European Union Sovereign Debt Level Control

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A Senior Thesis for

Major in Economics

Department of Economics

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May 1st, 2025

Abstract

The European Union is a monetary union where member states control their fiscal budget. Yet some overborrow, imposing debt-spiraling risks for themselves and financial externalities for the rest. I propose a taxation mechanism imposed by the EU monetary authorities to restrain irresponsible fiscal behaviors, corresponding to the twofold concern of deficit spending and the overall debt level. The optimal tax estimation model incorporates a country-specific financial distress cost measure, historical European Central Bank assistance programs, and a replication of the debt sustainability condition. The proposed mechanism has positive implications for EU financial stability. Although I do not find evidence for a Covid-period structural break, the taxation mechanism has much room for evolvement in today's changing EU regulatory policy landscape.

Acknowledgement

I owe this beautiful thesis journey to Prof. Antonella Tutino, my advisor. The experience of conquering difficult problems with you is invaluable. I am also grateful to Prof. Richard Ball for introducing me to the statistical tools that brought me thus far. I thank the Economics Department and my peers for an irreplaceable experience.

"fatti non foste a viver come bruti, ma per seguir virtute e canoscenza"

—Dante, Inferno 26.119–120

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1 Introduction

A number of economists have documented the source of the European Union's overborrowing problem (De Grauwe, 2015; Feld, 2015; Baldi, 2016). Ever since the commitment to a monetary union in 1999, the rules of which were outlined by the Maastricht Treaty in 1992, the ECB controls euro's exchange rates and the countries are left with fiscal policy as their main decision-making. While the countries are supposed to be jointly responsible for the health of the EU balance sheet, the lack of sufficient fiscal policy regulation and the ECB's equal treatment of its member's sovereign bonds encouraged aggressive fiscal borrowing in the decades leading up to the Global Financial Crisis. From 1999 to 2007, there were 34 instances of borrowing over 3% of the country's GDP in a year, a deliberate prohibition stated in the Maastricht Treaty (Feld, 2015). By 2007, Irish, Portuguese, and Spanish banks have each loaned more than 150% of GDP to the private sector (Lane, 2012). After the financial crisis, doubts were cast upon EU governments' ability to absorb non-performing loans, and thus the pulling away of investments and decreased accessibility to capital widened the sovereign bonds' premium gaps, ultimately leading to several sovereign debt crises as the premiums became too high for the countries to borrow sustainably.

Perhaps the most poignant failure of EU's sovereign debt management is the inherent moral hazard of a monetary, but not fiscal, union. Irresponsible members overborrow and hope that the deteriorated financial condition will be mediated by the entire union. A single member's financial distress raises the risk premium on Euro bonds, and all member states have to bear a higher cost of capital. The European banking system can only alleviate the distress to a certain extent, as once enough negative shocks such as defaulting incidents happen, the banking system quickly succumbs to the spread of financial contagion (Acemoglu, 2015). The ECB is rightfully concerned about the member states' financial wellbeing and whether they pose a systemic threat to the region. Allowing irresponsible behaviors to accumulate means at least a high bailout cost and at most extinguishing contagion and restructuring debt programs at the loss of future growth and Euro competitiveness.

My project takes up the ECB perspective and tries to address this persisting moral hazard problem. Although the European Banking Union established a decade ago has been successful at unifying regulations and supervising major banks, the sovereign central banks still have total discretion on borrowing and on being lenders of last resort for domestic banks. The

danger of the ECB losing monetary control to fiscally irresponsible members is still present—the EU needs a strong and direct disciplining mechanism (Brunnermeier et al., 2012). This thesis proposes a country-specific tax on the sovereign government to constrain their borrowing under the thresholds stated in the 1997 EU Stability and Growth Pact (SGP); the makeup of the tax reflects the ECB's twofold concern both for individual member's fiscal wellbeing and for the financial externality it may cost the rest of the union. Taxation as an incentive compatibility mechanism is an especially relevant topic now. Currently, the EU faces a heightened level of financial fragility after the ECB temporarily lifted the SGP rules in 2020 and purchased €1.85 billion worth of debt securities in support of necessary government spending to combat COVID-19 (Quaglia et al., 2023). As of the yearend of 2024, EU average government gross debt is at an alarming 87.4% of GDP, significantly above the 60% of GDP ceiling proposed by the SGP (Eurostat). Coupled with other concerns such as high energy costs due to war in eastern Europe and an innovation deficit, it is imperative that the EU states strive for a good fiscal standing to embrace the challenges to come (Draghi, 2024). The objective of my thesis, therefore, is to shape a theoretically sound optimal tax estimation model that seeks to guide and improve the fiscal debt resilience and financial stability of the union.

2 Literature Review

A number of works have commented on the structure of the Maastricht Treaty's efficacy and structural problems, as well as to address the debt crisis problem circa 2012. Historically, economists have documented countries restraining borrowing behavior in the years leading up to 1999, and overborrowing once in the monetary union. With the implicit assumption of partial or full bailout administered by the ECB, investors tend to view the risk levels of all sovereign debt as intimately connected and co-moving, which is at the root of the overborrowing moral hazard (Lane, 2012; Inman, 2013). Economists explored stronger regulations regarding the solvency and financial resilience of major European banks and national banks, such as the establishment of Single Supervisory Mechanism (SSM) in 2014 which harmonizes banking regulations, as well as the European Safe Bonds (ESBies), a "safe" and diversified portfolio of sovereign debts to improve financial stability (Brunnermeier et al., 2016). However, improving EU's ability to weather harsh financial winters is one thing, and supervising prudent sovereign borrowing during economic prosperity in preparation

for the hard times is another. So far, there are few proposals on enforcing the borrowing constraint at the EU level.

My thesis takes its main inspiration from a proposed enforcement on bank-level overborrowing in Acharya et al.'s 2010 paper "Measuring Systemic Risk". The paper assumes a central bank's perspective on managing the systemic externalities that irresponsible banks may impose through their risky lending behaviors to the extent of defaulting. The proposed taxation model achieves an efficient outcome, which is the systematic financial stability achieved once the idiosyncratic expected shortfall (ES, i.e. the entire deposit portfolio that is lost when defaulting happens) and the systemic expected shortfall (SES, i.e. the bank's expected contribution to a future systemic financial crisis because it fails to meet the reserve requirement in the current period) are factored into the tax. Acharya's model provides a solid foundation for me to extrapolate bank-level taxation to the country-level. Both banks and sovereign countries are debtors to their investors, enjoy bailout packages from a higher monetary authority, and are supposed to meet a reserve requirement/SGP borrowing limits. My optimal tax model modifies the ES and SES to suit EU realities while using the SGP rules as measurements of idiosyncratic and system risk levels. I make two significant contributions to this literature: expanding the debt level estimation formula to fit the classic government debt accumulation model (Lehnert, 1999) and debt sustainability conditions (Piketty, 2014); and rethinking the taxation components to reflect the bailout programs' burden on the ECB and fiscally responsible countries.

In 2007, Almeida and Philippon, in their paper "The Risk-Adjusted Cost of Financial Distress", proposed a distress cost estimation model for bond-issuing firms. The authors incorporated bond yield premia and recovery rate as the risk-adjustment when formulating the probability of default; the distress cost is the loss in value of the firm given the event of default, normalized by the systematic default risk (risk-free yield). In order to make this strategy work on the sovereign countries in this study, I expanded the "loss-given-default" component to reflect the country's loss from financial penalties and exile from the bond market, whereas the authors took this term to be given and synonymous as the unrecoverable portion of its bond issuance portfolio. In specifying the source of a sovereign distress cost, I show that a country suffers its own welfare-loss, and is penalized upon its externalities on the rest of the union.

A handful of past literature have specified the government's budget constraint—its primary deficit and previous-debt servicing costs equal to tax revenue and current debt, where debt is a stock variable (Barro, 1979; Lehnert, 1999; Debrun et al., 2019). This serves as the basis of my debt level estimation. An important discussion within this literature is the debt sustainability condition "r-g differential" which garnered much attention in Thomas Piketty's 2014 book *Capital in the Twenty-First Century*, where he proposed the golden rule of long-term nominal government bond interest rate equating nominal GDP growth rate. To construct the default condition in my country welfare maximization function, I replicate this debt sustainability condition, which is a good indicator of a country's proximity to default: the bigger the difference when r>g, the less the country's repayment ability. However, recent studies have questioned the relevancy of Piketty's golden rule, especially concerning how a sustained low-interest-rate environment could imply that public debt has no fiscal cost and little-to-none welfare cost (Blanchard, 2019; European Commission, 2022). A recent study projects negative long-run r-g differentials for most European countries in the next 20 years, meaning heightened debt-raising capacity and virtually no unfavorable r-g differentials compared to the previous decades (Heylen et al., 2024). Nevertheless, I hold the Piketty's condition to be relevant and mathematically fitting for my model, since it had reliably tracked EU's debt sustainability in the past decades, during which one observes mostly positive r-g differentials. With this assumption, I replicate Piketty's debt sustainability condition in Section 3.5.

3 Theoretical Framework

3.1 Debt Dynamics

I start by introducing the components that motivate government borrowing and its budget constraint (Debrun et al., 2019). Every year, the government accumulates a certain amount of deficit and issues an amount of new debt B_t^s. The deficit is the result of a government's primary deficit and interest payments to services previously-issued debt:

$$T_t^s - G_t^s - Z_t^s = (1 + R_t^s)\, B_{t-1}^s + B_t^s \tag{1}$$

where the left-hand side is the primary surplus S_t^s expressed as tax revenue less government expenditure and transactions, and R_t^s is the interest rate promised in year t. Rewriting the

equation and normalized by GDP y_t^s, we have:

$$\frac{B_t^s}{y_t^s} = \frac{(1+R_t^s)\,B_{t-1}^s}{y_{t-1}^s} * \frac{y_{t-1}^s}{y_t^s} - \frac{S_t^s}{y_t^s} \tag{2}$$

Expressing $\frac{y_{t-1}^s}{y_t^s}$ with GDP growth rate $\frac{1}{1+g_{y,t}}$, the debt-to-GDP ratio is:

$$b_t^s = \frac{(1+R_t^s)}{1+g_t^s} b_{t-1}^s - \frac{S_t^s}{y_t^s} \tag{3}$$

Per SGP rules, a member state cannot accumulate more than 3% of GDP worth of debt in a year, which is equivalent to the difference in debt issued and the primary deficit. The optimal budget constraint is therefore described by:

$$b_t^s - b_{t-1}^s + \frac{S_t^s}{y_t^s} = \frac{(R_t^s - g_t^s)}{1+g_t^s} b_{t-1}^s \leq 3\% \tag{4}$$

Nevertheless, the country may choose to breach the threshold and borrow more than 3% of GDP every year until it falls into a debt trap, which is when the interest rate promise is too high for investors to believe in the possibility of repayment. At that point, the country is exiled from the bond market and defaults on all existing debt promises. The threshold at which the debt trap happens is further discussed in Section 3.6.

3.2 Financial Distress Cost

As the country's debt position worsens, the investors perceive a higher probability of defaulting and ask for a higher rate of return, which is a direct cost the country has to bear. I use the risk-adjusted cost of financial distress model from Almeida and Philippon (2007) and modify it to best explain the loss experienced by the bond-issuers:

$$\phi_t^s = \frac{q_t^s * LGD_t^s}{1+R_t^{eu}} \tag{5}$$

where the sovereign loss-given-default LGD_t^s, in the event of the default probability q_t^s happening, represents the loss a sovereign country bears if its debt is no longer sustainable. ϕ_t^s is therefore a time-specific flow variable, as if the distress cost could only happen for this period, but never again in the future. To discount the cost incurring at the end of the

period into present terms, the loss is normalized by the European "risk-free" rate R_t^{eu}, which is, in reality, the ECB standard interest rate of a Eurobond that is made up of weighted components of each EU member's bond rate. This ECB bond is therefore considered diversified and safer than any individual sovereign bond because it's issued on behalf of and backed by all EU members.

While the LGD component for the investors is simply their total debt holdings less the recoverable portion, loss for a sovereign country is very different. Once a country defaults, it suffers two things: the impossibility of borrowing in the near future and the tax penalty. The assumption is that the country is exiled from the bond market for the second year, and is able to quickly restructure and enter the market again in the third year. Obviously, a country may be stuck in a debt trap for multiple years, but for simplicity and for the model to best suit EU realities, I assume a loss of only one-year's access to borrowing, B_{t+1}^s , for the EU monetary authorities will likely intervene through last-resort lending and debt restructuring[1]. For example, Greece received assistance packages from the EFSF (European Financial Stability Facility) in 2011 and 2012, and didn't return to bond issuing until April 2014, losing its debt financing option for 2013. I will later show what it means to incorporate the tax component to the sovereign loss-given-default, which is formally expressed as:

$$LGD_t^s = \frac{B_{t+1}^s}{1 + R_t^{eu}} + \tau_t^s \tag{6}$$

It may seem that the value $1 + R_t^{eu}$ is used in both Equations 5 and 6 for the same term. However, the discounting happens twice: B_{t+1}^s is first discounted to the present end-of-the-period value in LGD_t^s, which is then present-value-discounted in Equation 5 as a part of the financial distress cost. The second operation reflects the timing of estimating ϕ_t^s, which is valued at the beginning of the present period t and factored into the debt level estimation of the present period. I use the ECB standard rate R_t^{eu} when discounting future period debt-issuance, and not the country-specific interest rate R_t^s, to standardize present value across the EU members. Using the country-specific rate, which has a higher risk premium than the ECB standard, lowers the LGD_t^s estimation, while this difference is in

[1]The assistance packages will be repaid in the future time window and benefit the ECB and the countries that assisted through loans. Since all repayment schedules are yet to happen, and therefore no observable behavior, my model doesn't include repayment installments. In other words, neither is the ECB expecting nor are the beneficiary countries planning for repayments.

fact the borrowing cost born by the country—the country's loss should increase with the risk premium.

3.3 Debt Position

When a country first enters the EU, its debt position in market value is $w_0^s = B_0^s$. At any given year after the entry, the debt level is an aggregate of deficit and distress cost accumulated in each period, adjusted with time-discounted with risk-free rate:

$$w_t^s = B_0^s + \sum_{n=1}^{t} \left[\left(R_n^s B_{n-1}^s + G_n^s - T_n^s + Z_n^s - A_n^s \right) \prod_{j=n}^{t} \left(\frac{1+R_j^s}{1+g_j^s} \right) \right] + \phi_{t-4,t}^s \tag{7}$$

$$\phi_{t-4,t}^s = \sum_{n=t-4}^{t} \left[(\phi_n^s) \prod_{j=n}^{t} \left(\frac{1+R_j^s}{1+g_j^s} \right) \right] \tag{7a}$$

The main component of debt level is the aggregate of previous-period debt servicing and primary deficit, less the assistance amount A_n^s, which is the amount received from ECB financial assistance programs, including programs specifically for bailout of sovereign banks and asset purchasing programs aimed for covid-relief, administered in year t. Assistance amount is treated as if the country receives it completely for free, without any repayment concerns, which contradicts the fact that bailout programs are long-term loans from the ECB, and more accurately loans from the fiscally well-behaving countries. However, I treat A_n^s in the model as such for two reasons: mainly, the repayment schedules start in 2030s, hence I do not have the relevant repayment behavior data to work with; moreover, in order to receive bailout, a country must propose recovery and growth strategies as a demonstration of willingness and capacity to repay, therefore making the repayment installments contingent upon the country-specific growth characteristics—to model the repayment behavior would be beyond the scope of my study. Nevertheless, empirically, this assistance amount does lower the country's debt level during years of default; more importantly, this setup ameliorates the problem of a structural break during defaulted years, since the beneficiary countries never technically defaulted and the ECB programs shouldered much of the costs in making the country's debt bond-worthy again. Hence, there is no need for an explicit modeling of structural break, and the debt level estimation is continuous even though there are years of exile from the bond market.

When aggregating annual deficits and distress costs, every period's deficit and distress cost amount needs to be translated to current terms. $\frac{1+R^s}{1+g_s}$, representing the country's repayment ability as the ratio of its interest rate and GDP growth rate, is a replication of the Piketty debt sustainability condition "r-g"[2] (Piketty 2014). If the country's debt servicing cost is higher than the country's growth rate, the current period deficit is amplified because the pool from which tax revenue is collected, the GDP, cannot keep up with the growth of interest payments. In other words, the ratio is a crude approximation of how many years of GDP growth the country is promising as this year's debt repayment. The product term in Equation 7 therefore represents the accumulation of debt repayment wellbeing (an amplification or dampening of deficit): to translate the deficit that happened $t-n$ periods ago to current time t, I adjusted it with the product of annual $\frac{1+R^s}{1+g_s}$ ratios from time n through t (Blanchard, 2019). The ratio approximates the reality of perceived debt sustainability levels—ceteris paribus, investors perceive the higher-GDP-growth-rate country to be more sustainable in the long run, even though the returns are similar, resulting in a punishing or dampening effect on the country's deficit.

Finally, financial distress cost is a term of the debt level estimation that exists outside of the deficit aggregation. As ϕ_t^s is a flow variable, it necessarily exists in debt level estimation as an aggregation. Yet it is unreasonable either to sum past distress costs from each year, or to factor in the current year's costs only. As the primary component of ϕ_t^s, LGD_t^s, is an expression of both the current ECB tax cost τ_t^s and the foreword-looking bond market exile cost B_{t+1}^s, the perception of distress cost mainly concerns the immediate future as well as the near past where the previous occurrences of distress cost have not dissipated throughout the financial system. I use a 5-year backward-looking moving window to represent ϕ_t^s's time-relevance in Equation 7a. The same debt sustainability condition ratio is applied. The aggregation of distress cost begins on the year of entry to the monetary union, assuming: 1) that the countries managed their debt prudently and constrained themselves to a negligible amount of distress cost in the years leading up to the entry (i.e. $\phi_{1998}^s \approx 0$); 2) that the vetting process by the union, upon entry, rejects applicants with existing significant financial distress.

[2]The Piketty condition is replicated by virtue of log approximation: $\log\left(\frac{1+R}{1+g}\right) \approx r-g$.

3.4 Defaulting and the Expected Shortfall

As per SGP rule, the “safe" debt level is under 60% of GDP: $\frac{w_t^s}{GDP_t^s} \leq 60\%$. We also define the EU aggregate debt position as $W_t = \sum_{s=1}^{N} w_t^s$, and the EU aggregate GDP as $Y_t = \sum_{s=1}^{N} y_t^s$. w_t^s encompasses debt-issuance both by the central bank and the municipalities of a government. The financial linkages between local and state banks are assumed to be strong and efficient enough that, even when the country “selectively” defaults on some of its debt obligations, investors view the event as country-wide and the entirety of w_t^s is defaulted.

When a country defaults, EU authorities such as the European Stability Mechanism (ESM) act as lenders of last resort by purchasing unwanted government debt to stabilize price level and maintain Euro competitiveness. The expected shortfall of a country is therefore the recoverable amount of its defaulted debt, i.e. the amount of debt securities covered by EU-level asset-purchasing packages: $ES_t^s = w_t^s * \rho^s$, where ρ^s is the time-invariant country-specific recovery rate. Investors who hold those securities are compensated to the extent of the coverage of those assistance packages. Since 1999, there are only 5 EU member states that have received significant financial assistance from the ESM due to high levels of financial distress or de-facto default events: Ireland, Greece, Spain, Cyprus, and Portugal. Due to the lack of data, for the observable countries, ρ^swill be the amount of assistance packages as a percentage of defaulted debt; for those unobservable countries, they're expected to fully repay the defaulted debts. Setting $\overline{\rho} = 1$ instead of a fraction avoids ex-ante moral hazard imposed by the countries—as a regulatory $\overline{\rho}$ must be consistent for all EU members. If it is a fraction, the governments would have a morally hazardous incentive to calculate the amount they're allowed to be irresponsible for, which encourages debt binging, especially in times of high default risks. Of course, $\overline{\rho} = 1$ doesn't reflect EU realities. Notably, when issuing assistance packages, EU monetary authorities are primarily motivated by price stability and a feasible repayment schedule, where the amount of investor loss and the GDP recovery speed of its beneficiaries are of secondary concerns, which is why the recovery will always be a fraction in reality.

3.5 Optimal Tax

The planner aims to constrain the countries' borrowing behavior under two thresholds states in the SGP, namely 1) a deficit of under 3% of GDP per year; and 2) an overall debt level of under 60% of GDP. The optimal tax, therefore, must reflect both constraints so

that no breaches and no taxes would be observed in equilibrium. Although the taxation is proportionally increasing with the expected bailout costs in the event of defaulting and/or regional financial crisis, since the tax exists solely as an incentive compatibility constraint in the equilibrium, the planner doesn't expect this tax to cover the bailout funds necessarily to inject monetary stability.

$$
\begin{aligned}
\tau_t^s = q_t^s \cdot ES_t^s \cdot \Bigg(& 1_{\left[\frac{\left(R_t^s - g_t^s\right)}{1+g_t^s} b_{t-1}^s > 3\%\right]} \cdot \beta_0 + 1_{\left[\frac{w_t^s}{y_t^s} > 60\%\right]} \cdot (1 - \beta_0) \Bigg) \\
& - \left[60\% y_t^s - w_t^s\right] \cdot 1_{\left[60\% y_t^s - w_t^s < 0\right]} \\
& \cdot \Bigg(1_{\left[\frac{\left(R_t^s - g_t^s\right)}{1+g_t^s} b_{t-1}^s > 3\%\right]} \cdot \beta_1 + 1_{\left[\frac{w_t^s}{y_t^s} > 60\%\right]} \cdot \beta_2 + 1_{\left[\frac{\left(R_t^{eu} - g_t^{eu}\right)}{1+g_t^{eu}} b_{t-1}^{eu} > 3\%\right]} \cdot \beta_3 + 1_{\left[\frac{W_t}{Y_t} > 60\%\right]} \cdot \beta_4 \Bigg) \\
& - \frac{w_t^s}{W_t} \left[60\% Y_t - W_t\right] \cdot 1_{\left[\frac{\left(R_t^s - g_t^s\right)}{1+g_t^s} b_{t-1}^s < 3\%\right]} \cdot 1_{\left[60\% y_t^s - w_t^s \geq 0\right]} \cdot 1_{\left[\frac{W_t}{Y_t} > 60\%\right]} \\
& \cdot \Bigg(1_{\left[\frac{\left(R_t^{eu} - g_t^{eu}\right)}{1+g_t^{eu}} b_{t-1}^{eu} > 3\%\right]} \cdot \beta_5 + 1_{\left[\frac{W_t}{Y_t} > 60\%\right]} \cdot \beta_6 \Bigg) \qquad (8)
\end{aligned}
$$

The expected shortfall accounts for the costs of bailing out a particular defaulted country, and is dependent on which debt thresholds it breached—or in some cases, both thresholds. Well-behavers aren't taxed, and the irresponsible countries can't be taxed beyond the full extent of their risk-adjusted expected shortfall. In other words, the punishment is not amplified in response to the transgression. Furthermore, overborrowing in a singular year is assumed to pose much less risk than having a dangerously high debt position, meaning $0 < \beta_0 < 0.5$.

The $[60\% y_t^s - w_t^s]$ component accounts for the systemic distress that the one overborrowing country is costing the rest of the union when overborrowing occurs at the EU-level. This externality cost is equal to the amount of overborrowing above the 60% of GDP ceiling set by the SGP. By assuming that the ceiling, albeit vaguely arbitrary, is a reasonable alarm threshold, the model uses the overborrowed amount as a good proxy for the costs that the rest of the union starts to feel through channels such as a higher euro premium and reassessments of financial linkages. Clearly, the more a country overborrows, the larger will its contagion impact be during financial stress and larger the τ_t^s burden should be. An

important implication behind this proportionality is that the ECB tax revenue is directly linked with its ability to administer bailout programs. Although we don't expect the tax to be ever collected in a perfect world, the tax serves as an insurance against individual debt crises and systemic events.

As mentioned earlier, a country's financial distress cost includes the tax component within its loss-given-default component. The rationale is twofold. Firstly, the country pays the full extent of its expected shortfall ES_t^s in a defaulting scenario. Additionally, this component also accounts for the high borrowing cost when issuing new debt once the exile from bond market is over, given how investors will be risk averse towards newly-restructured bonds, even though they're unlikely to default again with the EU bailout programs. Secondly, in the case of losing its debt financing ability, the country will have to raise taxes in the following years to compensate for its shortfall in government spending, which presumably is high to stabilize its economy during a critical period. The rise in taxes will result in a loss of GDP growth, which is contained within the $[60\%y_t^s - w_t^s]$ component[3].

There are four unevenly-weighted conditions for this tax component to occur—the two country-specific debt thresholds and two additional EU-level debt thresholds. The weighting scheme has the following assumptions:

> Assumption 1: a country can at most be punished by its overborrowed amount (Equation 8a). Intuitively, a financially-irresponsible member demands its fellow members to be more financially responsible, whereby they become more constrained and less well-off. Therefore, a country is penalized on its misbehavior even if the union is not under any financial distress.
>
> Assumption 2: whether there is distress at EU level is weighted more than whether the country is overborrowing (Equations 8b and 8c).
>
> Assumption 3: the relative importance of the two SGP thresholds stays the same at the country and EU level (Equation 8d).

[3]There usually is an interconnected-ness factor attached to this component, characterizing the severity of a country-specific contagion (Acharya et al. 2010, Buse and Schienle 2019). However, I am assuming away this factor because it results in multiple equilibria in the maximization problem, amounting to the equivalence of no interconnected-ness. In other words, each country is equally contagious to the union as the next in this model.

$$\begin{cases} \beta_1 + \beta_2 + \beta_3 + \beta_4 = 1 & (8a) \\ 0 < \beta_1 + \beta_2 < 0.5 & (8b) \\ 0.5 < \beta_3 + \beta_4 < 1 & (8c) \\ \frac{\beta_1}{\beta_2} = \frac{\beta_3}{\beta_4} = \frac{\beta_0}{1-\beta_0} & (8d) \end{cases}$$

There's an additional component of the tax that lays a burden on the well-behaving countries during times of EU-level financial stress. It seems unfair, but stable and well-behaving countries like UK and Germany have assisted their less well-off neighbors during times of systemic distress, often in terms of bilateral loans between governments. To account for this reality, responsible countries who have health deficit and debt levels are burdened with a contribution to the EU-level overborrowing problem $[60\%Y_t - W_t]$ when they occur $(\frac{W_t}{Y_t} > 60\%)$ proportional to how much their own debt position makes up the EU-level debt $\frac{w_t^s}{W_t}$. Assumptions 1 to 3 apply to this component, as $\beta_5 = \beta_0$ and $\beta_6 = 1 - \beta_0$ determine the weighting scheme of this burden, according to which type of overborrowing the EU is experiencing.

3.6 Country Maximization Problem

Now suppose all countries have incentives to borrow more, and that their utility is strictly increasing with their debt. Note that the ECB as the planner does not need to know the country-specific utility functions, but rather to estimate the appropriate τ_t^s. The maximization problem is therefore the debt amount less tax, subject to equations 1-8:

$$max. \;\; E(u(w_t^s * 1_{\left[\frac{\frac{1}{3}\sum_{n=t}^{t+2}(R_n^s)}{\sum_{n=t}^{t+2}\left(\frac{g_t^s}{p_{[n,\;\;n+2]}}|g_t^s>0\right)}<\zeta\right]} - \tau_t^s)) \tag{9}$$

where the debt position w_t^s only contributes to the country's utility when it is sustainable. To fulfill this condition, the country's three-year moving range of nominal interest rate to nominal GDP growth rate ratio must be smaller than a calibrated ratio ζ. In other words, interest rates cannot be significantly higher than domestic economic growth for a sustained period of time. This condition draws directly from Piketty's insight on debt sustainability, whereby the juxtaposition of the debt-servicing cost (i.e. 10-year government bond interest rate promised) and the nominal growth rate suggests the country's ability to

service its promises (Piketty, 2014). We can assume that the threshold for debt trap can be expressed as a ratio between interest rate and GDP growth rate: $\frac{R_t^s}{g_t^s} > \zeta$. The ζ threshold represents the number of years-worth of nominal GDP growth that a country may commit to servicing one year-worth of debt interest payments without losing investor confidence in its ability to consistently repay in the long run. In other words, ζ is the threshold above which the debt is overwhelmingly likely to spiral. It is impractical to estimate the threshold for each individual country in a particular year, as most developed countries never come close to defaulting due to factors like sufficient accumulation of reserved capital, sustained low-interest-rate conditions, and investor overconfidence. Subsequently, I will choose a time-invariant pseudoproxy ζ for all euro-using countries in Section 4.

The denominator of the ratio skips the years of GDP growth rate, where $p_{[n,\ \ n+2]}$ is the tracker of the number of positive growth rate years in the three-year time period. Admittedly, excluding those negative-growth years makes the model less powerful at suggesting planner policy during years of significant financial distress. However, the optimal tax is a tax that never occurs, whereby all countries are incentivized to well-behave, significantly lowering the chances of debt-induced financial distress. Additionally, the planner may want to switch to a subsidy and recovery-motivated disciplining model during stressful times, rather than a taxation-oriented model like this one.

It's important to consider whether we're recounting τ_t^s through the financial distress cost component ϕ_t^s when calculating debt position w_t^s. The higher the tax, the higher the estimated default rate will be because the country's debt structure is less resilient due to the tax payout to the ECB. Most of the heightened tax amount will then be normalized by the heightened default rate q_t^s. If the default rate is disproportionately low for a high tax amount, a large portion of the tax will be recounted. However, since this default rate mismatch implies inefficient incorporation of fiscal irresponsibility information from the investors' perspective, my model assumes away this market inefficiency.

4 Data and Methodology

In order to estimate the optimal tax amount for each country from 1999 to 2023, I specify the countries and their observational windows with the following concerns. Although 28 countries have historically joined the EU, only 20 of them adopted the euro as their official

currency and therefore fully under the ECB's monetary governance. Therefore, observational start year is the year when euro is adopted, not when the country joins the EU. Since my model needs certain backward-looking variables like the baseline debt position B_0^s, and forward-looking variables like next period debt-issuance B_{t+1}^s, I include the year before euro-adoption and the most recent 2024 observations in my dataset. In this section, I discuss the calibration and interpretation of three crucial parameters: Sovereign Bond Rate, Default Rate, and Assistance Amount, for which I have included a sample of finished calibration for Germany, Italy, and Greece (Table 1). The three countries are representative of strong, moderate, and weak fiscal discipline, and therefore differ significantly in their parameters.

When gathering data for the country budget constraint, I used the European Union official database Eurostat for annual GDP, revenue, expenditure, and market value of fiscal debt datapoints. The monthly spot interest rates of the country and of the Euro area's 10-year-maturity bond data are gathered from a private database named "the Global Economy" and from Eurostat, respectively. As it is used to represent the EU risk-free rate, the Euro area interest rate is an ECB estimation of the zero-coupon yield curve using a weighted scheme of AAA-rated sovereign bond yields. Although 10yr sovereign bond interest rate[4] is the standard measure of return on country-specific fiscal debt, a shortcoming is that it doesn't apply to debts that exist in non-bond forms or bonds of other maturity windows. Nevertheless, I show in Figure 1 that 75% of the country-year observations have more than 64% of the debt portfolio being 10yr sovereign bonds. Therefore, the 10yr sovereign bond yield[5] still holds a convenient and reasonably strong explanatory power. In calculating an annual average yield, no winsorizations of outlying monthly yields are used, as I expect sovereign interest rates to efficiently reward or punish the country's perceived debt sustainability.

Default probability is an important component in this estimation of financial distress cost and the optimal tax amount, which is calculated as an equally-weighted average of 10yr bond default rates, rated monthly by four independent credit rating firms: Fitch, Moody's, S&P, and Scope. They all operate under the EU sovereign credit rating regulations and use almost identical scales from "AAA" to "C", but give slightly different default rates for 10yr sovereign bonds. The differences are miniscule. While calculating an annual default rate,

[4]Not all bond-issuing countries have observable 10yr interest rates. E.g. Estonia, a fiscally conservative member, didn't start issuing 10yr-bonds until 2020.

[5]All negative interest rates are capped to the zero lower bound, as certain countries, starting 2019, discouraged savings and encouraged investments by pushing short-term rates below zero.

I carry over previous ratings for non-reported months, unless specified by the dataset as missing; additionally, while the monthly rating can be "SD" (selectively defaulted), I mark the default rate as 1, for I assume a unified fiscal debt planner such that "SD" really means a systematic default. Figure 2 shows the distribution of this annual default probability for all countries since 1999. No country experienced systemic default for a full year. As expected, if a country requires assistance and actively receives bailout packages (represented by red dots) from the ECB during the 2010 sovereign debt crisis (shaded years), it exhibits exorbitant or relatively high default probabilities in the immediate and following years. During such years, the default rate is interpreted as the possibility of being abandoned by the monetary parent ECB, whereby the countries would truly default due to the lack of bailout assistance. Notably, the fact that credit rating agencies did not adjust default risks upward in the years leading up to the crisis period may serve as evidence for investor overconfidence.

Financial assistance, or bailout packages, have been granted to five countries in EU's history: Cyprus, Greece, Ireland, Portugal, and Spain. Bond recovery rate is calculated by comparing the total assistance amount given during the crisis episode to the outstanding debt in the year of receiving the initial assistance. Due to the European monetary authorities granting the assistance amounts according to the countries' idiosyncratic growth and restructuring abilities, the recovery rates are time-invariant for the simplicity of the model. Additionally, the packages are granted and distributed to the countries at various, perhaps ad-hoc, instances during the crisis. Because of this convoluted process, the annual assistance amount is simply the total amount over the years of active assistance.

Of the five countries, Spain has the lowest "recovery rate" at 4.45% of its debt position, and I'm compelled to argue that this figure cannot be counted as a formal recovery rate for Spain. Shown in Figure 3, all countries experienced a higher premium except for Spain and Cyprus. Cyprus is a special case because its sovereign debt crisis had been well underway since 2010 and had soon been exiled from the bond market, hence receiving assistance in 2013 only lowered the public's perception of its risk. However, Spain is different because it was only receiving assistance to restructure its national banks to preemptively safeguard itself from a foreseeable debt crisis, whereas the other four countries were deep into the crisis. This explains why the risk premium reacted favorably towards Spain receiving assistance. For this reason, I exclude Spain's "recovery rate" observation. Other countries[6] that received

[6]Italian 10-year government bond yield reached 7.06% in November 2011, posing serious dangers of debt

informal ECB assistance through secondary market bond purchases are not counted as participants of a formal bailout program, and neither are the countries who benefited from the Pandemic Emergency Purchase Programme (PEPP)[7] after 2020.

Finally, I wish to address the calibration of ζ, the debt unsustainability threshold. Shown in Figure 4 is the distribution of the three-year-forward window of $\frac{R^s}{g^s}$ ratio specified in Equation 8, from 1999 to 2024. Of all country-year observations in my dataset, financial assistance years happen approximately 2.5% of the time, hence the ζ threshold is at $\frac{R^s}{g^s} = 2.35$ so that 97.5% of the observations have reasonable debt sustainability.

5 Results and Analysis

5.1 Stylistic Features of Debt Level and Tax Estimations

Across all country-year observations, the average debt level estimation from Equation 7 exceeds the reported debt amount by 16.7%; excluding the four countries that have received substantial assistance packages, the excess is 3.5%. This expected excess amount represents the factoring of debt sustainability condition, r-g differential, and the additional element of financial distress cost. Shown in Figure 5, Luxemburg is the only country to ever experience lower-than-actual debt level estimation. Due to persistent primary fiscal surplus and outstanding debt sustainability conditions (interest rate to growth rate ratio significantly lower than 1), it experienced a small, negative debt level estimation since 2000, meaning no negative effects from debt issuance. Among the countries that experienced significant financial distress, which is reflected by large excess estimated debt level, Portugal and Italy's problems persisted since the sovereign debt crisis in the early 2010s, Cyprus was able to rein in the heightened debt level estimation starting around 2018, and countries like Ireland and Spain were able to effectively restructure their banks, which is shown on the graph as spikes in debt but closely-tracking debt level estimations.

To address the elephant in the room, Figures 6 and 7 show a combination of causes that led to the spiral of Greece's debt level estimation, which reached 11.4 times its GDP in 2016. Because Greece experienced both extremely high default rates (from 2011 to 2020) and

unsustainability. Despite receiving indirect support from the ECB through secondary market government bond purchases in 2012, Italy never experienced bond market exile due to debt unsustainability. Source: Eurostat.

[7] PEPP consists of sovereign bond purchases to assist Covid relief (ECB). Please refer to Appendix Figure A2 for information on its data structure and cleaning.

precarious debt sustainability conditions (2015 and 2016), the debt level estimation model is particularly unforgiving. Cyprus suffered a similar spike and leveling out of the default rate starting 2012, yet it maintained surprisingly good debt sustainability due to sufficient and timely bailout packages. The abnormally high debt level estimations for Greece and certain other countries, on the one hand, show the severe and lasting impact of a period of near-default financial distress, but on the other hand, shows that the model needs to be supplemented with some distress-dampening factor that prevents a spiraling debt estimation.

As the tax is imposed by the ECB, it has the discretion to adjust the β terms in Equation 8, according to its understanding of the importance of the 3% deficit threshold relative to the 60% debt level threshold. My baseline tax estimation uses a β_0 of 0.3. Using this parameter and assuming that this relative importance is fixed for all three components of the tax (Equation 8d), the tax estimation yields 51 tax occurrences among 412 available country-year observations.

To put the cost of tax in perspective of the country's budget, I choose to represent the tax burden as a ratio of tax and government revenue (Figure 8). For a total of 412 country-year observations, enforcing this tax would mean an average extraction of 3.6% of revenue every year. However, this number is skewed by the country-year observations where financial assistance occurred, as extreme tax estimations, extreme debt level fragilities, and bailout programs often coincide. Excluding financial assistance year observations, this tax model suggests an average annual cost of 0.5% of government revenue from 1999 to 2024, if the tax had been implemented and the countries had disregarded this cost every year.

Plotting best-fit lines to the left and right of the debt level threshold (60% of GDP) in Figure 8 shows how the country's tax burden increases at a faster proportionality once the SGP rule is breached, supported mathematically by Equation 8. As expected, as long as the country is fiscally responsible, a relatively higher or lower debt-to-GDP ratio has statistically insignificant effects on the tax burden. In comparison, once on the right side of the threshold, the government spends 0.00516%[8] more their annual revenue for every 1% increase of debt-to-GDP ratio, meaning that the tax is increasingly punishing after the threshold. This feature of the tax model counteracts the moral hazard whereby, perceiving a flat cost of breaking the SGP rule, countries are incentivized to aggressively overborrow

[8]Significant at the 1% level.

once the threshold is breached.

5.2 Implication on Financial Stability and European Financial Competitiveness

Tax burden is expected to increase during times of significant financial distress, during which the countries often have to raise debt beyond the SGP limits in support of their failing national banks. Figure 9 shows this positive correlation: for every unit increase of the financial distress index "CISSIndex", tax burden increases 0.0065%[9]. From a scale of 0-100, the Composite Indicator of Systemic Stress (CISS) is a weighted aggregation of five major economic indicators, with a cross-correlational structure (Holló, 2012). Its method accounts implicitly for country differences, and the weighting scheme for the indicators is catered for the whole of euro area. A higher score suggests higher financial instability in the region. In Figure 9, 50% of the tax burden observations are below an index value of 14.3 (to the left of the solid grey line), and 90% of them are below an index value of 33 (to the left of the dashed grey line). The three panels roughly correspond to three different debt-sustainability scenarios that the tax model is reacting to: well-behaved EU where almost all countries comply with SGP rules (left panel); distressed EU where certain countries have alarmingly high deficit and debt levels, and the union's financial integrity is being challenged (middle panel); and EU in crisis, where certain countries have defaulted, bailouts are underway, and almost all members experience a spillover effect (right panel). The tax burden, which increases with this financial stress, serves as a restraining mechanism on the member states before the worst scenario is actualized. This tax model thus has an implication for the long-term financial system stability and European competitiveness[10] in the eyes of foreign investors.

5.3 Covid Period "Structural Break"

Starting 2020, the ECB temporarily lifted the SGP thresholds and initiated the Pandemic Emergency Purchase Programme (PEPP) for all 19 of its euro-using members[11], resulted in a cumulative sovereign bond purchase of 1,635,462 million euros by February 2025 (ECB). This operation is similar to the financial assistance packages during the 2010s' sovereign debt crisis, and raises the question as to whether the mass assistance led to a structural

[9]Significant at 10% level, with P-value of 0.070 for 411 observations.

[10]Tax burden does not have a meaningful correlation with trade competitiveness, as shown in Appendix Figure A1 using USD-EURO exchange rate as a measure of trade advantage.

[11]Two countries are not on the list: UK, which exited in 2020, and Croatia, which joined in 2023.

break in overborrowing behavior.

Theoretically, the years during which the SGP general escape clause was activated (March 2020 to Dec 2023) is not a structural break period, as countries expect the thresholds to reapply and their debt level should revert to mean after an initial period of aggressive borrowing. However, several factors complicate this intuition empirically. Firstly, the PEPP relief given by the ECB catered towards country-specific recovery and growth needs, together with long-term repayment installments that have yet to factor into the countries' fiscal planning. As shown in Figure 5, almost all countries exhibited a slight kink in their reported and estimated debt levels since 2020 because of PEPP. Secondly, the reinstatement of SGP rules in Jan 2024 was revised to differentiate and respect country-specific fiscal positions and growth prospects, stressing diverse and viable growth plans over strict compliance and allowing for a larger degree of fiscal liberty (Menguy, 2024). The reversion to mean borrowing behavior is unlikely to happen. Thirdly, the revised SGP has only been implemented for 1 year at the time of this thesis. I am only able to work with observations up to 2023 with available data.

Nevertheless, a differentiated plotting of debt level trends and a Chow test suggest no structural break up to 2023. In Figure 10 and Table 2, best-fit lines are plotted for debt level estimation observations before and after the PEPP "treatment" starting 2020. Before 2020, the debt level grows at a statistically significant 2.8% of GDP per year. No significant growth trend is estimated for the post-2020 period, meaning on average, the debt level to GDP ratio did not move systematically during the years of PEPP administration. On the other hand, using pre- and post-2020 sample groups, I used the Chow test to evaluate the null hypothesis ($H_0 : \beta_{pre} = \beta_{post}$) that the coefficients are equal across samples, which yielded a statistically insignificant chi-squared value of 1.9 (Table 2). Until further observations become available in the coming years, my analysis finds that PEPP-era debt level estimation does not structurally break from previous trends.

6 Conclusion and Discussion

The optimal tax model that this thesis proposes is one possible solution among many to solve the problem of overborrowing within the European Union. My approach hinges on a willingness to enforce the SGP rules uniformly across the union. Theoretically, the tax

accounts for the twofold concern of the monetary planner: the cost of financially assisting individual countries and the cost of mitigating spillover effects when a country is in a weak fiscal position. I have demonstrated the debt level estimation, which features the debt sustainability condition and an original conceptualization of the financial distress cost. The taxation components correspond to and are designed to counteract the monetary union moral hazard issue and distress spillover realities. In this section, I wish to discuss potential improvements to the model and future research considerations.

Covid years saw the ECB's willingness to provide financial assistance and suspend the SGP rules during economic downturns. As it weighs the merits and rigidity of the historical SGP duo-thresholds, which constitute the foundation of this thesis, it seems that the EU is leaning towards a more lenient and flexible approach when it comes to fiscal debt level. As the 2024 SGP revision introduces a country-specific Medium-Term budgetary Objective (MTO), it is very likely that sovereign debt level and financial stability modelling requires a different and increasingly diverse set of tools. My proposal of an incentive compatibility tax model could be adjusted to fit country-specific parameters, but it would take administrative prowess to pass the political hurdles and embrace the idea of a tax mechanism. Currently, the preventative arm of the SGP is mainly working to update fiscal rules and guidance mechanism in response to the exploration of MTO (Menguy, 2024). The enforcement of taxation—of what is essentially a punitive measure—requires the oversight of an EU fiscal regulatory body.

Yet the idea of this new regulatory body could raise questions regarding democracy. If the tax is enforced, the ECB would be sharing fiscal power with the member states. In times of severe economic recessions or unpredictable shocks such as the Covid years, the ECB's discretionary decision on assistance packages would be crucial to the member states' economic recovery and growth prospects, as their fiscal spending is now choked by the taxation thresholds. Is this a form of fiscal kidnapping? Since the union was formed, the ECB has been the monetary authority, while the EU members have had the fiscal power to themselves. The re-introduction of strictly enforced SGP rules would upset this dynamic. Although my research does not explicitly consider political consequences, a possible way to combat this unsavoriness within my optimal tax model is to adjust the β terms in Equation 8, to the end of reducing the punishment for borrowing more than 3% of GDP every year. This amounts to implicitly permitting countries to break the deficit threshold in particular

years in response to emergencies, as long as they maintain an overall debt level wellbeing.

Future research on the taxation model may happen in a number of directions. Within the model, r-g differential is used to replicate the debt sustainability condition, which, in a changing landscape of research, may no longer apply in the future. Incorporating the interconnectedness of sovereign debt risks could more accurately represent the financial spillover effects when one national bank is distressed by debt unsustainability (Buse and Schienle 2019). Additionally, countries might have some incentive to help their neighbors and trade partners when they're in financial distress, but incorporating country-country aid may steer the focus away from studying ECB-level debt control. Perhaps future research could clarify whether neighborly aids are significant in comparison to ECB financial assistance packages. Beyond the financial interconnectedness, future studies may look into monetary and trade links with non-Euro-using EU member states: although they're less intimately linked than the Euro-using countries are among themselves, they are nevertheless integrated under the same financial regulatory structure.

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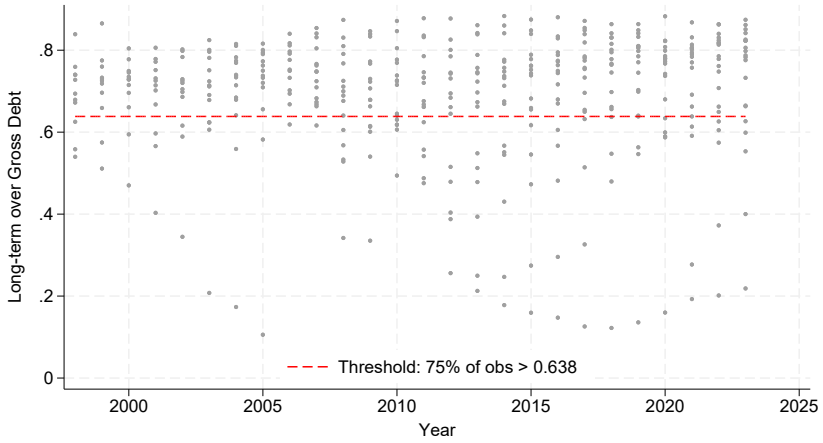
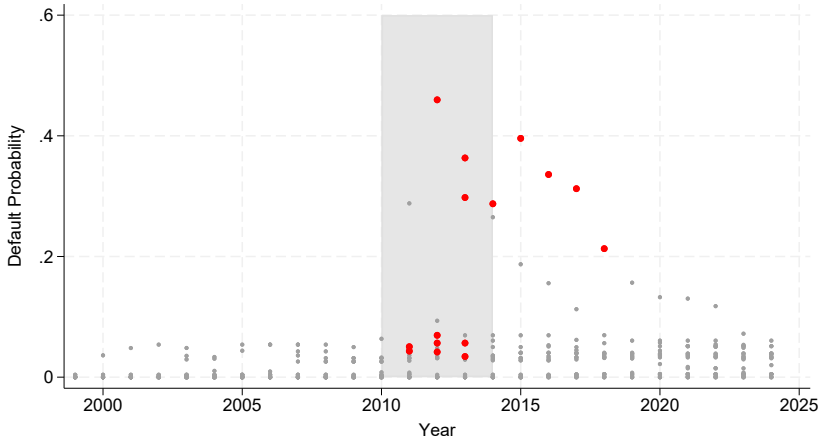
Figures and Tables

Figure 1: Long-term Bonds over Gross Debt (20 countries, 1999-2024)



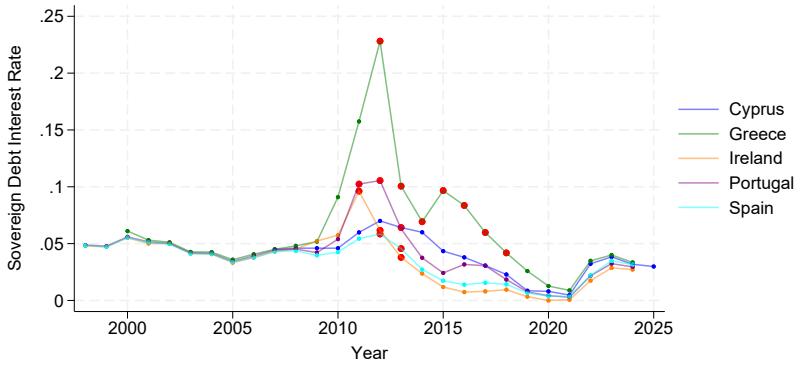
Notes: Figure 1 shows the percentage of long term, i.e. 10yr maturity, bonds within a country's debt portfolio, plotted over the years. The red dotted line is the cutoff point between the bottom 25% of observations and the top 75%.
Source: Eurostat

Figure 2: Annual Default Probability(20 countries, 1999-2024)



Notes: Figure 2 plots country-year observations of default probability, where red dots signify observations of countries that actively received financial assistance in the years thereof. The shaded area represents the period of EU sovereign debt crisis (2010-2014).
Source: www.theglobaleconomy.com

Figure 3: Annual Long-term Bond Interest Rate (Selected Countries, 1999-2025)

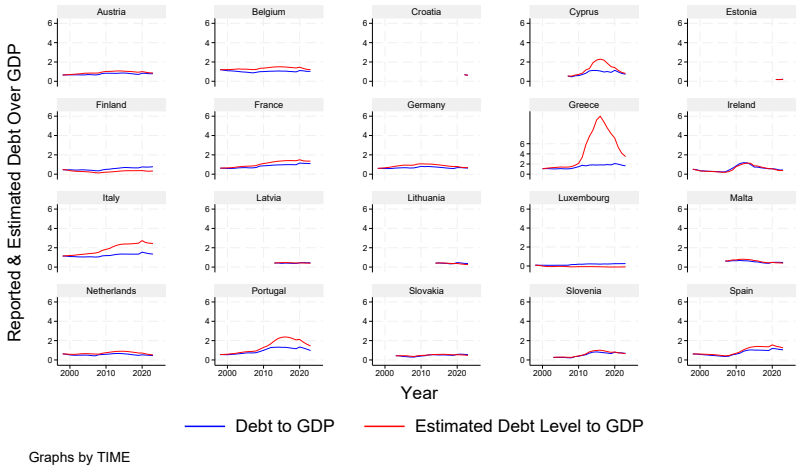


Notes: Figure 3 shows the trends of annual long-term (10yr maturity) sovereign bond interest rates of the five countries that have received financial assistance from the EU monetary authorities. The red dots signify interest rates of the years in which assistance packages are provided. Significant interest rate spikes on red-dotted years can be observed, as receiving assistance is a sign of weak fiscal position and are perceived by investors as riskier.
Source: www.theglobaleconomy.com

Figure 4: Interest Rate to GDP Growth Rate Ratio (rgRatio) and Debt Unsustainability Threshold (z) (20 countries, 1999-2024)

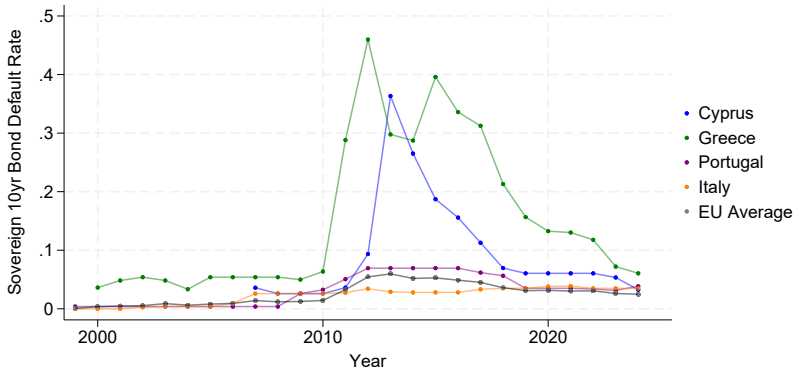
Notes: Figure 4 shows all country-year observations of the interest rate to GDP growth rate ratios, which are adjusted by the three-year-forward moving window method in Section 3.6, which effectively caps the lower bound to zero. The red dotted line is the cutoff point between the bottom 97.5% of observations and the top 2.5%. Debt unsustainability is expected to occur to the top 2.5% of the population.
Source: Eurostat, www.theglobaleconomy.com

Figure 5: Debt and Estimated Debt Level to GDP Ratios
(20 countries, 1999-2024)



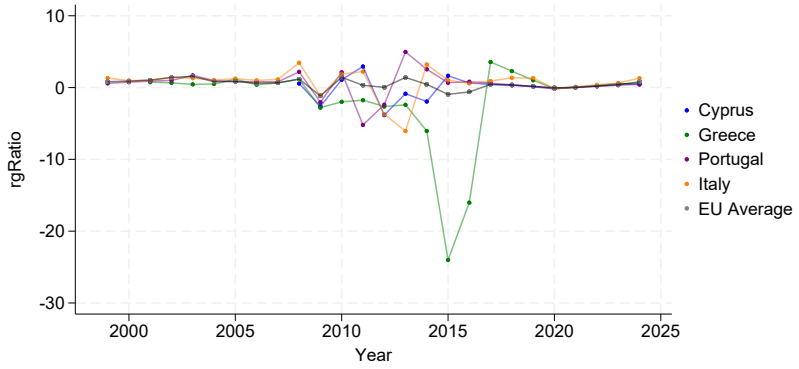
Notes: Figure 5 shows the estimation of annual country-specific debt level formulated in Section 3.3. The continuous estimation starts on the year of euro currency-adoption. The comparative significance of the reported debt and estimated debt level is show as a ratio to GDP.

Figure 6: Country and EU Average Default Rate Trend (4 countries, 1999-2024)



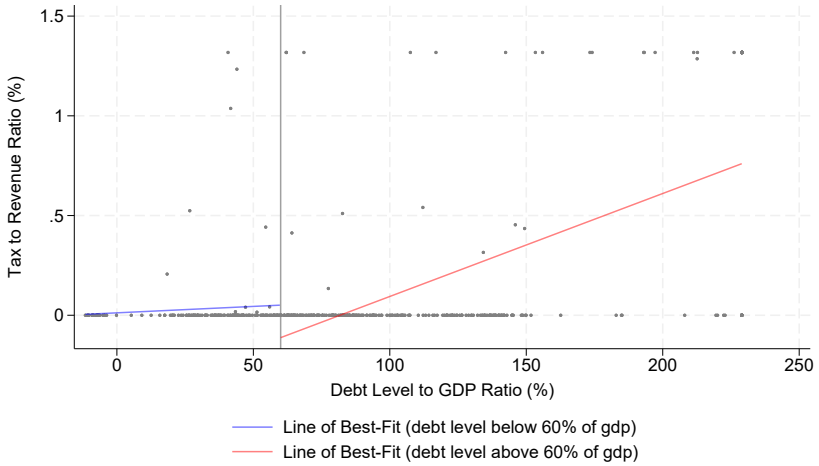
Notes: Figure 6 shows the annual long-term (10yr) bond default rate trend for the 4 countries that received significant bailout packages in EU's history.
Source: www.theglobaleconomy.com

Figure 7: Country and EU Average Debt Sustainability Ratio Trend (4 countries, 1999-2024)



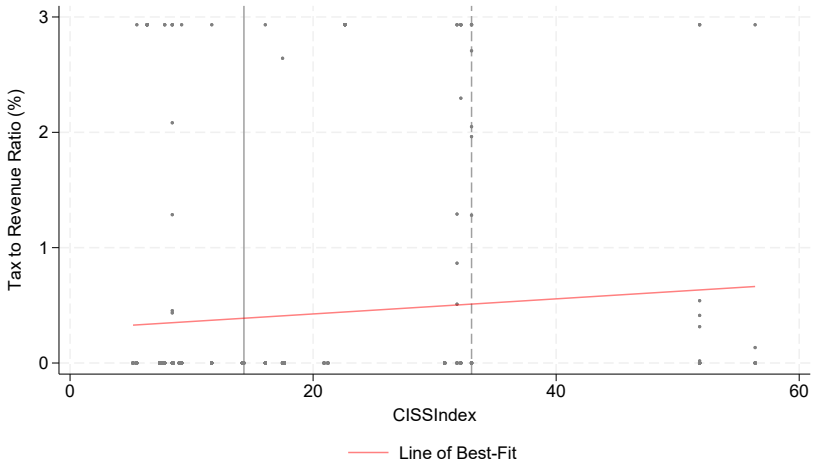
Notes: Figure 7 shows the trend of interest rate to growth rate ratio $\frac{1+R}{1+g}$ for the 4 countries that received significant bailout packages in EU's history. A lower rgRatio means worse debt sustainability for the country.
Source: www.theglobaleconomy.com, Eurostat

Figure 8: Tax Burden and Debt Level (20 countries, 1999-2024)



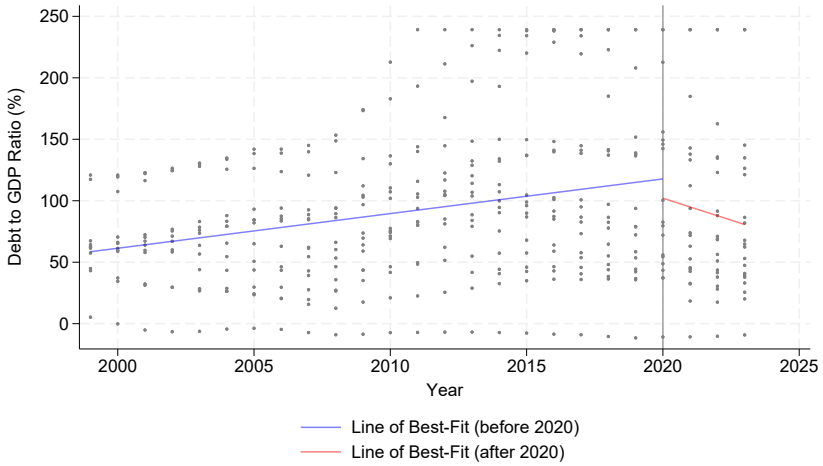
Notes: Figure 8 is a scatter plot of estimated annual tax burden, as in tax to government revenue ratio, against the estimated debt level over GDP. Both variables are winsorized at the bottom 95%. Country-year observations where the country received assistance packages are excluded. Top 5% of observations of both variables are winsorized (the top 5% of datapoints are kept and capped to the largest observation in the bottom 95%). The grey line is at 60% of the debt level to GDP ratio, a structural break threshold suggested by the SGP rule. Best-fit lines in blue and red and plotted on both sides of the threshold.

Figure 9: Tax Burden and Financial Distress (20 countries, 1999-2024)



Notes: Figure 9 plots the tax to government revenue ratio to Composite Indicator of Systemic Stress (CISS). Both variables are winsorized at the bottom 95%. CISS is a weighted aggregation of major economic indicators from 5 categories: Money Market, Bond Market, Equity Market, Financial Intermediaries, and the Foreign Exchange Market; it is calibrated to reflect euro-area stylistic features (Holló 2012). The CISS observations are lagged by 1 year in this plot because the countries' heightened fiscal borrowing, which translates to larger observations of the tax burden, is a lagged response to the initial detection of significant market distress.
Source: ECB

Figure 10: Debt Level Estimation Structural Break After Covid (20 countries, 1999-2023)



Notes: Figure 10 plots the debt level estimation as a ratio to GDP across time. The ratio is winsorized at the bottom 95%. The best-fit line before 2020 has a significant and positive slope, while the best-fit line after 2020 has an insignificant and negative slope. Please see Table 2 for details. (Due to lack of data, incomplete estimations in 2024 strongly skew the regression slope upward and are therefore excluded.)

Table 1: Calibrated Parameters (%, Selected Countries, 2010-2015)

	Countries		
	Germany	Greece	Italy
Year			
2010			
Interest Rate	2.74	9.09	4.04
Default Rate	0.00	6.36	2.59
Assistance to Debt Ratio*	0.00	0.00	0.00
2011			
Interest Rate	2.61	15.75	5.42
Default Rate	0.00	28.81	2.73
Assistance to Debt Ratio	0.00	0.00	0.00
2012			
Interest Rate	1.50	22.81	5.49
Default Rate	0.00	45.97	3.43
Assistance to Debt Ratio	0.00	12.02	0.00
2013			
Interest Rate	1.57	10.05	4.32
Default Rate	0.00	29.77	2.90
Assistance to Debt Ratio	0.00	11.41	0.00
2014			
Interest Rate	1.16	6.93	2.89
Default Rate	0.00	28.74	2.80
Assistance to Debt Ratio	0.00	11.40	0.00
2015			
Interest Rate	0.50	9.67	1.71
Default Rate	0.00	39.58	2.80
Assistance to Debt Ratio	0.00	11.64	0.00

Notes: Table 1 presents a selected sample of country-year calibrated parameters: Sovereign Bond Rate, Default Rate, and Assistance Amount as a portion of Debt. All values are in percentages. * This ratio is the average amount of assistance received in year t over the reported amount of outstanding debt in year t. *Source:* www.theglobaleconomy.com, European Commission.

Table 2: SUEST Regression Results: Debt Level Estimation Pre vs Post 2020

	(1) Pre	(2) Post
Year	2.820***	-7.117
	(0.517)	(7.089)
Constant	-5579.1***	14477.9
	(1038.7)	(14330.4)
Observations	342	77

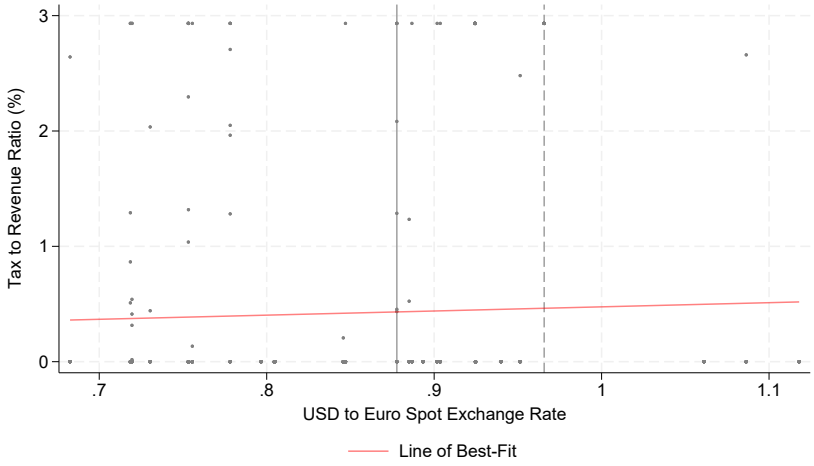
Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Table 2 is the result of a Seemingly Unrelated Estimation (SUEST) on the estimated debt level results before and after Covid. The equality of coefficients across the pre- and post-covid periods is tested using a Chow-type test derived from the SUEST framework. The null hypothesis $H_0 : \beta_{pre} = \beta_{post}$ is evaluated, which examines whether the effect of the year variable differs significantly between the two subsamples. The null hypothesis of equality is not rejected at conventional significance levels ($\chi^2(1) = 1.90,\ p = 0.1683$), suggesting no statistically significant structural break after 2020.

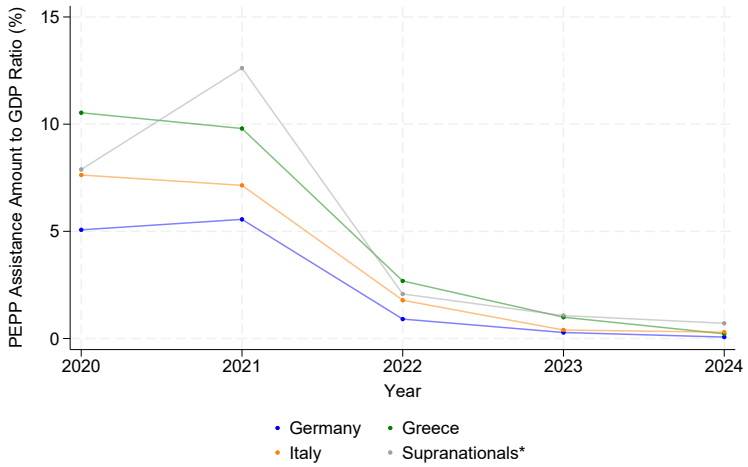
Appendix

Figure A1: Tax Burden to Euro Currency Competitiveness (%, 20 Countries, 1999-2024)



Notes: Figure A1 attempts to explore a positive relationship between tax burden and euro currency deterioration but fails to establish a significant correlation. A higher exchange rate value means larger euro depreciation. The line of best-fit has a slope of 0.36 and a p-value of 0.43. The figure employs a similar 50%-90% duo-threshold as Figure 9.
Source: Federal Reserve Bank of St. Louis (exchange rate data)

Figure A2: PEPP Amount to GDP Ratio (Selected Countries, 2020-2024)



Notes: Figure A2 plots the PEPP assistance amount, as a percentage of the country's GDP, received by selected countries from 2020 to 2024. Germany, Italy, and Greece are selected as they represent strong, moderate, and weak fiscal debt positions at the beginning of the Covid years. A weaker debt position means less fiscal spending power and more assistance needed to combat the economic downturn.

*The Supranationals term refers to the amount of PEPP assistance issued to cover economic recovery projects proposed by multiple countries jointly. For simplicity, this assistance amount is interpreted as a loan package to the entire region. The graph normalizes this term with the average GDP of euro-using countries. In practice of the model, the Supranationals assistance amount is allocated to each country's PEPP assistance amount according to their proportion of GDP in the EU (a weight of $\frac{y_t^s}{y_t^{eu}}$).

Source: ECB

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