big(\prod_{s=1}^{\tau}\theta_{js}\Big)\Big]. \end{aligned} \tag{40}$$

Given that, as shown in Proposition 1, $E_{t-1}\Big(\prod_{s=1}^{\tau}\theta_{js}\Big) > 0$ for all j and all $\tau \geq 2$ and $h(.)$ is convex, $p_{it}^{EU} > p_{it}^{*}$ for all t. The reason is that the decentralized decision of individual governments under market discipline is taken according to optimization condition (19), which does not include the positive, fiscal externality effect represented by the third term of Equation (40). Putting $\alpha = \beta = 0$ in Equation (40), the result is shown to hold also for $i = 0$. Moreover, the same optimal policies can be implemented by decentralized decisions of individual countries, provided that the EU central authority introduces an Euro-stability bond with any vector of country-specific, time-varying parameters $\{\alpha_{it}^{**}, \beta_{it}^{**}\}$ that satisfies the following condition:

$$\begin{aligned} \delta\gamma_i(\eta_i + \alpha - \beta) + \gamma_i(\eta_i + \alpha)\sum_{\tau=2}^{\infty}\delta^{\tau} E_{t-1}\Big(\prod_{s=1}^{\tau}\theta_{is}^{EU}\Big) + \sum_{j\neq i, i=0}^{N}\frac{\omega_j}{\omega_i}\gamma_j\eta_i\Big[1 + \sum_{\tau=2}^{\infty}\delta^{\tau}E_{t-1}\Big(\prod_{s=1}^{\tau}\theta_{js}^{EU}\Big)\Big] = \\ = \delta\gamma_i(\eta_i + \alpha_{it}^{**} - \beta_{it}^{**}) + \gamma_i(\eta_i + \alpha^{**})\sum_{\tau=2}^{\infty}\delta^{\tau}E_{t-1}\Big(\prod_{s=1}^{\tau}\theta_{is}^{**}\Big) \end{aligned} \tag{41}$$

for all i.

The intuition behind Proposition 3 is that the optimal policy designed for the country i at the euro area level fully internalizes the negative externalities of excessive fiscal expansion in the monetary union and particularly the excessive aggregate government debt's negative impact on the common component of interest rates. Conversely, even when the market discipline operates, individual countries do not implement the optimal policies, which is the standard reason for the EU fiscal rules.

The Euro-stability bond that aims at (just) mimicking the market discipline is unable to fully internalize fiscal externalities. To this extent, it may be considered as complementary rather than a full substitute to the EU fiscal rules. However, the mechanism of the fiscal discipline premium is very flexible and could use an appropriate choice of the weights α and β to implement the optimal coordination of countries' fiscal policies in a decentralized way. Though, condition (41) highlights the (political) complexity of such solution which should rely on a fiscal discipline premium featuring parameters that are not only country-specific, but also potentially time-varying.

The conventional wisdom in the Eurobond debate is that market's sovereign interest rates are the benchmark against which one can 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 theoretical discussion above and the stylized facts about the dynamics of Eurozone sovereign spreads in Section 2 leads us to conclude that the EU fiscal rules, their credibility, and their impact on the dynamics of sovereign spreads involve significant cross-country redistribution in the short run. These are unintended consequences of existing fiscal and financial externalities among countries that 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). Therefore, we analyse in the following the simplest version of the Euro-stability bond, one that just replicates market incentives, although the same instrument could be used to implement more encompassing policies for the EU optimal 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.

The model presented in this section primarily serves as a theoretical benchmark to illustrate the policy intuitions behind our Euro-stability bond proposal. In the remainder of the paper, we empirically test this proposal using a reduced-form GVAR model, rather than calibrating the theoretical model with data. The decision to rely on a linear approximation to bring the main predictions of our non-linear theoretical model to data is motivated by two reasons. First, a linear approximation of the theoretical model that we analyzed in this section is quite satisfactory to test the first order effects we are interested in. Second, GVAR models are very useful when, as in our case, we are interested into fully account for all potential spillover effects among countries. Indeed, the GVAR framework incorporates foreign variables as global regressor into the equations of all domestic variables, allowing it to capture the comprehensive and dynamic interdependencies between economies.

4 Empirical evidence: a Global VAR counterfactual analysis

This section empirically assesses the Euro-stability bond's theoretical capacity to increase macroeconomic and financial stability in the euro area. Our empirical exercise aim at comparing the future dynamics of public debt-to-GDP ratio for Eurozone countries with and without the Euro-stability bond and evaluate the results in terms of predicted uncertainty. We also use the Eurobond scenario to check for differences in the Eurozone economic system's resilience against possible key negative events by estimating their conditional probabilities (i.e., event probability forecasts). To get rid of self-selection and arbitrage problems, we assume Eurozone countries issue all their sovereign debt through an European debt agency, after the introduction of the Euro-stability bond mechanism.[18] As discussed in Section 3, the Euro-stability bonds are issued and traded on the secondary market at a unique benchmark interest rate that in our empirical analysis is approximated as the German bund rate. Member States thus pay an interest rate that is the sum of the yield paid to Euro-stability bond holders plus the fiscal discipline premium. The European debt agency would also supervise individual governments' fiscal behaviour and charge differentiated fiscal discipline premia according to the country-specific fiscal rules. In line with the theoretical model, we compute the fiscal discipline premium π_{it}, for country i at time t, as:

$$\pi_{it} = \max[0, s_{it}] \tag{42}$$

where the spread and its determinants $s_{it} = \alpha b_{it-1} + \beta p_{it-1}$ are defined in Sections 2 and 3. However, since other countries besides Germany may be *core* (i.e., fiscally responsible), we impose $\pi_{it} \geq 0$, to prevent the case of a negative fiscal discipline premium. Therefore, as in the theoretical model of Section 3, a core country simply pays the benchmark rate on the debt it issues.

Since the Euro-stability bond is designed to replicate the market discipline, in our empirical analysis α and β are estimated from historical sovereign spreads through a panel Weighted Least Square estimator for Equation (1). The main goal of these estimates is to define a statistical rule to predict future country specific spreads, that in our setup are the main ingredient of the fiscal discipline premium, as stressed in Equation (42). The estimates $\hat{\alpha} = 0.0047$ and $\hat{\beta} = -0.0247$ are consistent with the intuition that the credit risk priced by sovereign debt markets is increasing in the public debt-to-GDP ratio and decreasing in the primary balance-to-GDP ratio. To keep the analysis as simple as possible, we choose to average out mis-pricing events occurred 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, different estimates (and political determination) of α and β do not qualitatively affect our main results.

4.1 Methodology: GVAR and conditional forecasts

Once the statistical model for the fiscal discipline premium is calibrated, the Eurobond mechanism is empirically validated through the Global VAR methodology (Pesaran et al., 2004), that allows for a parsimonious representation of the economic dynamics in term of individual countries and their interactions. The spillover effects between each country and the rest of the world is defined through international variables, and account for potential, mostly fiscal, externalities.

The GVAR easily allows to compare the Eurobond scenario with the business as usual benchmark, through forecasts. The model is built in two steps: first, a standard VARX (VAR model with possibly exogenous regressors) is estimated for each country; second, all the country-specific VARX

[18] See Amato et al. (2021) and Amato and Saraceno (2022) for a similar proposal. 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.

are combined and solved contemporaneously, to obtain a unique VAR dynamics to describe global macroeconomic fluctuations, namely the GVAR.

Each country $i = 1, \ldots, N = 13$ is described by a VARX(1,1) model:

$$\boldsymbol{x}_{it} = \boldsymbol{\alpha}_i + \boldsymbol{\beta}_i t + \Phi_{i1}\boldsymbol{x}_{it-1} + \Lambda_{i0}\boldsymbol{x}^*_{it} + \Lambda_{i1}\boldsymbol{x}^*_{it-1} + \epsilon_{it} \tag{43}$$

where ϵ_{it} is a vector of Gaussian shocks, $\boldsymbol{x}_{it}$ is a vector of country specific variables, whereas $\boldsymbol{x}^*_{it}$ is a vector of *foreign* variables, obtained by a weighted average of the corresponding variables from other countries, with predetermined weights $w_{ij},\ i, j = 1, \ldots, N$, usually reflecting macroeconomic international relationships, namely:

$$\boldsymbol{x}^*_{it} = \sum_{j=1, j\neq i}^{N} w_{ij}\boldsymbol{x}_{jt}. \tag{44}$$

Furthermore, $\boldsymbol{\alpha}_i$ and $\boldsymbol{\beta}_i$ are vectors of parameters defining the deterministic VAR components, whereas Φ_{i1}, Λ_{i0} and Λ_{i1} are parameter matrices. For the European countries, the vector $\boldsymbol{x}_{it} = \{g_{it}, b_{it}, r_{it}, e_{it}, p_{it}\}$ referring respectively to real GDP growth rate, debt-to-GDP ratio, nominal interest rate on the 10-years bond, e interest expenditure-to-GDP ratio and primary balance-to-GDP ratio.

Once country specific VAR are estimated, VARXs are then stacked and solved, to obtain an highly multivariate VAR representation of the global economy. Let $\boldsymbol{x}_t = (\boldsymbol{x}_{1t}, \ldots, \boldsymbol{x}_{Nt})$ the stacked vector of all the endogenous variables, then the GVAR solution (Chudik and Pesaran, 2016) is:

$$\boldsymbol{x}_t = \boldsymbol{a} + \boldsymbol{b}t + \boldsymbol{F}\boldsymbol{x}_{t-1} + \boldsymbol{u}_t \tag{45}$$

where $\boldsymbol{a}$, $\boldsymbol{b}$ and $\boldsymbol{F}$ are parameter's matrices that are derived form each individual VARX output and the weighting matrix W. The error term $\boldsymbol{u}_t$ is a linear combination of $\epsilon_t = (\epsilon_{1t}, \ldots, \epsilon_{Nt})$.

The GVAR representation in Equation (45) has then been used to forecast the evolution of public debt-to-GDP ratio based on two different scenarios: the first (*regular prediction*) in which the debt is issued in a business as usual scheme, and the second (*counterfactual or conditional prediction*), in which the Euro Stability bond mechanism is introduced. Following Pesaran et al. (2007), our counterfactual exercise is based on the empirical comparison between the two set of forecasts. In our exercise, conditional predictions are built by imposing linear restrictions on future interest rates, that here are given by the German rate plus the fiscal discipline premium from equation (42).

Formally, for the whole forecasting horizon $h = 1, \ldots, H$, the counterfactual scenario forces the endogenous GVAR variables to satisfy a suitable system of restrictions:

$$\Psi\boldsymbol{x}_{T+h} = \boldsymbol{d}_{T+h} \tag{46}$$

where Ψ is a selection matrix and $\boldsymbol{d}_{T+h}$ is the fiscal discipline premium that is time varying and dependent on lagged endogenous variables. A precise definition of Ψ will be given in Section 4.3.

This counterfactual strategy is particularly convenient in our setup, since by construction the amount of forecasts uncertainty is *mechanically* reduced through the set of linear constraints, that in principle switch off some of the shocks in the model. As shown in section 3.1, the underlying reduction in future volatility of macroeconomic variables leads to beneficial effects in term of welfare as far as individuals and policy-makers are risk averse (Pesaran et al., 2007). This statistical methodology, therefore, is suitable for our exercise, since it describes the functioning of the euro area after the introduction of the Euro-stability bond which has the purpose of switching off contagion risk, while keeping a fiscal discipline mechanism. Moreover, even though the reduction in forecast uncertainty is rather mechanical under the considered methodology, our empirical analysis is very useful to assess both the size of such a reduction in uncertainty and the potential consequences on non-fiscal variables.

Here, we slightly deviate from Pesaran et al. (2007) by assuming that the set of linear constraints, which in our model is the fiscal discipline premium, is not fixed at T for the whole forecasting horizon, but is rather recursively updated on the basis of predictable macroeconomic fundamentals.[19] Being I_T the set of available information up to time T, then, under the regular scenario, predictions are computed as $\hat{\boldsymbol{x}}_{T+h} = \mathrm{E}[\boldsymbol{x}_{T+h}|I_T]$ with forecasting error matrix Ω_{hh}. It can easily be proved that the counterfactual predictions are:

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

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

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

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:

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

It is worth noting that even if $\boldsymbol{d}_{T+h}$ is a nonlinear function of the lagged endogenous variables, it can be predicted as a function of the observations available up to time T. Therefore, conditional on I_T, $\boldsymbol{d}_{T+h}$ can be considered as known, $\forall\ h$.

4.2 Data

To implement our analysis, data from the OECD database and the ECB data warehouse have been used. We collected data at quarterly frequency for a total of 68 observations, spanning from 2002Q4 to 2019Q3. The sample consists of the ten major Eurozone countries[20] and other three non-European countries (China, Japan and U.S.). Therefore, a VARX(1,1) is estimated using five domestic variables for EU countries, namely:

- g_t, the real GDP growth rate;[21]
- b_t, the debt-to-GDP ratio;
- r_t, the nominal interest rate on the 10-years bond;

[19] This hypothesis makes our strategy more flexible, albeit does not allow to focus on the commitment effect over the full forecasting horizon.

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

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

- e_t, the interest expenditure-to-GDP ratio;
- p_t, the primary balance-to-GDP ratio.

whereas for Japan and U.S. we considered just g_t and r_t and for China only g_t due to data unavailability.

Following Pesaran et al. (2007), weights w_{ij} have been ex-ante computed to mimic the trade shares of country i with respect to all the others $j \neq i$. Specifically, trade shares are the average exports plus import from 2015 to 2019 obtained from the International Monetary Fund (IMF), and are reported in Table 1.

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. Data are rescaled such that the columns, sum to one for each country.

4.3 Results: regular and conditional forecasts

Forecasts for the public debt-to-GDP ratio for a five-years horizon (20 quarters starting from 2019-Q4) for all the Eurozone countries have been computed. We estimate regular forecasts in the baseline scenario (without the Euro-stability bond) and conditional forecasts in the counterfactual scenario (with the Euro-stability bond) by restricting the values of the long-term interest rate to those obtained by applying the fiscal discipline premia described in Equation (42). The 9 restrictions on the European interest rates, excluding Germany, are summarized by the selection matrix in Equation (46) defined as:

$$\Psi_{9\times 58} = \begin{bmatrix} -\boldsymbol{\iota} & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \boldsymbol{\iota} & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_8 \\ \mathbf{0}_5 & -\boldsymbol{\iota} & \mathbf{0}_5 & \mathbf{0}_5 & \boldsymbol{\iota} & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_8 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & -\boldsymbol{\iota} & \boldsymbol{\iota} & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_8 \\ \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \boldsymbol{\iota} & -\boldsymbol{\iota} & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_8 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \boldsymbol{\iota} & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & \mathbf{0}_5 & -\boldsymbol{\iota} & \mathbf{0}_8 \end{bmatrix}$$

where $\boldsymbol{\iota} = [0, 0, 1, 0, 0]$ and $\mathbf{0}_k$ is a row vector of zeroes with k columns. The matrix Ψ together with the discipline premium $\boldsymbol{d}_t$ define for each country that $r_{it} - r_{it}^{ger} = \pi_{it}$ where r_{it}^{ger} is the bund rate.

The estimated forecasts are plotted in Figure 2 with shaded areas indicating the 95% confidence intervals. For the sake of simplicity and to avoid combining macroeconomic dynamics and micro-financial issues into the same analysis, the conditional forecasts are built and estimated under the assumption that countries issue all of their public debt in Euro-stability bonds, starting from the first quarter of the forecasting period.

Our results show no significant differences in the two scenarios for the future path of public debt-to-GDP ratio, but the counterfactual analysis (with the Euro-stability bond) provides a consistent reduction in term of estimated confidence intervals. The lower uncertainty on predictions in the Euro-stability bond scenario implies an higher stability for public debt dynamics over the next 5 years in the whole euro area. These findings are in line with the intuition that public debt stability must be interpreted as an improvement in the predictability of future debt trajectories.

Table 2 reports the percentage reductions in expected public debt's volatility between the baseline and the Euro-stability bond scenario at various time horizons. The estimated reduction in future uncertainty grows with the forecasting 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 flattened with the Euro-stability bond. After 5 years, the average reduction in volatility across countries is 68%, ranging from a minimum of 52% (Portugal) to a maximum of 77% (Germany). This evidence is consistent with our theoretical background, as the amount of uncertainty reduction observed with the introduction of the Euro-stability bond is positively correlated with the initial level of fiscal discipline of a specific country. Indeed, for high debt countries (e.g., Italy, Portugal, Spain) we observe a percentage decrease in volatility that is lower compared to the one of virtuous countries (e.g., Germany, Finland, Netherlands). The validity of these results is confirmed by the estimated predictions (regular and conditional) for the interest expenditure-to-GDP ratio (Figure 3), which show no significant difference in the two scenarios. Consequently, improved stability of future public debt is reached without any significant redistribution across countries in the short and medium terms, since the path of interest expenditures under the Euro-stability bond scenario shows no deviations compared to the regular estimate for all the EU countries. The fact that the results hold also for the core country (which in our exercise is Germany) is not counter-intuitive but rather strictly consistent with our macroeconomic framework. The existence of negative fiscal externalities from non-core countries to the core country, which are estimated in the GVAR model with the global exogenous regressors and are represented in the theoretical model with Equation (6), results in a beneficial stability effect even for the country whose funding cost serves as benchmark for the Euro-stability bond rate.

As stressed before, the results we obtain in terms of forecast volatility reduction are not surprising, since conditional forecasts mechanically suppress nine different shocks, and only the German rate is freely predicted by the model. It is worth to emphasize that this aspect supports the robustness of our results for at least two reasons. First, the statistical tool used is consistent with the economic intuition of the Euro-stability bond proposal, which is based on the idea of insulating euro-area countries from sovereign bond mispricing caused by contagion risks while replicating the market discipline mechanism.

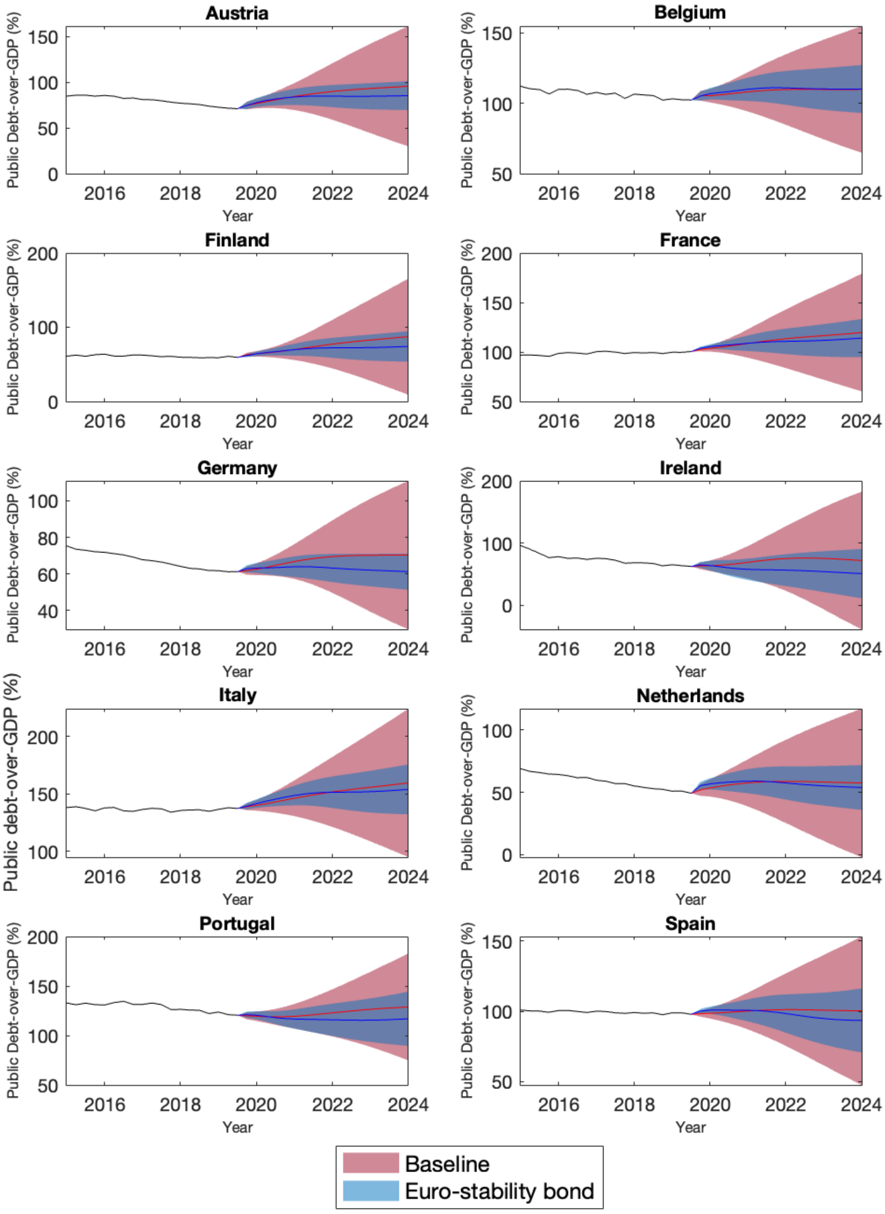

Figure 2: Regular and conditional forecasts for public debt-to-GDP ratio of the euro area countries in the sample for the period 2015-2024. Red and blue shaded areas are the 95% confidence intervals in the two scenarios.

Hence, our results can be interpreted as driven by careful policy design rather than a purely mechanical, statistical effect. Second, while the reduction of volatility is obvious, the size of this contraction is not. Furthermore, this mechanical effect cannot explain heterogeneity across countries, in which the reduction in volatility is related to the starting level of fiscal discipline. In particular, we found that virtuous countries mostly benefit from the introduction of the Euro-stability bond, likely because they are less affected by the costs of the fiscal discipline mechanism, but they gain from the benefits of the scheme.

	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-to-GDP ratio's volatility comparing the baseline and the counterfactual scenarios at different time horizons.

A possible criticism of our exercise refers to the *Lucas critique*, since our analysis is based on a reduced form model. It is in fact well known that policy interventions might alter the structure of an econometric model, and in particular its parameters (Lucas, 1976). In this respect, historical data should not be informative about parameter estimation purposes for the post-policy time and therefore counterfactual analyses based on forecasts might be inaccurate. However, following Pesaran et al. (2007), there are different arguments which make multivariate macroeconoemtric frameworks less exposed to the Lucas critique. The most relevant, given the policy exercise proposed by the paper, are the true empirical definition of a policy change and the aggregation assumption. Concerning the former, the empirical interpretation of a policy change is no trivial and it still lacks a general consensus. Should policy change be treated like a different realization from the same random variable or like a switch in the underlying data generating process? Are different policy regimes draws from a constant distribution of potential policies or changes in the parameters describing this distribution? There is not a unique answer and it is likely very much affected by the type and the magnitude of policy change one is analysing. Secondly, the Lucas critique embodies an agent-based perspective, assuming that the true structure of the economy, even when aggregated in a country-based macroeconomic model, is in line with the individual-based optimal decision processes. However, when data are empirically aggregated individuals heterogeneity are likely averaged out in the value of the estimated parameters, therefore the assumption of a in mean constant structure may seem fair. Despite our framework may hold same features which make it less exposed to the Lucas critique, we are certainly aware that part of the results here presented can be affected by the strong assumption of constant parameters which is at the basis of the reduced-form model (GVAR) estimations exploited to produce our baseline and conditional forecasts. A clear example of this limitation emerge if we consider the additional exercise of the issuance of a Plain-Vanilla Eurobond (PVE) for all countries in the sample. Being the moral hazard problem (and the consequent fiscal profligacy) out of the scope of a standard reduced-

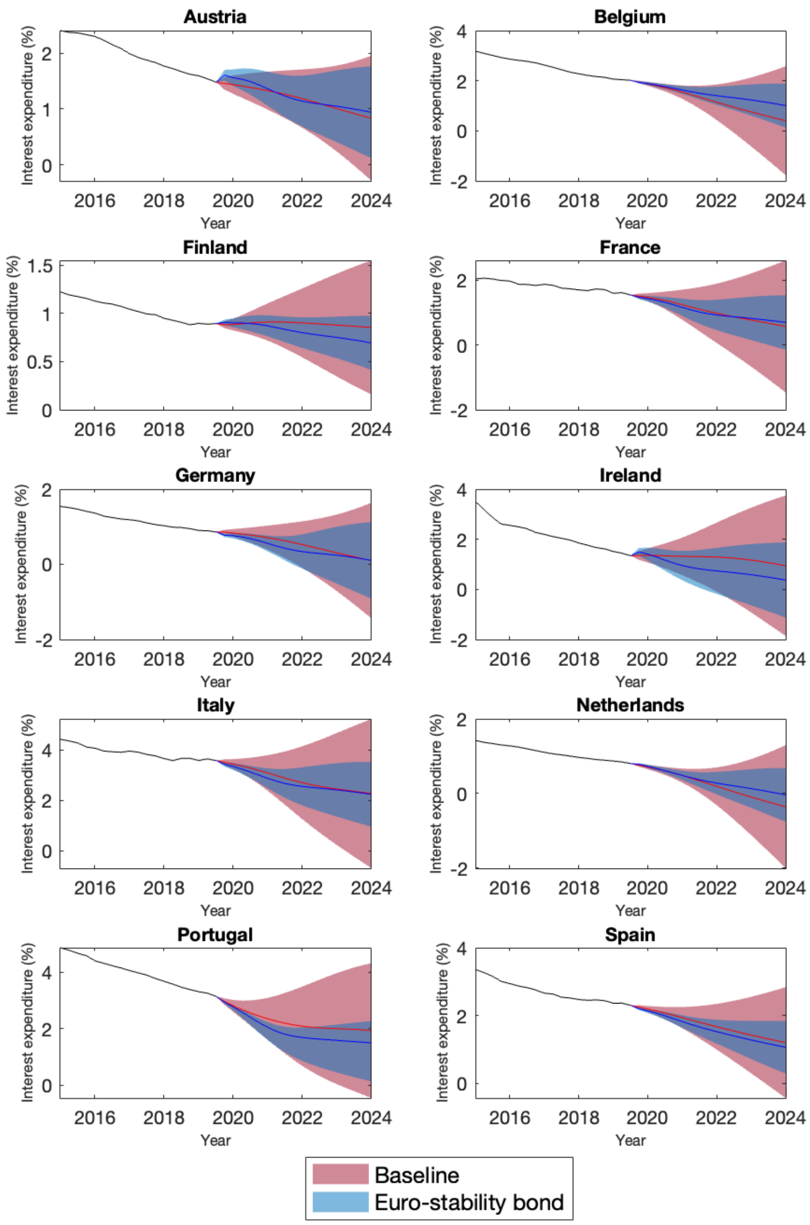

Figure 3: Regular and conditional forecasts for interest expenditure-to-GDP ratio of the euro area countries in the sample for the period 2015-2024. Red and blue shaded areas are the 95% confidence intervals in the two scenarios.

form estimation, conditional forecasts for the public debt ratio and the primary balance for the PVE introduction are even more favourable than for the Euro-stability bond in terms of reduced uncertainty and point estimate.[22] To this extent, the Euro-stability bond we propose is likely less subject to this specific issue of moral hazard since it embeds a penalizing mechanism which induces a cost (through the fiscal discipline premium) for less virtuous governments.

[22]Results of for the GVAR conditional forecasts in the case of a PVE introduction are available upon request.

4.4 Results: event probability forecasts

The results presented in the fan charts (Figure 2) focus primarily on the different predictions in the two scenarios. However, Greenwood-Nimmo et al. (2012) suggest that probability forecasts on some specific and policy relevant events might provide useful information on the future. In particular, probability forecasts refer to quantifying the likelihood a future event might occur.

In the GVAR setup, since the model is completely parametric, and the error term is 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.

For each country i and for a given forecast horizon $H = 20$, we identify the following key events, that can be detected from $\boldsymbol{x}_{T+h}$:

- Event 1: Technical recession, defined as two following quarters of realized negative real GDP growth rate. We compute the probability at time $t + h$ of:

$$g_{it+h} < 0 \text{ and } g_{it+h+1} < 0, \text{ for } h \in \{1, \ldots, 20\}. \tag{47}$$

- Event 2: Achievement of debt-to-GDP target b^*, with $b^* \in \{60, 80, 100, 120\}$. We compute the probability at time $t + h$ of:

$$b_{it+h} \leq b^*, \text{ for } h \in \{1, \ldots, 20\} \tag{48}$$

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

$$\frac{1}{h}\sum_{i=1}^{h} e_{t+i} \leq \bar{e_i}, \text{ for } h \in \{1, \ldots, 20\}. \tag{49}$$

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

$$\sum_{n=1}^{4}\sqrt{\frac{1}{4}(b_{it+h+n} - \bar{b_i})} \leq \sum_{n=1}^{4}\sqrt{\frac{1}{4}(b_{it+h-n} - \tilde{b_i})} \tag{50}$$

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

In this paper, probability forecasts have been obtained through Monte Carlo simulations, where a number S of out-of-sample trajectories from the GVAR model in both scenarios have been drawn. For this exercise, we assume absence of uncertainty on the parameters, which are therefore set at their point estimates regardless the standard error values produced by the GVAR estimation. GVAR shocks are still Gaussian with null average and known variance/covariance matrix computed from point estimates. Following Greenwood-Nimmo et al. (2012), the probabilities of such events might be estimated as:

$$\frac{1}{S}\sum_{s=1}^{S} I[event_{it}^{s}] \tag{51}$$

where $I[event_{it}^{s}]$ is just an indicator function that is 1 if the *event* at time t for country i is observed in the simulated s-trajectory and 0 otherwise. For instance, for a technical recession, defined as a sequence of two contiguous negative GDP growth rates, $I[event_{it}^{s}] = 1$ if we observe a sequence of two negative values for the GDP growth rates and is 0 otherwise. This experiment has been iterated for $S = 100,000$ times, and the results averaged, to obtain an estimate for the desired probabilities.

Observing the results on the probability forecasts for the four designed events in the two scenarios provides insights about the ability of the Euro-stability bond to dampen the likelihood that negative events like recessions will occur or to improve the macroeconomic system's capacity to stabilize fiscal dynamics over time.

Figure 4 shows the probability forecasts for the technical recession (Event 1). The results suggest that the probability of recession tends to converge, in the medium term, to values in the Euro-stability bond scenario that are lower than those in the baseline. These results have two caveats. First, the probabilities are small in both cases, moving from a minimum of 0 to a maximum of 3 % (for Ireland). This is not surprising, as our forecasts for real GDP are optimistic for the future growth dynamics. Our last historical observation was the third quarter of 2019, so estimates do not account for the unusual fiscal dynamics that have affected the Eurozone since 2020 (caused by the Covid-19 pandemic and the war in Ukraine). Second, even for countries displaying an initial spike in the probability of recession in the Euro-stability bond scenario above the baseline scenario (i.e., Belgium, Finland and Ireland), then in the medium term these estimates reduce, perhaps because of the Euro-insurance bond's disciplining mechanism, which initially exposes some countries to higher interest rates. Probability forecasts for Event 2 are illustrated in Figure 5 and 6, whose 3D plots report the probability of reaching a debt target as a function of time and debt-to-GDP ratio targets. The results show that these probabilities converge to medium-run values that are positively correlated with the target regardless to the scenario considered. Moreover, in most of the countries, the probability of reaching a lower debt-to-GDP targets (i.e., 60 and 80) is higher with the Euro-stability bond, even though when the threshold increases (i.e., 100 and 120) we observe the opposite. This conclusion is in line with our theoretical foundation, that a common debt instrument that embeds a fiscal discipline mechanism would increase the probability of more stable public debt-to-GDP trajectories.

The results for Event 3 are reported in Figure 7. In this exercise, we evaluate each country's probability of maintaining a path of interest expenditure that is in line with (or better than) its historical average. The probabilities of keeping the country-specific interest expenditure-to-GDP ratio below its historical average are reported. Probabilities are high (close to 1), which can be explained by noting that the estimated forecasts (for both the baseline and the counterfactual scenarios) for interest expenditures are characterized by a marked negative trend (Figure 3). These results suggest that these probabilities are substantially similar in the two scenarios for all the countries, with the exception of a negligible deviation for Ireland where the Euro-stability probability falls below the baseline scenario. Keeping a similar path in the interest expenditure-to-GDP ratio in the Euro-stability bond is a necessary condition to meet the principle of avoiding unacceptable cross-country fiscal redistribution, which would question the proposed scheme's political feasibility. Similar paths in the probabilities of the event suggest that no significant differences in the interest expenditure-to-GDP ratios would be induced by adopting the Euro-stability bond.

Finally, Figure 8 reports the probability forecasts for Event 4, on the public debt stability over time. The two scenarios share similar paths over time for all countries, converging to medium-run values that are generally higher in the Euro-stability bond scenario than in the baseline scenario (except for Portugal). In this framework, in the short run, high-debt countries as Italy, Portugal, and Spain tend to have an higher probability of maintaining 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.

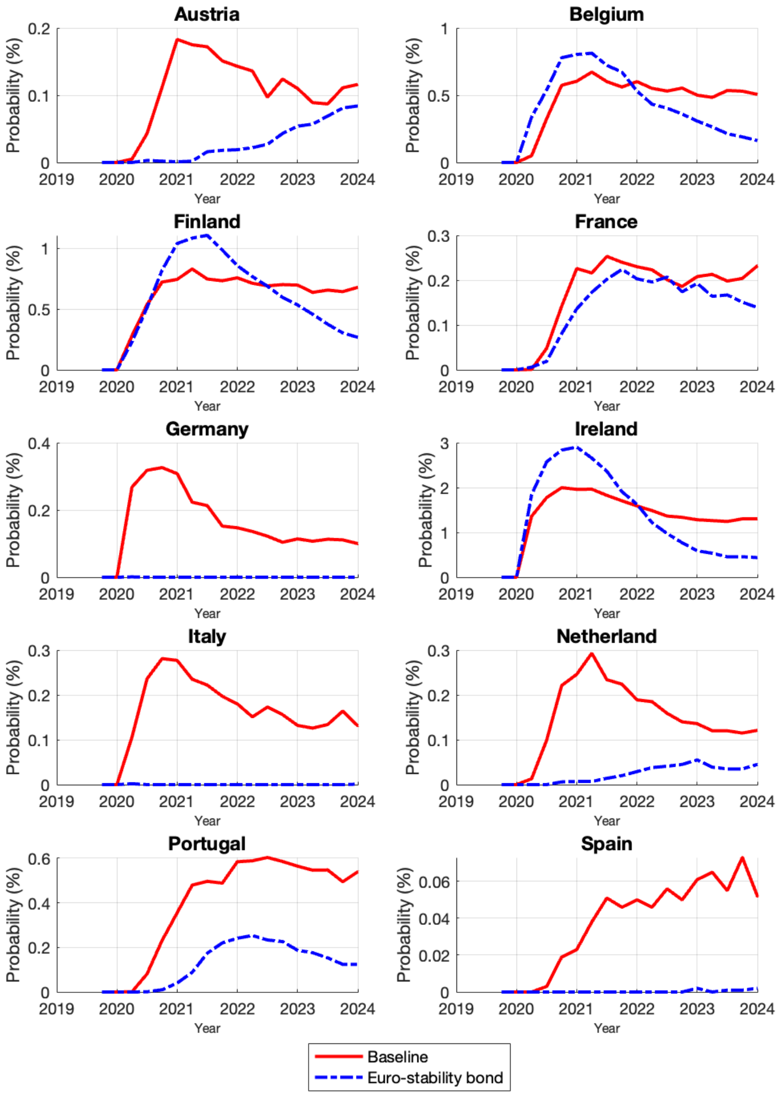

Figure 4: Event probability forecasts for the Event 1 – Technical recession.

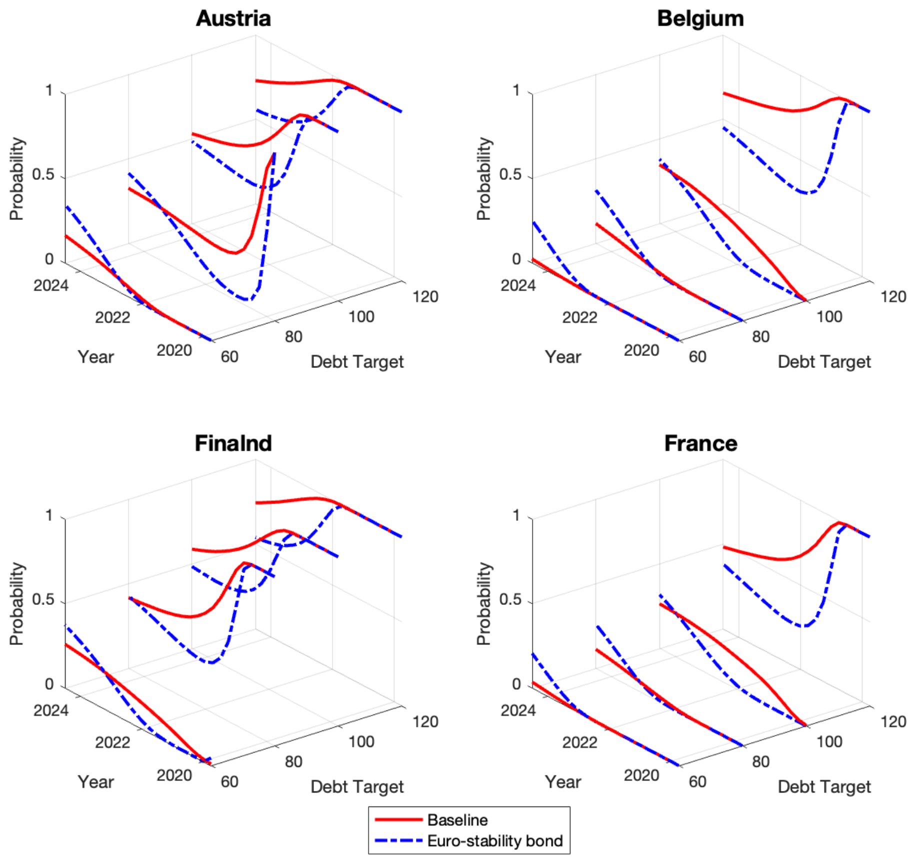

Figure 5: Event probability forecasts for the Event 2 – public debt-to-GDP targets.

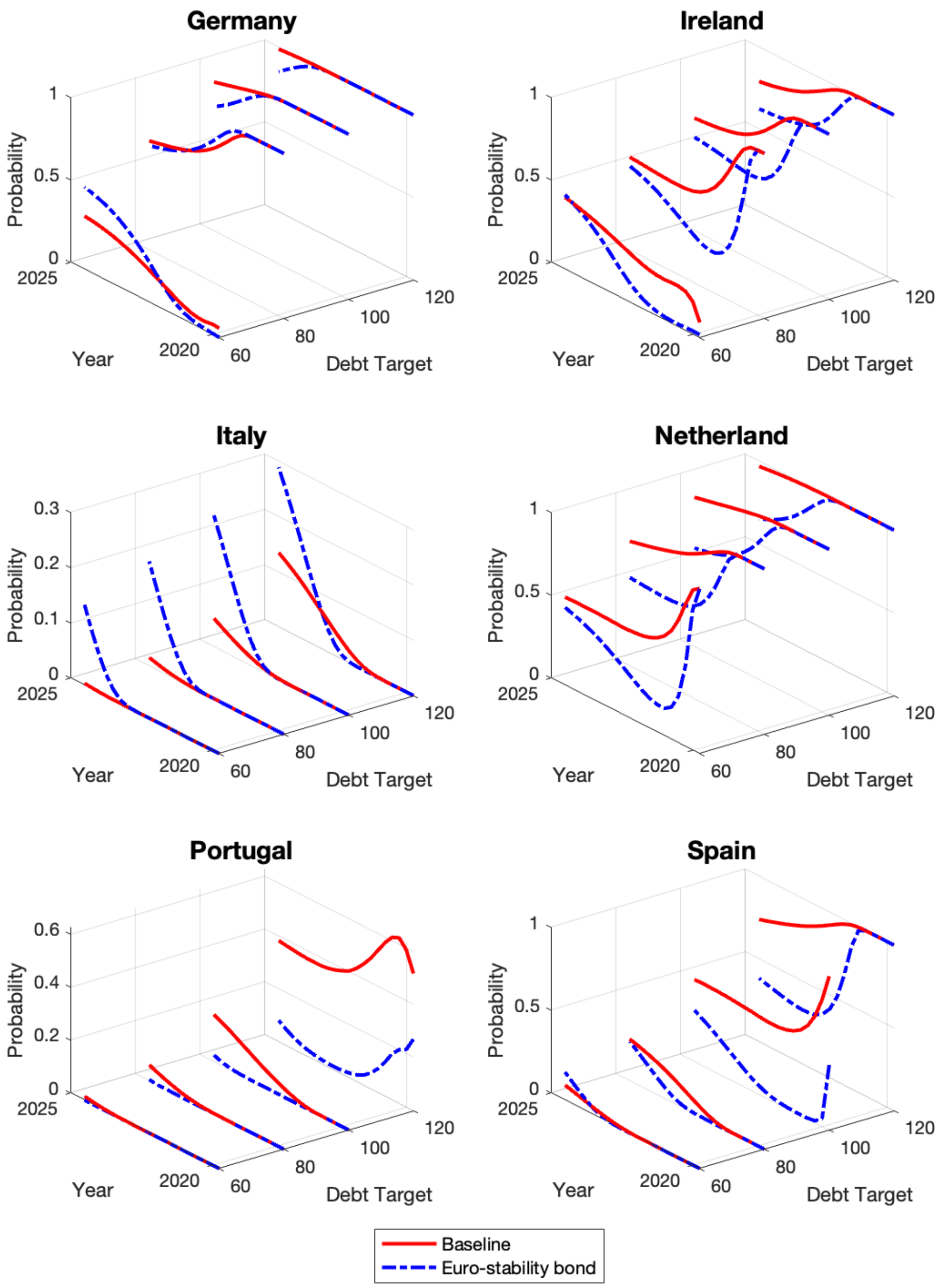

Figure 6: Event probability forecasts for the Event 2 – public debt-to-GDP targets.

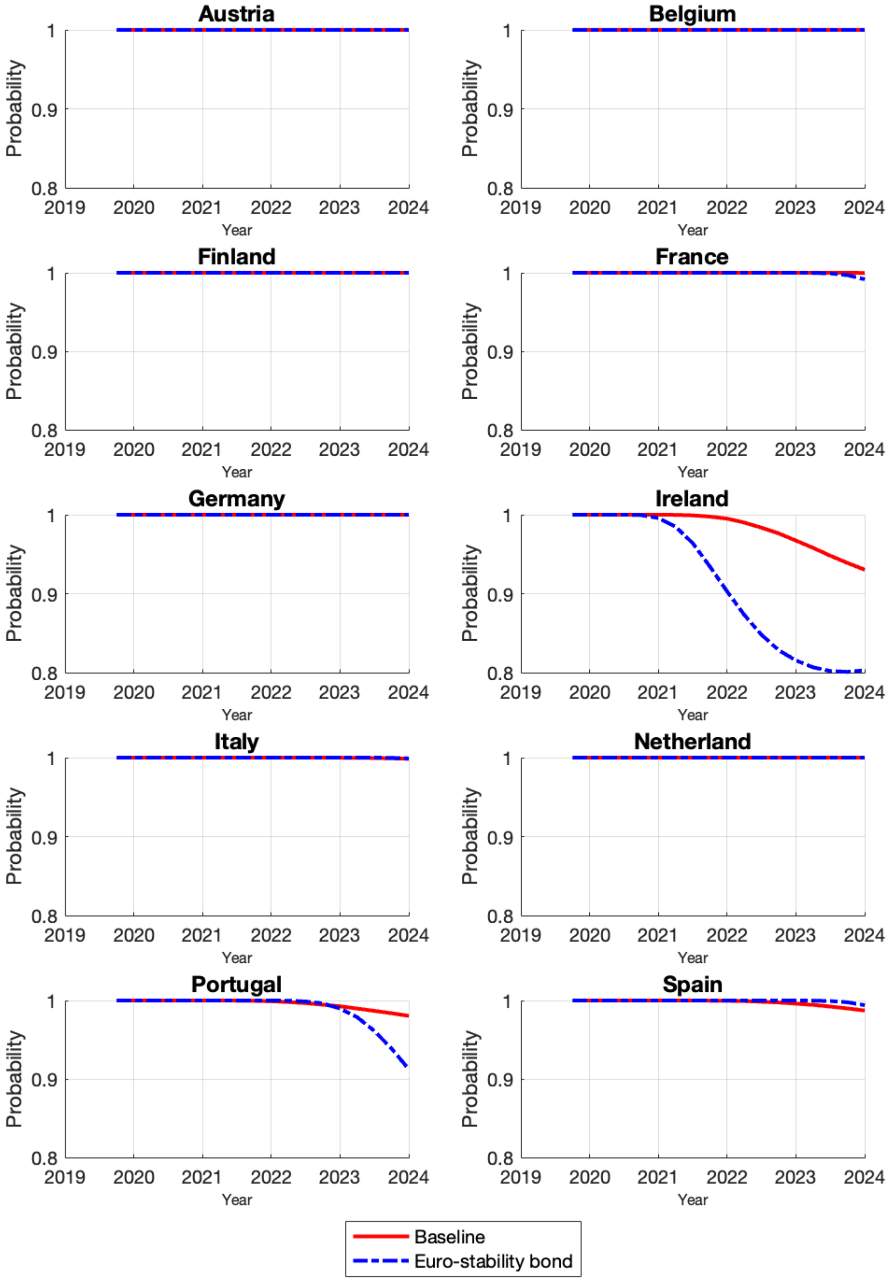

Figure 7: Event probability forecasts for the Event 3 - interest expenditure-to-GDP path.

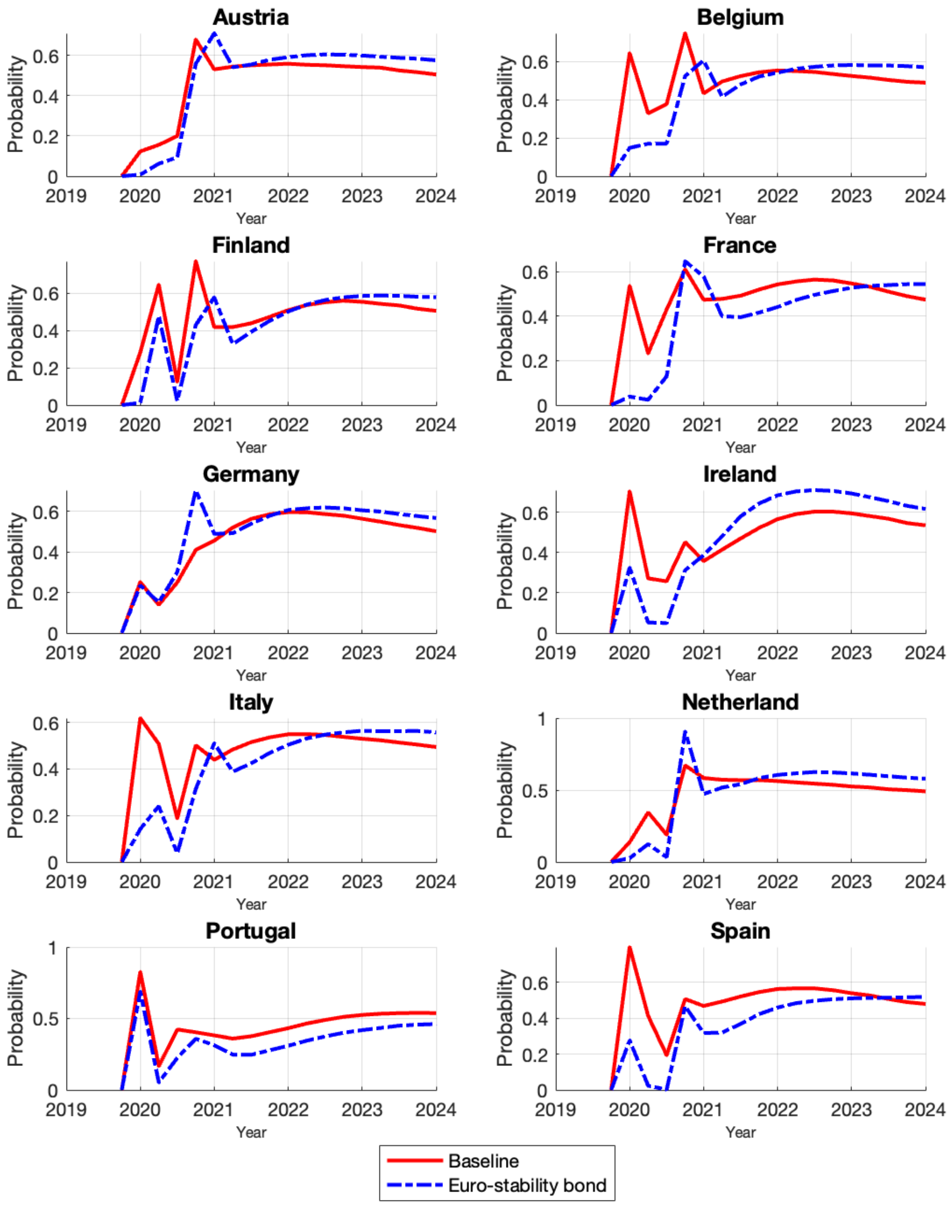

Figure 8: Event probability forecasts for the Event 4 - public debt stability.

5 Conclusion

We propose a scheme for sovereign debt mutualization in the Eurozone that complies with the guiding principles to establish a central fiscal capacity in the EU. Our Euro-stability bond does not involve significant short-term redistribution across countries or incentives to fiscal profligacy. The 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 use them to borrow may pay an extra fiscal discipline premium that is based on their fiscal fundamentals. In our main analysis, the fiscal discipline premium replicates the market discipline without incurring the contagion effects that caused mispricing of the European sovereign securities in the last two decades. The extra payments that result from country-specific spreads would be accumulated as EU's own revenues. In the short run, such revenues would be significant (estimated, based on our empirical model, in 0.66% of the Eurozone GDP); however, the fiscal discipline induced by the Euro-stability bond would cause this amount to decrease to around 0.10% of the Eurozone GDP after five years.

A simple structural model of the economy helps us to illustrate how the proposed scheme would function. Our main theoretical results show that the Euro-stability bond can reproduce market discipline while increasing the social welfare of all countries (including the core country) with respect to real market discipline, because of the improvement in macroeconomic and fiscal stability. We also discuss how a more encompassing version of the Euro-stability bond could be used to substitute for the EU's fiscal rules.

To complement our theoretical analysis, we estimate a GVAR à la Pesaran et al. (2007), that includes the Eurozone countries, U.S., Japan, and China, and use this model to predict the future evolution of public debts and other standard macroeconomic variables under two scenarios: the baseline scenario, which 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 forecasts in the Euro-stability bond scenario. Our empirical results reveal no significant differences in the future evolution of the public debt-to-GDP ratios in the two scenarios but suggest a consistent reduction in the estimates' levels of uncertainty in the conditional forecast with the Euro-stability bond with respect to the baseline. Moreover, the improvements in the stability of public debt is obtained with no significant differences in the paths of the interest expenditure-to-GDP ratio in the two scenarios for all countries, thus avoiding cross-country redistribution in the short run.

Finally, we use our empirical model to assess (by means of event probability forecasts) the Euro-stability bond's ability to decrease the probability of certain adverse macroeconomic and fiscal events. With a horizon of 20 quarters, our results suggest that introducing the Euro-stability bond may reduce the medium-run probability of recession in all countries, compared to the baseline scenario. The probability of reaching lower public debt targets (i.e., 60 and 80 percent of GDP) could also improve, confirming the theoretical prediction that the proposed scheme would increase fiscal discipline and stabilize future trajectories of the public debt-to-GDP ratio.

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