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Re-evaluating sustainable sovereign debt: A theoretic and econometric evaluation of the suggested new EU fiscal rule

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Re-evaluating sustainable sovereign debt: A theoretic and econometric evaluation of the suggested new EU fiscal rule

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Abstract

The Commission of the EU proposed a new fiscal rule in 2022 focusing on the primary surplus of governments in the euro area rather than on public deficits. This paper analyses the suggested new rule by setting up a simple optimal control problem. Governments determine the optimal reaction of the primary surplus to public debt such that the squared deviation from a certain target surplus is minimized. We study the structure of the model and highlight its implications for the economy's stability. In addition, we perform panel data analysis for euro area countries where we empirically estimate the fiscal space for each country. We apply panel smooth transition regressions to account for distinct regimes depending on the differences between the interest rate on public debt and the GDP growth rate of the economies.

JEL: H61, H63, E62

Keywords: Public debt, primary surplus, fiscal rule, sustainability

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1 Introduction

In November 2022, the European Union (EU) Commission proposed a reform of the Stability and Growth Pact (SGP) that was passed at the end of the 1990s and entered into force in January 1999. The goal of this treaty was to ensure that fiscal discipline would be maintained and enforced in the Economic and Monetary Union (EMU) of the EU. That pact stated that the government deficit should not exceed 3% of GDP and public debt should remain below 60% of GDP, as already stated in the Maastricht treaty. If the second criterion is violated, governments should take action to ensure that the debt-to-GDP ratio declines each year at a satisfactory pace towards a level less than 60%. However, the SGP did not reach its goal of keeping the public debt ratio below 60% in most countries; in the 3rd quarter of 2023, it amounts to 91% on average in the euro area.[1] This raises doubts about the effectiveness of the SGP leading the EU commission to suggest a reform as already proposed by some economists (see, for example, Wyplosz, 2019; Blanchard et al., 2021).

According to the proposal of the EU Commission, the "fiscal adjustment path would be set in terms of net primary expenditure, i.e. expenditure net of discretionary revenue measures and excluding interest expenditure as well as cyclical unemployment expenditure." (European Commission, 2022, p. 12, and identical in content European Commission, 2023, p. 3). In economic terms, that is the government's cyclically adjusted primary surplus. The discussion of the new fiscal rule implies that proposals are needed for how countries with higher debt positions can transition to a lower debt position in the medium run. Those aspects, the trend of spending and revenues and adjustments to that trend, need some macroeconomic evaluation since they are timely but not without perils, see Blanchard and Zettelmeyer (2023).

As to that issue, focusing on the cyclically adjusted primary surplus, we can explore the mean-reverting properties of the sovereign debt dynamics to some long-run sustainable debt to GDP ratio. When the new fiscal rule is followed such that the growth rate of public spending and revenue is aligned to the debt-to-GDP ratio in an economy, this rule resembles the Bohn (1995, 1998) rule. Bohn suggested estimating a so-called reaction

[1] See e.g. https://de.statista.com/statistik/daten/studie/163692/umfrage/staatsverschuldung-in-der-eu-in-prozent-des-bruttoinlandsprodukts/

coefficient that determines the response of the primary surplus to variations of public debt relative to GDP respectively. The new EU rule could be a dynamic motion allowing more flexibility for member countries of the monetary union with diverse fiscal authorities, as is the case for the euro area. Therefore, we also need to analyze the individual fiscal space of the different EU countries, where we define the fiscal space as the distance between the reaction coefficient, on the one hand, and the difference between the interest rate on public debt and the GDP growth rate, which we denote as the interest-growth rate differential, on the other hand. That is of importance because the debt-to-GDP ratio remains bounded only if the reaction coefficient exceeds the interest-growth rate differential (cf. Greiner and Fincke, 2015, p. 9).

In this context, another issue has come up. Recent macroeconomic research has shown that private and public spending will likely create negative and positive macroeconomic externalities. In particular, public spending can exert positive externalities and stimulate potential GDP growth (Korinek and Stiglitz, 2022). In principle, one would need to estimate a time-varying potential GDP as Laubach and Williams (2013) and Holston et al. (2017), including the impact of all those externalities on the guiding growth path determining future government revenues and, thus, potential primary surpluses. By itself, this is already a challenging issue.

Moreover, the rule proposed by the Commission of the EU is usually defined as net of interest payments on sovereign debt. However, one knows that the actual interest rate paid by the borrower is impacted by the risk premium, which is likely to affect the debt dynamics via a "good" and a "bad" debt equilibrium (Blanchard, 2019). Hence, monetary authority is needed to assist in such debt dynamics, though, given the European Central Bank's (ECB) central goal to control inflation, it may not be that flexible. In addition, fiscal authorities may not have perfect control over taxes and spending rates to bring public spending in line with potential GDP growth if their primary goal is to be re-elected and the voters' preferences do not necessarily put a high weight on the sustainability of public debt.

This paper aims to analyze the suggested new fiscal rule from a theoretic point of view and empirically analyze whether the reaction coefficient determining the reaction to public debt exceeds the interest-growth rate differential of an economy. To do so, we set up a simple optimal control problem, where a government determines the optimal

reaction coefficient such that the squared deviation from a given target value for the primary surplus to GDP ratio is minimized. Thus, we want to gain insight into the basic relationships between the reaction coefficient, the debt-to-GDP ratio and the stability of the model economy. As regards the empirical part, we cannot evaluate the new rule since it has yet to be passed. However, in the context of the suggested fiscal rule, knowing how the primary surplus reacts to public debt is crucial. It is, therefore, of interest to determine the magnitude of the reaction coefficient and whether it exceeds the interest-growth rate differential. We address the issue by performing econometric estimations for a panel of euro area economies, where we allow for different regimes using a panel smooth transition regression (PSTR).

The rest of the paper is organized as follows. In the next section, we set up and solve the optimal control problem. In section 3, we determine the fiscal space for euro area economies, where we estimate the reaction coefficient of the primary surplus to variation in public debt for distinct regimes depending on the difference between the interest rate on public debt and the GDP growth rate. Section 4, finally, concludes.

2 The optimal response to rising debt

As pointed out in the introduction, the Commission of the EU has suggested a new fiscal rule focusing on the primary surplus to GDP ratio of euro-area economies. It does so because the primary surplus plays a vital role in controlling the public debt-to-GDP ratio, which is crucial as regards public debt sustainability. A bounded debt to GDP ratio is necessary but not sufficient for a sustainable debt policy (see e.g. Greiner and Fincke, 2015, p. 9-10).[2] To see under which conditions the debt to GDP ratio, b, remains bounded when the goal of a government is to realize a certain pre-determined primary surplus to GDP ratio, we start with the differential equation that describes its evolution. The latter is given by

$$\dot{b}(t) = r(t) \cdot b(t) - g(t) \cdot b(t) - ps(t),\ b(0) = b_0, \tag{1}$$

[2]Boundedness of the debt-GDP ratio is not sufficient for sustainability since the ratio could be so high that the necessary surpluses cannot be achieved because they cannot exceed a certain fraction of GDP.

with r the interest rate on outstanding debt, g the growth rate of GDP, ps the primary surplus to GDP ratio and t denotes the time.

Now, assume that the primary surplus to GDP ratio is a positive function of the outstanding debt to GDP ratio. The motivation for that assumption is that a rise in public debt must be accompanied by an increase in the primary surplus (see e.g. the seminal papers by Bohn, 1995, 1998). That makes the time path of the debt-to-GDP ratio a mean-reverting path, thus preventing the debt ratio from diverging to infinity. Denoting the reaction coefficient by $\psi(t) \geq 0$, the simplest specification is written as

$$ps(t) = \psi(t) \cdot b(t). \tag{2}$$

Finally, we posit that the interest rate on public debt is given by the risk-free rate r_f plus a risk premium. As regards the risk premium we use a quadratic risk premium $\sigma b^2(t)$, $\sigma > 0$, because Debrun and Kinda (2013) find that interest expenditures are a convex function of public debt, relative to GDP respectively, and S&P data show that the risk premium rises exponentially with the risk rating (see e.g. https://www.roedl.de/themen/internationale-unternehmensbewertung/laender-risiko-praemie-methoden-zinsstruktur-credit-default-swaps-cds-risk-rating). Thus, the evolution of the debt to GDP ratio is described by the following differential equation

$$\dot{b}(t) = r_f(t) \cdot b(t) - g(t) \cdot b(t) + \sigma b^3(t) - \psi(t) \cdot b(t)\ b(0) = b_0. \tag{3}$$

In order to determine the optimal reaction coefficient, we formulate and solve an optimization problem for the government. The government wants to minimize the squared difference of the actual primary surplus from a target value $\bar{ps}$. This target can be considered the outcome of a static optimization problem where the government sets the tax revenue and public spending such that a well-defined function becomes maximal. For example, a benevolent government would maximize welfare, and a more realistic approach would allow for the self-oriented goals of politicians in the government. Without going into the details of that optimization problem, we suppose that its outcome is given by the primary surplus-GDP ratio $\bar{ps}$.

With an infinite time horizon, the optimization problem of the government can be

formulated as $\min_{\psi(t)} \int_0^\infty e^{-\rho\, t} \left(\psi(t)\, b(t) - \bar{ps}\right)^2 dt$, or, equivalently

$$\max_{\psi(t)} (-1) \int_0^\infty e^{-\rho\, t} \left(\psi(t)\, b(t) - \bar{ps}\right)^2 dt, \tag{4}$$

with $\rho > 0$ the subjective discount rate of the government and subject to

$$\dot{b}(t) = r_f\, b(t) - g\, b(t) + \sigma b^3(t) - \psi(t)\, b(t),\ b(0) = b_0,\ \text{and}\ \lim_{t\to\infty} b(t) < \infty. \tag{5}$$

It should be noted that we use constant values of the exogenous variables r_f and g in the constraint (5) since one can limit the investigation to the average values when the analysis focuses on the boundedness of the debt ratio (cf. Greiner and Fincke, 2015, ch. 2.1).

To solve the optimization problem we set up the current value Hamiltonian $\mathcal{H}$ which is given by

$$\mathcal{H}(\cdot) = (-1) \left(\psi(t)\, b(t) - \bar{ps}\right)^2 + \lambda(t) \left(r_f b(t) - g b(t) + \sigma b^3(t) - \psi(t) b(t)\right), \tag{6}$$

with $\lambda(t)$ the co-state variable or shadow price of the debt to GDP ratio.[3] Maximizing $\mathcal{H}(\cdot)$ with respect to ψ gives the optimal reaction to public debt as

$$\psi = \frac{\bar{ps} - \lambda/2}{b} \tag{7}$$

and in optimum the shadow price evolves according to the following differential equation

$$\dot{\lambda} = \lambda\, (\rho - r_f + g) - 3\, \sigma\, \lambda\, b^2. \tag{8}$$

For $\lambda b < 0$ the necessary conditions are also sufficient if the limiting transversality condition $\lim_{t\to\infty} e^{-\rho t} \lambda(t) b(t) = 0$ holds because in this case the maximized Hamiltonian is strictly concave in b. The canonical differential equation system is then obtained as

$$\dot{b} = (r_f - g) b + \sigma\, b^3 - \bar{ps} + \lambda/2,\ b(0) = b_0, \tag{9}$$

$$\dot{\lambda} = \lambda\, (\rho - r_f + g) - 3\, \sigma\, \lambda\, b^2,\ \lambda(0). \tag{10}$$

[3] In the following we delete the time argument t as long as no ambiguity arises.

Above, we pointed out that a bounded debt-to-GDP ratio is necessary for the sustainability of public debt. That implies that the debt to GDP ratio in (9)-(10) must converge to a finite value. Therefore, we now study the asymptotic behaviour of (9)-(10) as regards the existence and stability of a rest point that we term as a steady state of the system. The following proposition 1 demonstrates that there are three possible steady states, where the symbol * denotes steady-state values.

Proposition 1 *Steady states of the canonical system* (9)-(10) *are given by*

$$b^\star_{1,2} = \pm \left(\frac{\rho - r_f + g}{3\,\sigma} \right)^{1/2}, \; \lambda^\star_{1,2} = 2\left(\bar{ps} - (r_f - g)\, b^\star - \sigma\, (b^\star)^3 \right)$$

and for $\bar{ps} = 0$ *by* $b^\star = \lambda^\star = 0$.

Proof: The proof is obtained by setting $\dot{\lambda} = 0$ and solving with respect to b and, then, setting $\dot{b} =$ and solving for λ. □

Proposition 1 shows that the steady state with a zero debt-to-GDP ratio is a feasible objective only if the target primary surplus of the government, $\bar{ps}$, equals zero, meaning that the tax revenue of the government exactly equals its spending. Note that this is only possible if the initial debt-to-GDP ratio equals zero, i.e. if the government starts with no outstanding public debt. In the following, we neglect this case since it is of no relevance for EU economies and because it is not generic.

The other two steady states go along with either a positive debt-to-GDP ratio or with a negative ratio, the latter implying that the government is not a debtor but a creditor that lends to the private sector.[4] From the steady-state values for the debt-GDP ratio in proposition 1, it can be seen that the existence of a real value for $b^\star$ is always given when the GDP growth rate, g, exceeds the risk-free interest rate on government bonds, r_f. If that does not hold, i.e. in the case of $r_f > g$, the steady state public debt is real if the government's discount rate, ρ, exceeds the difference between the risk-free interest rate and the GDP growth rate. The interpretation of that outcome is that the government must put a sufficiently high weight on the present relative to the future in evaluating deviations of the primary surplus-GDP ratio from its target value. As a consequence of

[4]In this case a positive reaction coefficient means that the government limits the indebtedness of the private sector.

the latter, the change of the shadow price is larger because the discount rate ρ positively impacts the growth rate of the shadow price, which is readily seen from (10). That implies that the reaction coefficient reacts stronger than the situation with a lower discount rate such that the change in the primary surplus is larger, *ceteris paribus*, than in the case of a lower discount rate.

Besides whether a steady state exists, its stability properties are important because the boundedness of the debt-to-GDP ratio is necessary for the sustainability of public debt. In the following proposition 2, we give conditions that guarantee local saddle point stability of the steady state.

Proposition 2 *For $b^\star > (<)\, 0$ a necessary and sufficient condition for saddle point stability of the steady state is that its shadow price is strictly negative (positive), i.e. $\lambda^\star < (>)\, 0$ must hold.*

Proof: To prove that proposition we compute the Jacobian evaluated at the steady state as

$$\mathrm{J} = \begin{bmatrix} 0 & -2\lambda^\star \left(\pm \left(\rho - r_f + g \right)^{1/2} \right) (3\sigma)^{1/2} \\ 1/2 & \rho \end{bmatrix},$$

where we used $b^\star_{1,2} = \pm \left(\rho - r_f + g \right)^{1/2} (3\sigma)^{-1/2}$ and $\lambda^\star$ is evaluated at its steady state. Knowing that $\det \mathrm{J} < 0$ is necessary and sufficient for saddle point stability of the steady state leads to the result in the proposition. □

This proposition shows that for a positive (negative) steady-state public debt to GDP ratio, its steady-state shadow price must be negative (positive) to get saddle point stability. That means an additional unit of public debt (public wealth) relative to GDP must reduce the optimal value of the functional (4) at the steady state. From the maximum principle (7), we see that this holds for $\psi b^\star > (<)\, \bar{ps}$ when the debt to GDP ratio at the steady state is positive (negative). That implies that the primary surplus-GDP ratio at the steady state must exceed (fall short of) its target $\bar{ps}$ such that any additional marginal unit of the debt-GDP ratio would raise its deviation from the target and, therefore, lower the value of the functional (4).

It should also be pointed out that a situation with a positive shadow price of public debt λ cannot be optimal when the government is a debtor, i.e. for $b > 0$. That holds

because, in such a situation, the government could further raise the value of the objective functional (4) by setting $\psi = 0$ and let public debt grow since a positive shadow price means that an additional unit of the debt-GDP ratio has a positive effect on (4). Consequently, it would do so until the effect of an additional public debt unit does not further raise its objective functional (4) and the shadow price of the debt to GDP ratio becomes negative.

Finally, we study how the risk premium affects the outcome. We limit our considerations to the case $b > 0$, i.e. where the government is a debtor, which is the relevant case for EU economies, and we assume $\bar{ps} > 0$ because, with a positive value of outstanding public debt, the government must achieve positive primary surpluses. The risk premium is given by σb^2 and is an endogenous function. However, it can be affected by variations of the parameter σ. For example, the European Central Bank (ECB) can reduce the risk premium a government has to pay by buying its bonds on the secondary market. The latter can be done in the context of the Transmission Protection Instrument (TPI) or the Outright Monetary Transaction (OMT) program.[5] Proposition 3 gives the results when the risk premium is varied.

Proposition 3 *An increase of the risk premium modelled through a rise in σ reduces the steady state debt to GDP ratio $b^\star$ and raises the determinant of the Jacobian. The latter can lead to instability of the steady state.*

Proof: To prove that proposition we note that the debt to GDP ratio at the steady state is $b^\star = (\rho - r_f + g)^{1/2} (3\sigma)^{-1/2}$ and its derivative with respect to σ is negative.

The determinant of the Jacobian evaluated at the steady state is

$$\mathrm{J} = \begin{bmatrix} \rho + g - r_f - 3\sigma \left(b^\star\right)^2 & -6\sigma\lambda^\star b^\star \\ 1/2 & r_f - g + 3\sigma \left(b^\star\right)^2 \end{bmatrix}.$$

Inserting the steady state values for $b^\star$ and for $\lambda^\star$ the determinant can be computed as

$$\det \mathrm{J} = (2/3) \left(2(g - r_f)^2 - \rho(\rho + r_f - g) + 3\,\bar{ps}\, (\sigma)^{1/2}\, 3^{1/2}\, (g + \rho - r_f)^{1/2} \right)$$

[5] As regards the difference between these two instruments, see Buiter (2022).

Differentiating $\det \mathrm{J}$ with respect to σ leads to

$$\frac{\partial \det \mathrm{J}}{\partial \sigma} = \frac{3^{1/2}\,\bar{ps}\;(g+\rho-r_f)^{1/2}}{\sigma^{1/2}} > 0.$$

Since $\det J > 0$ implies instability the proposition is proven. □

This proposition states that a higher risk premium goes along with a smaller debt-to-GDP ratio. From an economic point of view, this can be explained by the disciplinary effect of higher interest rates. Higher interest rates imply a higher burden of public debt, and consequently, the government will strive to reduce the debt-GDP ratio. On the other hand, proposition 3 shows that a higher risk premium tends to destabilize the economy. That holds because the interest and compound interest effect leads to an exponentially rising time path of the debt-GDP ratio, and the higher the risk premium is, the faster the debt ratio goes up. Therefore, instruments such as OMT or TPI that aim to reduce the risk premium have a stabilizing effect on the debt-to-GDP ratio. However, it must be underlined that a bounded debt-to-GDP ratio is not sufficient for the sustainability of public debt; large debt-GDP ratios harbour the risk that public debt may become unsustainable. That holds because once a critical threshold of the debt-to-GDP ratio is reached, the necessary primary surplus cannot be achieved because it would require too high a percentage of GDP, see Greiner and Fincke (2015), p. 10, that countries cannot or are not willing to pay.

In the next section, we empirically analyze the fiscal reaction function of the euro area economies and specifically study the reaction of the primary balance of governments in that currency union considering multiple regimes of the interest-growth rate differential.

3 Fiscal reaction function for euro area

To estimate the fiscal reaction function for the euro area, we resort to PSTR models, thus accounting for the possibility of distinct regimes with different coefficients of the fiscal reaction function. The PSTR allows the estimation of the existence of a threshold in the behaviour of the reaction function and refrains from the country-wise perspective. It applies a regime-switching model to detect regimes with different reaction coefficients, where data is segregated endogenously via a logistic function, implying that the regimes

are identified using a data-driven approach. With the PSTR, we apply a methodology to the fiscal response analysis that overcomes the pooling problem in the panel data context, i.e. where one coefficient fits all. The advantage is obvious: the number of regimes is determined by the data, the coefficients are estimated for each regime (for example, high or low values of a certain transition variable), and the reaction coefficients yield a better fit than the commonly pooled ones in usual panel models, especially when there is evidence of structural breaks in the data-generating process. Individual countries are not restricted to remain in the same regime but can switch or alternate between the regimes depending on the heterogeneity in their fiscal behaviour. The implication is that different responses are feasible for the same country depending on the transition variable. Regression coefficients can switch smoothly between the regimes characterized by low or high values of the transition variable.

We specify a panel smooth transition regression model according to Gonzalez et al. (2017) as follows:

$$y_{it} = \mu_i + \beta_0 z_{it} + \beta_1 z_{it} G(k_{it}; \gamma, c) + u_{it} \tag{11}$$

where i represents the individual in the panel and t is the time dimension, y is the response variable, μ represents the time-invariant individual effect, z denotes the covariates, and β is the coefficients to be estimated. The function $G(k_{it}; \gamma, c)$ is the transition function which is a bounded function of k_t and continuous in the parameter space for all values of k_t. The variable k_{it} is the transition variable on which the regime-switching is conditioned, c is a vector of location parameters which represents the threshold between the two extreme stable regimes, whilst γ governs the slope of the transition function. The transition function is represented by a logistic function (see Teräsvirta, 1994, 1998), such that it is bounded between 0 and 1 and has a general form as below:

$$G(q_{it}; \gamma, c) = (1 + exp(-\gamma \prod_{j=1}^{p} (q_{it} - c_j))^{-1} \tag{12}$$

The number of regimes p could be more than one depending on the variations in the dataset. When $p = 1$, the model is characterised by two extreme regimes associated with high and low values of the transition variable (k_{it}). In that case, the coefficients from (11)

switches between β_0 and $\beta_0 + \beta_1$ and the change is centred around c_1.

Applying the PSTR, we conduct a model specification test known as the *linearity test*, which entails setting up an LM (Lagrangian Multiplier) based hypothesis test, where a linear specification with homogenous slope is tested against an alternative hypothesis of the PSTR model (heterogenous slope coefficient). The idea is to identify the PSTR model to infer heterogeneity in the coefficient of the slope parameter. Rejection of the homogeneity hypothesis leads us to ascertain the appropriate number of regimes suitable for the model known as the *sequence of homogeneity test*. Concerning the parameters in the PSTR framework, while individual fixed effects are normally eliminated via within-transformation, the model is estimated by nonlinear least squares, because of the nonlinearity introduced by the transition function. A detailed and technical presentation of the PSTR can be found in Gonzalez et al. (2017) and Teräsvirta (1994, 1998) (for the time series case) and in Owusu et al. (2023) with an application of PSTR to study a fiscal reaction function, where the regimes depend on public debt to GDP ratios.

The PSTR is applied here to model a fiscal reaction function where the primary balance is assumed to respond to variations in the debt-to-GDP ratio and is affected by other control variables that influence the primary balance.

We use the interest-growth rate differential as the transition variable in our PSTR setting. We do so because the interest-growth differential is an important variable that determines the evolution of public debt (Blanchard, 2019); if the growth rate exceeds the interest rate, public debt poses a small problem since an economy can grow out of debt. If the opposite holds, the higher the burden of public debt, the larger the difference between the interest rate and the growth rate. Based on the interest-growth rate differential, we estimate the fiscal policy response for two regimes: a regime with a low interest-growth rate differential and one with a high differential, where we control for macroeconomic and institutional variables. The PSTR endogenously distinguishes regimes across all observed states of the interest-growth differential. The number of regimes is determined by the data, and the coefficients are estimated for each regime (high or low interest-growth differential). In addition, they are not determined by particular economies but by the respective interest-growth differential. Individual country data points are not restricted to staying in the same group or category but can switch between the groups depending on the heterogeneity of their fiscal behaviour. Hence, we refrain from the country-wise

classification of regimes.

The data used for the study spans 18 years (between 2002 and 2019) for 16 euro area economies.[6] Cyclically adjusted primary balance is used as the proxy for our fiscal policy variable. The lagged debt-to-GDP ratio represents our covariate of interest since we are mainly interested in the response of fiscal policy to variations in the debt. We control international trade using the net export to GDP ratio. We also control for inflation using log changes in the GDP deflator. With motivations from Barro's (1979) tax smoothing hypothesis, we control for the business cycle using the output gap and some form of expenditure gap to capture transitory government spending. Regarding the expenditure gap, we use the deviation between real government spending and its trend component obtained using the Hodrick-Prescott filter. We adopt the latter filtering technique also to obtain the output gap.[7] The above-described data was obtained from the European Commission AMECO (2021). Due to the empirical evidence of the effect of institutions on fiscal policy (see de Haan and Sturm, 1994 and, Hallerberg and Wolff, 2008), we include a government effectiveness index and a rule of law index as controls in our model. Those institutional variables are sourced from the World Wide Government Indicators from the World Bank (2022). To account for time effects, we control for the financial crisis and the European debt crisis, which impacted fiscal policy in most EU countries, by using time dummies. Finally, we account for unobserved time-varying heterogeneity in some specifications by including time-fixed effects. The latter also keeps track of several common sources of variation for our countries, like monetary policy and global shocks.

In order to get an impression of the magnitude of debt to GDP ratios in the euro area, we show the summary statistics in table 1 and a picture of the interest-growth rate differential is obtained from figure 1.[8] Some euro area economies such as Italy, Greece, Belgium and Portugal had persistent high debt-to-GDP ratios with an average debt ratio of almost 100% with a low interquartile range (looking at the 25th percentile and 75th percentile of debt). Generally, interest rates on debt have been on a downward

[6]Countries are as follows: Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Italy, Latvia, Luxembourg, Malta, Netherlands, Portugal, Slovenia and Spain.

[7]As a robustness check, we used the Hamilton filter and output gap estimates based on production-function approach. The results are qualitatively unchanged and are available upon request.

[8]Interest rates and growth rates are in percentage.

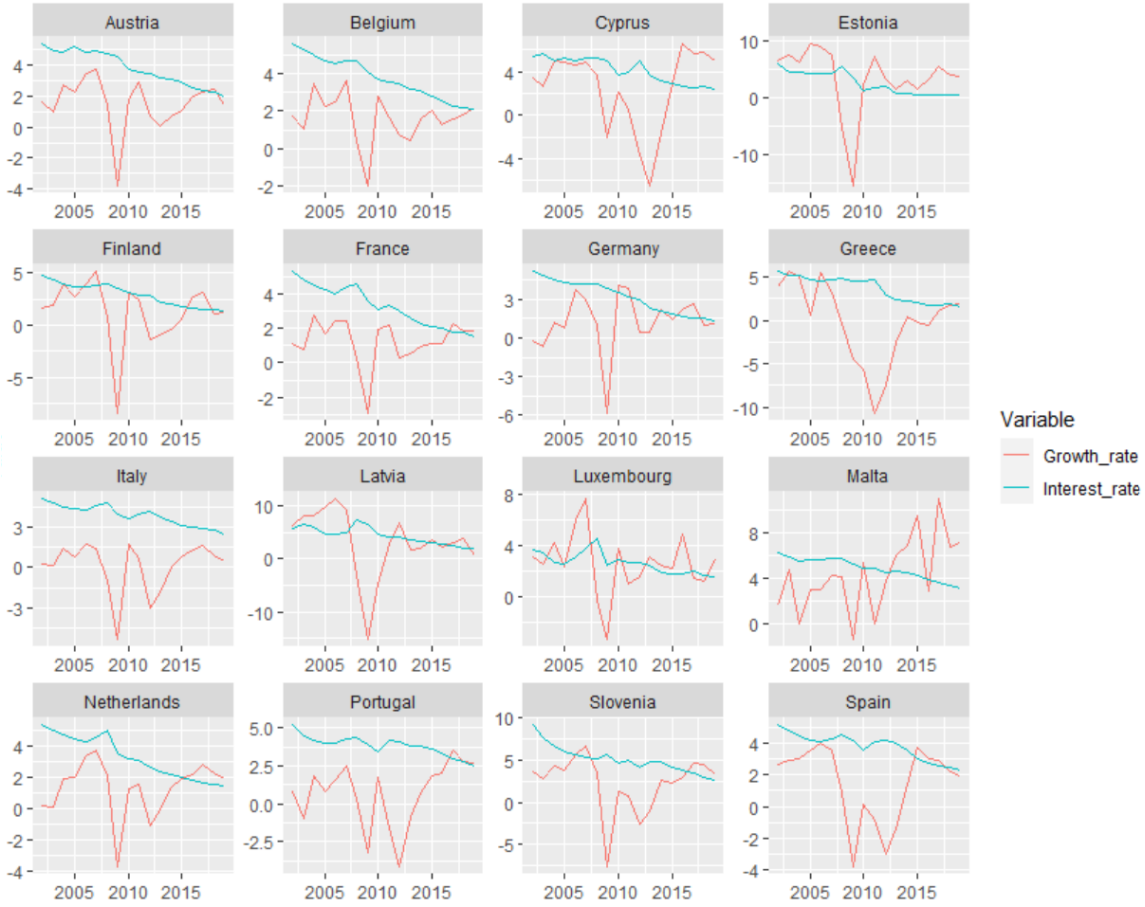
Table 1: Individual country summary statistics. Debt-to-GDP ratios

Country	Mean	Median	Std. dev.	25th Perct	75 Perct	Min	Max
Austria	0.748	0.763	0.078	0.669	0.823	0.650	0.849
Belgium	1.01	1.02	0.058	0.978	1.05	0.873	1.08
Cyprus	0.745	0.643	0.218	0.578	0.978	0.455	1.09
Estonia	0.070	0.0636	0.024	0.049	0.096	0.038	0.106
Finland	0.481	0.448	0.104	0.404	0.588	0.326	0.636
France	0.800	0.841	0.151	0.649	0.945	0.583	0.983
Germany	0.694	0.670	0.076	0.642	0.750	0.579	0.824
Greece	1.41	1.37	0.357	1.05	1.78	1.01	1.86
Italy	1.19	1.18	0.129	1.06	1.34	1.04	1.35
Latvia	0.284	0.370	0.144	0.139	0.403	0.085	0.479
Luxembourg	0.155	0.176	0.066	0.081	0.217	0.074	0.237
Malta	0.625	0.646	0.0714	0.617	0.662	0.452	0.713
Netherlands	0.559	0.557	0.0781	0.498	0.619	0.430	0.678
Portugal	0.972	0.940	0.295	0.724	1.28	0.574	1.33
Slovenia	0.463	0.364	0.232	0.265	0.702	0.218	0.826
Spain	0.676	0.573	0.254	0.460	0.970	0.358	1.01

trend whilst the GDP growth rate has fluctuated over the period, as shown in figure 1. Additionally, the summary statistics for the interest-growth rate differential can be found in the appendix in table 6. Once again, those euro area countries with high debt ratios recorded the highest average (mean) interest-growth rate differential, notably Greece, Italy and Portugal.

Before proceeding with the model estimation, we conduct a linearity test to justify our chosen model specification, that is to ensure that the PSTR is correctly identified. Table 4 in the appendix presents the results of the linearity test using the interest-growth rate differential as the transition variable. The null hypothesis indicates linearity of the model specification (homogeneous slope) against an alternative hypothesis of PSTR specification with two, three and four regimes ($m = 1$, $m = 2$, or $m = 3$). The null hypothesis of slope homogeneity is rejected for all three model specifications at a high significance level, irrespective of whether we consider the LM test based on the chi-square distribution or F-distribution. That indicates that a regime-dependent model specification with more

Figure 1: Interest rate on debt and growth rate of GDP for the euro area



than one regime is appropriate.

Since linearity is rejected, we resort to the sequence of homogeneity tests to ascertain the appropriate number of regimes for the model. From table 4, the null H_{01}^* is the regime with the most severe rejection since its p-value is the lowest. The null for the specification H_{02}^* and H_{03}^* are not significant at the 5% level. That implies that a model with one transition (two regimes) is more appropriate for the data.[9] In figure 2, we visualize the transition function characterized by two regimes, including the distribution of the data points. We notice that two stable regimes bound the function, and there is a smooth switch between the regimes (threshold value greater than 1).

[9]Teräsvirta (1994) provides the the selection of the appropriate regime with a theoretical ground.

Figure 2: Transition function - Interest-growth rate differential

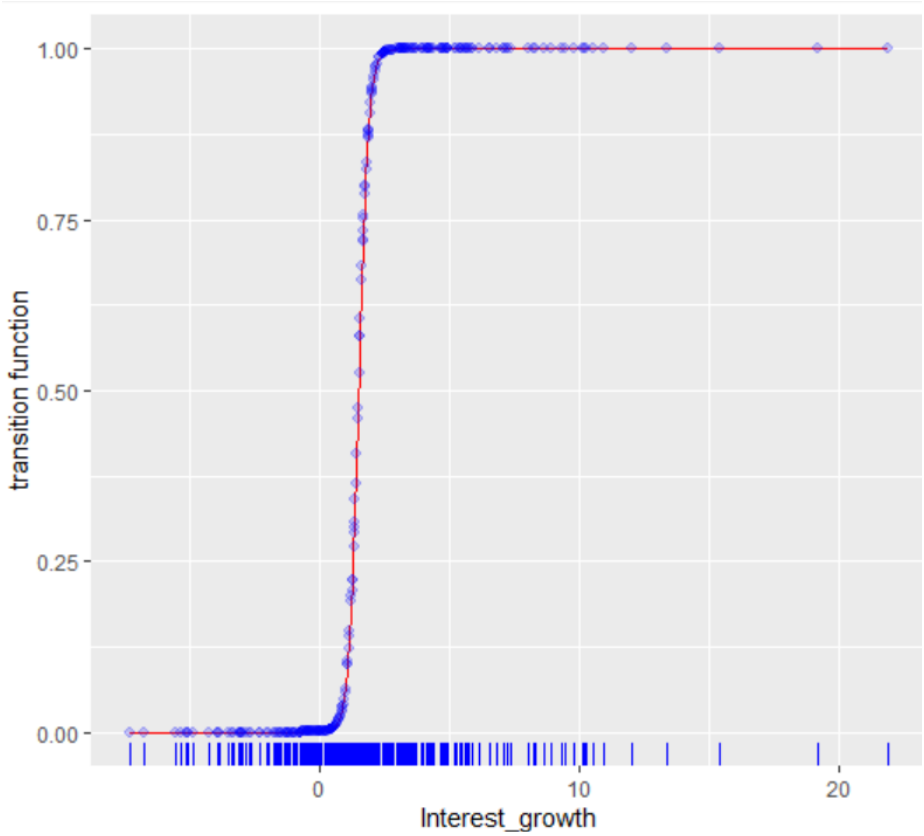


Table 2 presents the estimates of our fiscal reaction function with the application of the PSTR using the interest-growth differential as the transition variable. We present four different model specifications depending on which variables are included on the right-hand side of the model. That is to explore the sensitivity of the point estimates, which is shown to be quite robust across all the specifications. Mod IV is the full model, which includes all variables and fixed effects.[10] The threshold value separating the two regimes is about 1.5, indicating that data points below this threshold belong to the low (r-g) regime, and higher values indicate a high (r-g) regime.

All debt coefficients are positive and statistically significant, indicating sustainable

[10] We visualize the model prediction by comparing fitted and actual primary balance in figure 4 in the appendix; it can be observed a fairly good fit of our PSTR model specification.

Table 2: PSTR estimation of the reaction function

Variables	Mod I	Mod II	Mod III	Mod IV
Regime I : Low (r-g)				
Lagged debt	0.0191***	0.0251***	0.0198***	0.0198***
	(0.0025)	(0.0007)	(0.0002)	(0.0002)
Expenditure gap	-0.0003	-0.0003***	-0.0003***	-0.0002***
	(0.0002)	(0.0000)	(0.0000)	(0.0000)
Output gap	0.0001	0.0001***	0.0002***	0.0002***
	(0.0001)	(0.0000)	(0.0000)	(0.0000)
Trade (Net export)		0.1097***	0.1148***	0.1144***
		(0.0099)	(0.0007)	(0.0003)
Inflation		-0.0397***	-0.0252***	-0.0254***
		(0.0039)	(0.0009)	(0.0007)
Govt effectiveness index			0.0352***	0.0355***
			(0.0025)	(0.0022)
Rule of law			-0.0374***	-0.0374***
			(0.0016)	(0.0015)
Crisis Dummy				-0.0026
				(0.0018)
Regime II : High (r-g)				
Lagged debt	0.0159***	0.0419***	0.0463***	0.0454***
	(0.0013)	(0.0010)	(0.0009)	(0.0007)
Expenditure gap	-0.0016***	-0.0013***	-0.0013***	-0.0012***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Output gap	-0.0002***	-0.0001***	-0.0001***	-0.0001***
	(0.0000)	(0.0001)	(0.0000)	(0.0000)
Trade (Net export)		0.2137***	0.1985***	0.1982***
		(0.0354)	(0.0079)	(0.0071)
Inflation		-0.0594***	-0.0634***	-0.0618***
		(0.0032)	(0.0011)	(0.0009)
Govt effectiveness index			0.0025***	0.0023**
			(0.0010)	(0.0009)
Rule of law			0.0038**	0.0038**
			(0.0014)	(0.0012)
Crisis Dummy				-0.0017***
				(0.0000)
Threshold value(c)	1.502	1.502	1.502	1.502
Number of observations	288	288	288	288
Country fixed effects	Yes	Yes	Yes	Yes
Time effects	No	No	No	Yes

Estimation of $y_{it} = \mu_i + \beta_0 z_{it} + \beta_1 z_{it} G(k_{it}; \gamma, c) + u_{it}$ using PSTR. Where *,** and *** indicates statistical significance at 10%, 5% and 1% level respectively.

fiscal behaviour in both regimes. The intuition implies that if debt rises, primary balances are increased to stabilize the debt-to-GDP ratio. In a low (r-g) environment, however, the debt coefficient's magnitude is smaller compared to the high (r-g) regime. When (r-g) is low due to smaller interest on debt or a higher growth rate, a relatively smaller primary balance is needed to stabilize the debt. At this point, there is more room for fiscal manoeuvre (fiscal space) since only a smaller primary balance must be generated to pay off the debt. On the contrary, a higher (r-g) beyond the threshold (1.5) due to a higher interest rate on debt or a low growth rate implies that a higher primary balance must be generated to stabilize the debt. Hence, the magnitude of the reaction of fiscal policy to variations in the debt-to-GDP ratio appears to differ depending on the regime of the interest-growth rate differential.

All the control variables' coefficients have the expected sign. The expenditure gap is negatively associated with the primary balance, indicating that government expenditures above the trend lead to a deficit situation, irrespective of the regime of (r-g). The positive output gap coefficient in a low (r-g) regime points to a counter-cyclical fiscal policy behaviour; due to the additional room for fiscal manoeuvre in a low (r-g) environment, during periods of the negative (positive) output gap, primary deficits (surpluses) are more likely. We observe a negative output gap coefficient in the high (r-g) regime, synonymous with pro-cyclical fiscal policy behaviour. Trade (next export) predicts fiscal surplus, as depicted by positive coefficients in both regimes. In fact, trade is generally growth-enhancing, leading to high tax revenues and budget surpluses. Inflation has a negative impact on the primary balance in both regimes. Regarding the institutional variables, the government effectiveness index positively affects the primary balance in both regimes, indicating that a high quality of public institutions enhances the budget surplus. The rule of law, however, has a positive effect only in the high (r-g) regime, while the crises dummy has the negative effect in both regimes.

Next, we estimate a model specification in the same spirit of Ghosh et al. (2013), where the model is extended to allow for a polynomial term in the lagged debt. Specifically, we consider a linear, squared, and cubic term to explore the nonlinear effects of debt-to-GDP ratios on the primary balance. Again, we use the interest-growth rate differential as the transition variable in the PSTR framework. Table 3 shows a positive linear term of the reaction coefficient in both regimes. The squared term of the lagged debt coefficient is

negative, indicating a declining reaction as public debt ratios rise. Ghosh et al. (2013) referred to the negative sign of the squared term in the reaction function as *fiscal fatigue* since it implies that the reaction to higher debt declines with rising debt-to-GDP ratios. The cubic term is positive and significant, implying the possibility of multiple turning points in the relationship between lagged debt and primary balance. The coefficients' signs are preserved in the low and high (r-g) regimes, while their magnitude differs (also showing fiscal fatigue, especially with specifications III and IV). That similarity of the coefficients in the two regimes also pertain most of the covariates, which signals that higher order terms of lagged debt absorb part of the nonlinear effects specified in the model arising from the interest-growth differential.

In order to determine public debt's sustainability, it is again necessary to have a positive reaction of the primary surplus to higher marginal public debt relative to GDP respectively, that is the partial derivative of the primary surplus to public debt must be positive. To see whether this holds for our EU economies, we compute the average of the marginal reaction of the primary surplus for the two regimes, denoted as reaction-m, for specification IV in table 3. Figure 3 shows the values of reaction-m and the interest-growth rate differential, r-g, for the countries in our sample. One can see that the marginal reaction of the primary surplus to higher debt is positive for all countries, indicating the sustainability of public debt. In addition, it is interesting to see whether the marginal reaction of the primary balance to public debt exceeds the interest-growth rate differential. That holds because the public debt-to-GDP ratio remains bounded only when the reaction exceeds the interest-growth rate differential. However, this must hold asymptotically, i.e. for $t \to \infty$. Hence, no final conclusion can be drawn from our analysis, or say differently, only if the fiscal behaviour of the countries under consideration continued forever, statements regarding the boundedness of the debt to GDP ratio could be made.

From figure 3, one realizes that in most countries, the marginal reaction of the primary surplus to higher debt exceeds the interest-growth rate differential, at least since the financial crisis that ended in 2011. Three groups can be distinguished. First, there is the group of highly indebted countries Belgium, Greece, Italy and Portugal that experienced a strong increase in the marginal reaction of the primary surplus to debt after the financial crisis, leading to a large positive difference between the marginal reaction of the primary

Table 3: PSTR estimation with higher order terms in the reaction function

Variables	Mod I	Mod II	Mod III	Mod IV
Regime I : Low (r-g)				
Lagged debt	0.1191***	0.1145***	0.1200***	0.1207***
	(0.0054)	(0.0023)	(0.0081)	(0.0098)
Lagged debt-square	-0.1991***	-0.1954***	-0.1795***	-0.1802***
	(0.0060)	(0.0017)	(0.0114)	(0.0140)
Lagged debt-cube	0.0887***	0.0877***	0.0796***	0.0799***
	(0.0013)	(0.0003)	(0.0038)	(0.0047)
Expenditure gap		-0.0004***	-0.0004***	-0.0004***
		(0.0000)	(0.0000)	(0.0000)
Output gap		-0.00003***	0.0001***	0.00001***
		(0.0000)	(0.0000)	(0.0000)
Trade (Net Export)			0.0989***	0.0989***
			(0.0044)	(0.0058)
Inflation			-0.0374***	-0.0378***
			(0.0000)	(0.0003)
Crisis Dummy				-0.0018
				(0.0025)
Regime II : High (r-g)				
Lagged debt	0.0116***	0.0163***	0.0841***	0.0760***
	(0.0125)	(0.0050)	(0.0018)	(0.0021)
Lagged debt-square	-0.0177	-0.0207***	-0.0818***	-0.0745***
	(0.0219)	(0.0000)	(0.0011)	(0.0009)
Lagged debt-cube	0.0189***	0.0177	0.0377***	0.0354***
	(0.0092)	(0.0000)	(0.0000)	(0.0000)
Expenditure gap		-0.0015***	-0.0012***	-0.0012***
		(0.0000)	(0.0000)	(0.0000)
Output gap		-0.0002*	-0.0001***	-0.0001***
		(0.0001)	(0.0000)	(0.0000)
Trade (Net export)			0.2151***	0.2132***
			(0.0007)	(0.0021)
Inflation			-0.0538***	-0.0503***
			(0.0012)	(0.0019)
Crisis Dummy				-0.0029***
				(0.0002)
Threshold value(c)	1.502	1.502	1.502	1.502
Number of observations	288	288	288	288
Country fixed effects	Yes	Yes	Yes	Yes
Time effects	No	No	No	Yes

Estimation of $y_{it} = \mu_i + \beta_0 z_{it} + \beta_1 z_{it} G(k_{it}; \gamma, c) + u_{it}$ using PSTR. Where *,** and *** indicates statistical significance at 10%, 5% and 1% level respectively.

Figure 3: The average debt reaction coefficient and the interest-growth rate differential

surplus and the interest-growth rate differential.[11] Second, the group of low-indebted countries Estonia, Latvia and Luxembourg, where the marginal reaction of the primary surplus (almost) always exceeds the interest-growth rate differential. For the rest of the economies characterized by medium debt-to-GDP ratios with averages between 50 and 80 per cent, the marginal reaction of the primary surplus to GDP sometimes exceeds the interest-growth differential. It sometimes falls short of it, with the difference being positive after the financial crisis. The latter, however, is not necessarily due to an increase in the marginal reaction to public debt but might result from the effect of the unconventional

[11] For Belgium, the rise was not as distinct as for the other countries.

monetary measures of the ECB that reduced the interest rate on outstanding public debt.[12]

4 Conclusion

The boundedness of the public debt-to-GDP ratio is necessary to guarantee public debt sustainability. In a monetary union, each country should abide by the inter-temporal budget constraint since the financial problems of one economy may endanger the whole union, as the euro debt crisis of 2009 and 2010 demonstrated. An essential role in controlling public debt plays the primary surplus-to-GDP ratio: when the debt-GDP ratio rises, the primary surplus ratio must increase, too, in order to make the debt-to-GDP ratio a mean-reverting process. Therefore, the EU Commission proposed to focus on the primary surplus-GDP ratio in a reform of the SGP.

In this paper, we have analyzed such a rule by studying the optimal reaction of the primary surplus to higher debt relative to GDP, respectively, in a simple optimal control problem. We highlighted the conditions that ensure the existence and stability of a steady state, and we could show that a lower risk premium favours the stability of the model. However, a lower risk premium goes along with a higher steady-state ratio of public debt relative to GDP.

In the empirical part, we determined the reaction coefficient of the primary balance to variations in public debt. We allowed for heterogeneity of the countries by applying a PSTR framework that allows for different regimes depending on the interest-growth rate differential. We resorted to the latter as the transition variable because the burden of public debt increases the larger the difference between the interest rate on public debt and the GDP growth rate, which will affect the fiscal policy of economies. Our estimations showed that the average value of the reaction coefficient is positive, implying that the public debt policy is sustainable for the euro-area countries under consideration. That holds for the model where the primary surplus is a linear function of public debt and for the model where this relation is nonlinear.

[12]Notice that the latter may result from multiple channels and despite the inclusion of time-fixed effects, provided that unconventional monetary policy may mitigate the economic scars of deep contractions (see Lucidi and Semmler, 2023).

No clear-cut result regarding the fiscal space could be derived for the sample period. However, it turned out that for almost all economies, fiscal space has been positive since the end of the financial crisis in 2011. That might be partly due to unconventional monetary policy measures of the ECB leading to lower interest rates. However, in some countries, the higher fiscal space is also the result of a stronger reaction of the primary surplus to higher debt. That holds in particular for the highly indebted economies like Greece, Italy, and Portugal, where the rise of the reaction to higher debt is the strongest.

The SGP could not achieve its goal of preventing rising debt-to-GDP ratios in the euro area that meanwhile exceed by far the upper bound of 60% on average. Further, some euro area countries have argued that the SGP must be more flexible to address macroeconomic challenges. Therefore, the EU Commission suggested a new rule focusing on primary balances that the member countries still need to approve. However, whatever the new fiscal rule will like, it will not perform better than the SGP as long as the countries are not willing to adhere to it, as was the case in the past.

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Appendix

	LM_χ		LM_F	
Regimes	test	p-value	test	p-value
$m = 1$	25.33	(0.000)	4.872	(0.000)
$m = 2$	34.65	(0.000)	3.273	(0.001)
$m = 3$	36.36	(0.002)	2.248	(0.005)

Table 4: Homogeneity tests, transition variable (r-g). Results of langrangian multiplier test of homogeneity/linearity based on chi-square (LM_χ) and F distribution (LM_F). The null hypothesis of homogeneous coefficient is tested against an alternative hypothesis of heterogeneous coefficients (PSTR).

	$LM\chi$		LM_F	
m	test	p-value	test	p-value
H_{03}^*	25.330	(0.000)	4.872	(0.0003)
H_{02}^*	10.220	(0.069)	1.931	(0.089)
H_{01}^*	1.948	(0.856)	0.361	(0.875)

Table 5: Sequence of homogeneity tests, transition variable (r-g). Results of LM sequence of homogeneity test based on chi-square and F distribution. The hypothesis is based on the following; $H_0^* : \beta_3^* = \beta_2^* = \beta_1^* = 0$, $H_{03}^* : \beta_3^* = 0$, $H_{02}^* : \beta_2^* = 0| = \beta_3^* = 0$ and finally $H_{01}^* : \beta_1^* = 0| = \beta_3^* = \beta_2^* = 0$

Table 6: Summary statistics - Interest-growth rate differential

Country	mean	median	Std. Dev	p.25	p.75	Min	Max
Austria	2.26	1.98	1.97	0.786	3.12	-0.222	8.32
Belgium	2.14	1.72	1.63	0.924	2.75	-0.120	6.16
Cyprus	1.73	1.03	4.00	-0.008	3.31	-3.89	10.3
Estonia	-0.832	-2.62	6.16	-3.49	-0.978	-5.57	19.2
Finland	1.62	0.696	3.12	-0.054	2.94	-1.67	12.0
France	2.02	1.64	1.80	1.03	2.65	-0.464	6.51
Germany	1.97	0.895	2.82	-0.007	3.31	-1.04	9.76
Greece	3.75	1.97	4.58	0.348	5.16	-0.991	15.4
Italy	3.78	3.21	2.15	2.09	4.87	1.25	9.43
Latvia	1.20	-0.528	6.72	-1.97	1.32	-6.77	21.8
Luxembourg	0.050	-0.115	2.43	-1.17	0.787	-3.90	5.75
Malta	0.481	1.02	3.83	-2.11	2.59	-7.32	6.56
Netherlands	1.95	1.71	2.28	0.241	2.85	-1.18	7.33
Portugal	3.17	2.74	2.47	1.71	4.64	-0.485	8.25
Slovenia	2.79	2.16	3.69	0.188	4.61	-1.52	13.4
Spain	2.30	1.64	2.64	0.267	3.65	-0.771	8.03

Figure 4: Actual primary balance and PSTR fitted primary balance