REM WORKING PAPER SERIES

COMPLIANCE WITH FISCAL SUSTAINABILITY AND THE EURO

António Afonso, Catarina Farinha Miranda

REM Working Paper 0371-2025

March 2025

REM – Research in Economics and Mathematics
Rua Miguel Lúpi 20,
1249-078 Lisboa,
Portugal

ISSN 2184-108X

Fundação para a Ciência e a Tecnologia
U LISBOA | UNIVERSIDADE DE LISBOA
ISEG Lisbon School of Economics & Management Universidade de Lisboa
REM RESEARCH IN ECONOMICS AND MATHEMATICS

REM – Research in Economics and Mathematics

Rua Miguel Lupi, 20
1249-078 LISBOA
Portugal

Telephone: +351 - 213 925 912
E-mail: rem@iseg.ulisboa.pt

https://rem.rc.iseg.ulisboa.pt/

https://twitter.com/ResearchRem

https://www.linkedin.com/company/researchrem/

https://www.facebook.com/researchrem/

COMPLIANCE WITH FISCAL SUSTAINABILITY AND THE EURO[1]

António Afonso[2] **Catarina Farinha Miranda**[3]

2025

ABSTRACT

Through fiscal reaction functions, we investigate fiscal sustainability for five European country-group panels and check for a change in fiscal behaviour after countries adopted the euro as their currency. Using annual data for the period between 1990 and 2021, we identify evidence of average compliance with sustainability restrictions among Eurozone nations. However, for the Eurozone countries there is a smaller response, 0.046 percentage points (pp), to an increase in the debt ratio than in the case of the European economies without euro, where the response is around 0.1036 pp. Conversely, the euro membership has decreased the average responsiveness of primary balances to debt shocks as compared to the period before the implementation of the euro.

JEL classification: E62, H62
Key words: Fiscal Sustainability, Debt, Primary Budget Balance, Fiscal Reaction Functions, Euro Area

[1] This work was supported by the FCT (Fundação para a Ciência e a Tecnologia) [grant number UIDB/05069/2020]. The opinions expressed herein are those of the authors and do not necessarily reflect those of the authors' employers. Any remaining errors are the authors' sole responsibility.
[2] Instituto Superior de Economia e Gestão (ISEG), Universidade de Lisboa, Rua do Quelhas 6, 1200-781 Lisboa, Portugal. Research in Economics and Mathematics (REM) and Research Unit on Complexity and Economics (UECE), ISEG, Universidade de Lisboa, Rua Miguel Lupi 20, 1249-078 Lisbon, Portugal. CESifo Research Fellow (Center for Economic Studies and Ifo Institute). email: aafonso@iseg.ulisboa.pt.
[3] Instituto Superior de Economia e Gestão (ISEG), Universidade de Lisboa, Rua do Quelhas 6, 1200-781 Lisboa, Portugal email: l50703@aln.iseg.ulisboa.pt.

1. INTRODUCTION

Numerous developed countries, have had fiscal sustainability issues in recent decades. Moreover, peripheral Euro Area nations saw an increase in long-term interest rates during the 2008 Global and Financial Crisis (GFC), forcing them to turn to international and institutional financial aid programmes to guarantee the necessary budgetary funding. Additionally, the budgetary strain experienced by the nations who had to deal with both growing debt ratios and interest rate costs raised some concerns about the viability of the Euro Area (Afonso *et al*., 2024). More recently, almost a decade after the GFC, the COVID-19 health crisis challenged, once again, the limits and the fiscal capacity of governments facing a sharp rise in their public expenditures. The fact that the European institutions and the European Union framework were not ready for these adverse shocks only served to confirm that the Eurozone was far from being an optimum currency area.

Due to this economic context, it is pertinent and interesting to ask the question if there is an expressive difference in fiscal sustainability between the group of countries belonging to the Euro Area and the group of countries that chose not to adopt the single currency but are members of the European Union.

Hence, in this study, we investigate fiscal sustainability in five panel groups of European countries, namely: Euro Area, Non-Euro Area without UK, Non-Euro Area with UK, both without UK and both with UK, using annual data for the period between 1990 and 2021. To assess this objective, firstly we carry out unit root tests, notably for the relevant fiscal variables to determine the presence or absence of stationarity. Secondly, in each panel, we estimate a fiscal reaction function to quantify the average reaction in the primary budget balance to sovereign debt shock, maintaining everything else constant.

According to our results, the aforementioned reaction function was observed to be less expressive in the panel referring to Eurozone nations than in the Non-EA without UK panel. Following this result, it was felt that calculating the impact of entry into the Eurozone, specifically for the panel of EA countries, would help to better understand whether belonging to a monetary union was one of the justifications for the result obtained. In general, and in line with other researches, it can be established, to some extent, that belonging to the single currency has negatively impacted the ability of governments rebalance public finances when debt level rise. Indeed, for the Eurozone country-group there is a smaller response, 0.046 percentage points (pp), to an increase in the debt-to-GDP ratio debt ratio than in the case of the European economies without euro, where the response is around 0.1036 pp. Conversely, the euro

membership has decreased the average responsiveness of primary balances to debt shocks as compared to the period before the implementation of the euro.

The remainder of the paper is organized as follows. Section 2 provides the literature review; Section 3 presents the methodology. Section 4 describes the data and the estimation results. Section 5 concludes.

2. LITERATURE

The government's intertemporal budget constraints (IBC) in present value terms (also referred as the present value budget constraint) is often the starting point for the assessment of the sustainability of government finances in the long run. If the IBC is not fulfilled, then public expenditure cannot be sustained in the long run. In other words, a government is anticipated to run surpluses in the future if there has been a deficit for a while.

The existing literature on the sustainability of public finances relies largely on two fields of studies. One assesses the fiscal sustainability by examining the cointegration relationship between government revenues and expenditures, and the second one measures fiscal reaction functions, such as the improvement of primary budget balances in response to rising government debt ratios and the effects of primary budget balance on public debt.

However, the first studies carried out on this topic were quite simple in terms of the models and techniques used, the assumptions applied, and the variables chosen. The conclusions reached were later called into doubts, due to questions such as whether the considerations used were sufficient conditions of sustainability criteria or not, which led to a triggering of the development and improvement of the assessment of the sustainability of public finances.

The first investigations on the IBC studied historical series of public deficit and debt, testing for stationarity. Halmilton and Flavin (1986) took this approach to test the compliance with the no-Ponzi condition[4] in a pioneering work for the United States (US) data. They used data over the period 1960 – 1984 and found evidence for sustainable fiscal policy in the US. Subsequently, many studies using US data have supported government´s intertemporal sustainability (e.g., Trehan and Walsh, 1991; Hakkio and Rush, 1991; Quintos, 1995; and others).

[4] The No-Ponzi condition says that the present value of the public debt stock should decrease to zero in infinity under a sustainable fiscal policy, preventing debt growth beyond the interest rate (Afonso, 2000).

As the studies progressed, several authors began to state that when both time series lead to a non-stationary result, the fiscal solvency criterion needs a cointegration relationship between government spending and revenues. Therefore, the investigations carried out later began to use the cointegration method as one of the main methods for the assessment of fiscal sustainability. For instance, Bravo and Silvestre (2002) tested if there was any cointegration between government receipts and spending for 11 member states of the European Union (EU) between 1960 and 2000. According to the findings, Austria, France, Germany, the Netherlands, and the United Kingdom all have sustainable governmental budgets. Afterwards, Afonso and Rault (2010) also examine the cointegration between the two parts of budget balance for a group of EU – 15 countries between 1970 and 2006, concluding that fiscal authorities of countries such Finland, United Kingdom, Austria, France, Germany, and Sweden, incline to exhibit fiscal discipline. Similar to this, Chen (2016) investigates, by using a unique quantile technique (never used before), the cointegration relationship between government income and expenditures for the US from 1960Q2 to 2010Q3. The author concluded that the coefficient of the cointegration relationship is lower the higher the quantile of government revenues and expenditures. As a result, the convergence of government spending and revenue depends on the quantile. Additional relevant studies carried out using the cointegration method are Hakkio and Rush (1991), Quintos (1995), Payne (1997), Camarero *et al.* (2013), among others.

According to Trahan and Walsh (1991), fiscal sustainability requires that the first differences in the stock of real public debt is a sufficient condition. However, Bohn (2007) states that the absence of sustainability in public finances does not always follow the rejection of stationarity. These standard tests methods are conducted under the strong assumption of certainty. However, expectations and uncertainty around future fiscal variables are essential factors to consider when evaluating fiscal policy (Bohn, 1998). The marginal rate of substitution between consumption at time t and time $t+1$, as opposed to the "safe interest rate", is what determines the right discount factor for solvency test in the presence of uncertainty (Weichenrieder and Zimmer, 2014). Therefore, there is a possibility that some of the current empirical tests are unreliable because they use the incorrect discount factors.

Notwithstanding, Bohn (2007) noted that there is not a necessity to confirm a cointegration analysis between total government income and expenditures (including payment on debt interests). As this author shows, the intertemporal budget restriction may be shown even in the absence of cointegration or stationarity of the variables that explain the debt trajectory. On the other hand, and to try to address the obstacles encountered, Bohn (1998) proposes the alternative notion of a fiscal reaction function (a model-based sustainability

approach) to evaluate fiscal sustainability because the optimal discount factor is based on a several assumptions about potential states of nature that are hard to estimate. This methodology examines for certain time series aspects of fiscal data, in contrast to the conventional empirical approaches, and does not rely on any assumptions on the appropriate discount rates. The model does not need a special knowledge on the design of fiscal policy or any specific assumptions about the debt structure in terms of its composition (Weichenrieder and Zimmer, 2014).

The foundation of Bohn´s method is an examination of how changes in the sovereign debt caused by economic shocks affect the primary fiscal balance, which is the fiscal balance excluding interest payments on public debt. When the government adjusts the main fiscal balance in a systematic manner in response to a change in the public debt, fiscal policy is seen to be sustainable within this framework. The reasoning for this is that if a fiscal policy were thought to be sustainable before a specific economic shock, the lack of any systematic policy response to this shock would lead to the newly issued debt being uncovered by subsequent surpluses, breaking the no-Ponzi condition (Weichenrieder and Zimmer, 2014). Hence, to preserve fiscal sustainability, the government must consistently respond to the high debt-to-GDP ratio by raising the primary surplus-to-GDP ratio. The simplest and most widely used form assumes that the primary surplus of period *t* and the level of inherited debt are linearly related, which can be written as follows:

$$s_t = \rho \, . \, d_{t-1} + \mu_t \qquad (1)$$

where s_t is the primary surplus of period *t* in terms of GDP, d_{t-1} is the one period lagged initial debt as a percentage of GDP, and μ_t is indicating other influences of the primary surplus. Bohn (1998) showed that if μ_t is in terms of GDP and the present value of GDP is finite, then $\rho > 0$ satisfies the economy´s intertemporal budget constraint and the no-Ponzi condition. However, the underlying assumption of invariability that such a broad definition contains poses a dilemma. For instance, Daniel and Shiamptains (2013) demonstrate that if there is a limit for positive values of primary balances, a positive coefficient ρ cannot be seen as a being sufficient to achieve sustainability. In addition, Gosh *et al.* (2013) refer to this term as a "weak sustainability condition". Furthermore, according to Weichenrieder and Zimmer (2014), while the debt level may reach a finite level d^* in the absence of primary surplus restrictions, with a restriction on the maximum primary surplus, the level d^* may exceed what can be supported by the maximum primary surplus, and the difference between the growth rate and the interest rate becomes more significant for the primary surplus needed for sustainability. Similarly, Fincke and Greiner (2012) have an opposite position to Bohn´s (1998) method. They specified that this approach is insufficient to ensure a bounded government debt ratio in the long run,

which is essential to ensure a sustainable growth path for public debt, as well as that global budget balances should be stationary, based on an empirical analysis carried out for some European countries. In addition, the robustness of the finding is thought to be critically dependent on the model specification used for the fiscal reaction function analysis (Afonso *et al*., 2024).

The fiscal reaction functions literature poses the question of whether it is preferable to estimate country – specific fiscal reaction functions that rely on long time series or if it is preferable to pay more attention to the time consistency dimension and estimate a single fiscal reaction function across a panel of nations and shorter period (Berti *et al*., 2016). Country – specific fiscal reaction functions do, in fact, capture the country – specific characteristics of fiscal behaviour, but they often need to rely on very lengthy time horizons that cover a variety of macroeconomic situations. In light of this, it may be considered a strong hypothesis to assume that fiscal behaviour is time-invariant (with respect to debt and other factors) (Berti *et al*., 2016). However, a single fiscal reaction function computed over a panel of nations and a shorter period assumes that fiscal behaviour will be consistent throughout the sample of countries taken into count, which may prove to be an even more reliable assumption (Berti *et al*., 2016).

For example, Greiner *et al.* (2007) examine fiscal reaction functions for industrialized nations with high debt-to-GDP ratios or that have not met the Maastricht Treaty´s requirement of 3% of deficit. The conclusion was that the fiscal authorities have demonstrated budgetary sustainability despite not achieving this fiscal criterion. Another example is Gali and Perotti (2003) where for the period 1980 – 2002, calculated the fiscal reaction functions for eleven EMU member states and concluded that participation in the Euro Area did not result in less counter cyclical discretionary fiscal policy than in the EU countries that did not wish to join the euro.

However, some researchers report that fiscal authorities of developing countries have also demonstrated a willingness to respond fiscally to rising public debt ratios. Furthermore, fiscal reaction functions are shown to be more robust for low-debt nations, not just because such behaviour is grater for lower income economies than for the most developed economies (Afonso *et al*., 2024). For instance, Mendoza and Ostry (2008), for the period between 1990 and 2005, assessed fiscal reaction functions for both industrial and emerging market countries. They concluded that there is a solid empirical support for a positive conditional link between primary surpluses and public debt for equally emerging and advanced economies.

Although the importance of selecting the method to be utilised in a study, the variables that will be included in the model are as crucial. Regarding the dependent variable in fiscal reaction functions, according to Checherita-Westphal and Žďárek (2017), there are two main policy variables, the cyclically adjusted primary balance (CAPB) and the primary budget balance (PB), that the use depends on the aim of the study. The distinction between both variables lies in the fact that models with CAPB do not reflect business cycle and assess fiscal effort, whereas models with PB are linked with the output gap and show the total change. The PB, which is also the focus of this study, is the dependent variable in the majority of empirical investigations. In terms of explanatory variables, various studies (for instance, Ilzetzki and Vegh 2008; Darvas 2010) concentrates on fiscal factors such as tax rates or discretionary expenditure in order to determine the policy aims of the decision makers.

While other investigations (such as Bernoth *et al.*, 2008) employ real-time data to present a more accurate representation of current fiscal policymaking (Baldi, G., & Staehr, K., 2016). Each model should apply the variables that make the most sense given the subject of their study. However, certain variables are thought to be the most used ones. Some of them include control variables such as output gap and expenditure. To take into consideration the pressure on the financial markets and the impacts of valorisation, variables like the interest rate and inflation are frequently added (Berti *et al*., 2016). Recent changes in the European Union connected to the financial and sovereign debt crises necessitate extra control for some other factors because, with a significant rise in the short-term fiscal multipliers, the severity of the crisis has changed the average connection between public expenditure (and receipts) and GDP (Berti *et al*. 2016). Therefore, variables such as index fiscal rules are introduced with the objective of trying to explain some restrictions applied to improve the budget balance.

Lastly, some analyses assess the impacts of fiscal behaviour on government debt yield, others explore the relationship between fiscal reaction functions and the business cycle, and various evaluate how Eurozone membership´s exposure to default risk on the financial markets is affected by participation in the Euro Area, and so on. For instance, more recently and more in a field of study in the Euro Area, Afonso and Coelho (2024) evaluate, for 19 countries in the EA over a 25-year period, the factors that affect the fiscal sustainability coefficients and primary balance reactions to past government debt. According to their findings, among other things, trade openness is bad for fiscal sustainability whereas economic success and fiscal laws both promote the sustainability of government finances. A summary of some relevant related literature is provided in Table A1 in the Appendix.

3. METHODOLOGY

3.1 UNIT ROOT TESTS

In panel data, the data's time series characteristics might be crucial. In particular, non-stationary errors can bias coefficient estimations. Particularly, when calculating fiscal reaction functions using longer time series this issue might arise. When series are non-stationary, or when they contain stochastic trends, as is frequently the case with GDP series, this problem occurs (Afonso and Jalles, 2011). Therefore, in order to assure unbiased findings, we conducted two unit root tests to assess potential non-stationarity issues.

The unit root tests used are the Levin, Lin and Chu (LLC) and the Im, Persaran and Shin (IPS) tests (Levin *et al*., 2002; Im *et al*, 2003), which are first-generation models of panel-based unit root tests that assume data is independent and identically distributed across individuals. This form of panel unit root test is often founded on the following univariate regression:

$$\Delta y_{it} = \rho_i y_{it-1} + z_{it}'\gamma + u_{it}, i = 1,2,\dots,N\ , t = 1,2,\dots,T \quad (2)$$

where z_{it} is the deterministic component (could be zero, one, the fixed effects or fixed effect as well as a time trend) and u_{it} is assumed to be stationary and uncorrelated (Barbieri, 2009). The null hypothesis, in statistical terms, is: H_0: $\rho_i = 0\ \forall i$.

The degree of heterogeneity evaluated by the alternative hypothesis is the key distinction between LLC and IPS tests and this more standard regression (2).

The first test, the LLC test, "allow for heterogeneity of individual deterministic effects and heterogeneity serial correlation structure of the error terms assuming homogeneous first order autoregressive parameters" (Barbieri, 2009). The authors created this method by comparing the alternative hypothesis, that each time series is stationary, with the null hypothesis that each individual time series has a unit root, using the estimator's pooled *t*-statistic (Barbieri, 2009). Therefore, taking regression (2) into account, LLC assumes homogeneous autoregressive coefficients between individual, i.e., $\rho_i = \rho\ \forall i$, in order to test the null hypothesis H_0: $\rho_i = \rho = 0$ against the alternative hypothesis H_1: $\rho_i = \rho < 0$ (Barbieri, 2008). The regression is the following:

$$\Delta y_{it} = \rho y_{it-1} + \alpha_{0i} + \alpha_{1i} t + u_{it},\ \ i = 1,2,\dots,N\ , t = 1,2,\dots,T. \quad (3)$$

where there is a time trend, $\alpha_{1i} t$, and individual effects, α_i. It is assumed that u_{it} follows a stationary invertible ARMA process for each individual and is independently distributed across individuals.

The second test, Im, Pesaran and Shin (2003) use the likelihood framework to propose an alternative unit root testing approach for panels (known as the *t*-bar statistic), which allows

for simultaneous stationary and non-stationary series (i.e., ρ_i can vary between individuals) (Barbieri, 2009). Furthermore, this technique considers group-specific heterogeneity in dynamics and error variances between groups, as well as residual serial correlation (Barbieri, 2009). When the model's error term of (2) is serially correlated, potentially with different serial correlation patterns across cross-sectional units (i.e., $u_{it} = \sum_{j=1}^{p_i} \varphi_{ij}\, u_{it-j} + \varepsilon_{it}$) and N and T are large enough, IPS considers the mean of Dickey and Fuller (1979, 1981) statistics assessed for each cross-section unit in the panel rather than pooling the data (Barbieri, 2009). They then derive the follow regression by replacing this into (2), and allowing for a linear trend for each of the N cross-section units:

$$\Delta y_{it} = \alpha_{0i} + \rho_i y_{it-1} + \sum_{j=1}^{p_i} \varphi_{ij}\, \Delta y_{it-j} + \varepsilon_{it}, \quad i = 1,2,\dots,N\,, t = 1,2,\dots,T \quad (4)$$

The null and the alternative hypothesis are:

$$H_0: \rho_i = 0\ \forall i$$

$$H_1: \begin{cases} \rho_i < 0\ for\ i = 1,\dots,N_1 \\ \rho_i = 0\ for\ i = N_1 + 1,\dots,N \end{cases} with\ 0 < N_1 \leq N$$

that allows for unit roots for certain (but not all) individual series.

However, it is essential to mention some important distinctions between LLC and IPS that make direct comparisons between them impossible. Even if the null hypothesis for both tests is the same, the alternatives are quite different because the IPS test use a variety of individual first order autoregressive coefficients, whereas the LLC test employs individual stationary series with the same first order autoregressive coefficient. Therefore, although both tests are used in this study for robustness reasons, the findings of the LLC test (also known as the common unit root test) will receive greater attention.

As previously stated, given the nature of this research, it is predicted that some variables, such as inflation and the output gap in terms of GDP, will be non-stationary, as their evolution is more reliant on other factors. When the variables exhibit non-stationary, endogeneity issues arise, and it is necessary to find a solution to correct/combat endogeneity before creating the regression so that the findings are not biased. According to Wooldridge (2015), one of the solutions found is the differentiation of the variable between present and the year before, that is, $\Delta y_t = y_t - y_{t-1}$ (where y is the non-stationary variable and the index t (t=1,…, T) express the period).

3.2 FISCAL REACTION FUNCTION

The empirical model employed in the study to validate the existence of fiscal sustainability is an extension of Bohn's (1998) econometric specification, as shown by regression (1). As previously stated in the literature review, such an approach attempts to determine if fiscal authorities are driven by both stabilisation and sustainability motivations, and if so a positive reaction of the budget balance to the debt stock should be expected. The main goal of this study is to measure the difference in this exact reaction between groups of countries belonging and not belonging to the EMU. Hence, with different fiscal and budgetary constraints, it was decided to build the following base regression, which is later adjusted based on whether variables are non-stationary in each panel and other possible problems related with time series, to obtain non-spurious results

$$pb_{it} = \beta_0 + \beta_1 pb_{it-1} + \beta_2 debt_{it-1} + \beta_3 gap_{it-1} + \beta_4 infl_{it} + \beta_5 rg_{it} + \beta_6 rules_{it} + \beta_7 eu_{it} + \beta_8 ea_{it} + u_{it} \qquad (5)$$

with,

$$eu_{it} = \begin{cases} 1, if\ country\ i\ belongs\ to\ European\ Union\ at\ period\ t \\ 0, otherwise \end{cases}$$

$$ea_{it} = \begin{cases} 1, if\ country\ i\ belongs\ to\ Euro\ Area\ at\ period\ t \\ 0, otherwise \end{cases}$$

where pb_{it} is the primary budget balance in terms of GDP; pb_{it-1} is the lagged primary budget balance as a percentage of GDP; $debt_{it-1}$, is the lagged public debt stock, which is the core of the study; gap_{it-1} is the lagged output gap; $infl_{it}$ is the inflation rate; rg_{it} is the difference between the long-term interest rate and the economic growth rate; $rules_{it}$ is a fiscal rules index, where higher values indicate stricter restrictions; eu_{it} and ea_{it} are both dummies to indicate whether or not a country is a member of the European Union or of the Eurozone, respectively; and, u_{it} is the error term and is assumed that is independent across countries. In expression (5) the index *i* (*i*=1,…, *N*) denotes the country and the index *t* (*t*=1,…, *T*) indicates the period of time.

Hence, from regression (5) it is possible to test if the group of countries have fiscal sustainability through the following hypotheses:

1) If $\beta_2 > 0$, the government attempts to enhance the primary balance in response to the stock of public debt.

2) If $\beta_2 \leq 0$, the primary balance does not respond positively to the level of public debt, indicating that the government might implementing pro-cyclical policies.

Furthermore, because the main goal of this study is to compare fiscal sustainability from a long-term perspective, explanatory variables that focus more on the category of fiscal factors than on real-time variables were chosen. For instance, the output gap is used as a proxy for cyclical conditions and to account for market pressure and valorisation effects it is used the inflation rate and the difference between long-term interest rate and economic growth.

Additionally, the lagged public debt is the central component of this regression, and its coefficient represents the average government response with respect to public debt. Given that we are analysing various panels, each of which comprises several countries, it is predicted that this coefficient will be positive in all of them, albeit with different degrees of response. Notwithstanding, the rules variable was applied in order to serve as a proxy for fiscal policy institutionalization and both dummies were integrated to incorporate essential qualitative information.

Lastly, as already mentioned, when considering fiscal balances and government debt, if governments seek to reduce the stock of public debt, it is normal to expect them to achieve primary surpluses. Hence, it makes sense to utilize the primary budget balance, since primary expenditure is more easily under discretionary control of government (Afonso, 2008). Based on such fiscal policy rule, it is assumed that the primary balance for period *t* depends on the PB for the previous year. In fact, governments find it difficult to implement enough policies in a single year to significantly modify overall fiscal policy position (Afonso, 2008). In particular, the more important budgetary expenditures are virtually little modified in the short term. Thus, it is appropriate to employ the primary budget balance lagged one period as an explanatory variable. In other words, using a lagged dependent variable, as a control explanatory factor, provides a straightforward method for accounting for past events that contribute to present disparities in the dependent variable but are difficult to account for in other ways (Wooldridge, 2015).

Posteriorly, an extension of the specification tests specifically the EA panel, which is based on the interaction of the ea_{it} dummy with the remaining explanatory variables.

The specification is the following:

$$pb_{it} = \delta_0 + \delta_1 pb_{it-1} + \delta_2 debt_{it-1} + \delta_3 gap_{it-1} + \delta_4 infl_{it} + \delta_5 rg_{it} + \delta_6 rules_{it} + \delta_7 ea_{it} + \theta_1 debt_{it} \times ea_{it} + \theta_2 gap_{it} \times ea_{it} + \theta_3 infl_{it} \times ea_{it} + \theta_4 rg_{it} \times ea_{it} + \varepsilon_{it} \quad (6)$$

with,

$$eu_{it} = \begin{cases} 1, if\ country\ i\ belongs\ to\ European\ Union\ at\ period\ t \\ 0, otherwise \end{cases}$$

$$ea_{it} = \begin{cases} 1, if\ country\ i\ belongs\ to\ Euro\ Area\ at\ period\ t \\ 0, otherwise \end{cases}$$

where all variables represent the same as the variables from regression (5). ε_{it} is the error term and is assumed that is independent across countries, the index i (i=1, …, N) denotes the country and the index t (t=1, …, T) indicates the period.

In this sense, the coefficient of variable debt is no longer the main focus of expression (6), but rather the coefficient associated to the interaction of the ea_{it} dummy with the debt variable, that is, θ_1.

In addition, and besides the variables' non-stationarity, potential problems of endogeneity and cross-section dependence must be considered when estimating fiscal reaction functions, given the expected interactions between the variables in the regression and the dependent variable with the error term. Moreover, serial correlation and heteroscedasticity in a dynamic panel setting for a homogeneous group of countries are to be anticipated (Checherita-Westphal and Žďárek, 2017). In this study, as reported in Appendix Tables A4-A8, we can detect some correlation between variables. For instance, there is a positive correlation between the output gap and debt, as well as debt and fiscal rules. Furthermore, although we included the most significant key variables in this study's fiscal reaction function, it is possible that other essential variables that explain the dependent variable were overlooked. These missing variables may certainly have some link with the dependent variable and with some applied explanatory variables as well, which might lead to endogeneity issues. One popular method to address endogeneity is introducing instrumental variables. Therefore, it was decided to apply instrumental variables techniques, the Two Stage Least Squares (TSLS) and the Generalized Method of Moments (GMM), in order to avoid/reduce endogeneity problems and robust standard errors to deal with heteroscedasticity, serial correlation and cross-sectional dependence. It was also utilized, for robustness effects, the Least Squares technique. Additionally, fixed cross-section effects[5] were applied to all tests performed on all techniques for each panel in order to control spurious results too.

The use of fixed effects in instrumental variables techniques is criticized because of the Nickell's bias[6]. However, despite the criticisms of its application, we state that the potential

[5] Fixed effects is a method of controlling for variables, whether they are observed or not, as long as they stay constant within some larger category.

[6] When used in the context of a dynamic panel data model, the fixed effects model presents significant challenges, particularly with a small T and large N setting. This occurs because there is a link between the regressor and error

bias should be kept to a minimum due to the panels being medium to large in time dimension compared to the cross-section dimension. Besides, the Bond (2002) "rule of thumb" indicates that the potential bias of the fixed effects should be minimal for scenarios when T is more than 20 (Checherita-Westphal and Žďárek, 2017). Therefore, it was decided to still apply it.

4. EMPIRICAL RESULTS

4.1 DATA AND VARIABLES

The study's data sample consists in five panel groups of European countries, namely: Euro Area, Non-Euro Area without UK, Non-Euro Area with UK, both without UK and both with UK, using annual data mostly from the start of 1990 to 2021 (for a detailed description of the countries included in each group, see Appendix Table A2).

The panels are unbalanced due to missing a few observations at the beginning of the sample and the inclusion of the more recent EU member states, whose time series are usually shorter. Additionally, certain data on inflation variable, reported in several eastern countries, were excluded to avoid biasing the final results, as they are regarded outliers. The ea_{it} dummy was omitted in some panels since it was not a statistically significant variable as well as eu_{it} was omitted from the EA panel due to the same reason. The data sources are AMECO database and European Commission (see description of the variables in Appendix Table A3). Finally, it is important to mention that the main focus of the analyses that will be carried out from now on will fall essentially on the panels: EA and Non-EA without UK.

Before proceeding with the regression analysis, a preliminary examination of the data may be conducted to determine the size of the existing association between the primary balance and changes in the debt stock. For instance, and based on the data, that correlation is comprised between -0.049 and -0.1207 for the five panels (Appendix Tables A4-A8). In this case and on the one hand, all the values reveal a weak negative correlation, which may be a hint that most governments apply countercyclical fiscal policies, in other words, it can indicate the possibility of fiscal sustainability. On the other hand, it reveals different degrees of IBC fulfilment.

It is also important to examine the variables primary budget balance and public debt in terms of GDP across time. Through Tables A9-A12 in the Appendix, it can be seen that the average of the debt variable in the panels is greater in the Eurozone (roughly 67.2) than in the Non-EA without UK panel (about 48.6). These numbers may already be an indication that the

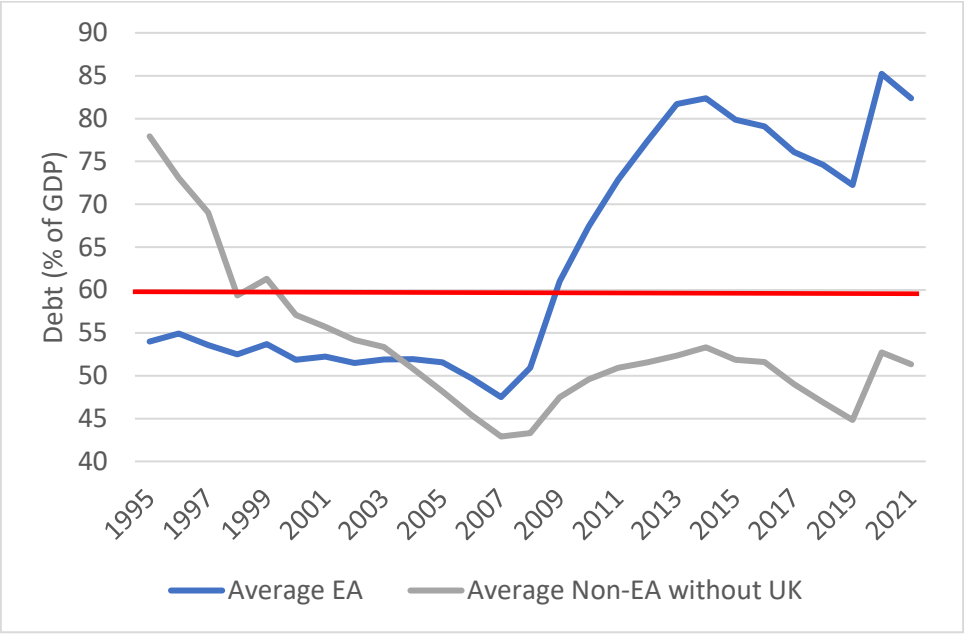
due to the demeaning process that subtracts each country's mean value of y and x from the appropriate variable, as demonstrated by Stephen Nickell (1981).

degree of fiscal sustainability among Euro Area nations can be lower than non-Eurozone countries. Analysing the remaining panels, we see that the rest of the means are included between the previously indicated values, which appears to be normal given that they are averages.

The evolution of the average of the public debt and the primary balance for both panels are shown in Figures 1 and 2. To meet the prerequisites for the launch of the European Monetary Union, in 1999, the nations that constitute the Euro Area today, had to pursue a strategy of fiscal consolidation in the middle of the 90s and, after entry, they should continue to meet the convergence criteria. Therefore, through Figure 1 we can observe that, as a group, the EA countries had a consistent average public debt ratio below 60% until 2007, even though after entry some countries had a slight increase in their debt. The mean increased significantly with the start of the subprime crisis and shortly after the sovereign debt crisis that various nations (for example, Portugal, Greece, Spain and others) were pulled into. Thus, in 2014, the average debt ratio reached slightly more than 80%, putting the euro's sustainability into doubt at times and prompting Mário Draghi (President of the European Central Bank at the time) to declare that he would do whatever it was necessary to save the euro. Since 2014, a slow decrease has been registered, but once more it has recently risen rapidly due to the COVID-19 pandemic crisis (reaching a new maximum of 85%), forcing to adopt new measures.

Regarding the Non-EA without UK panel, we can observe that the average debt ratio was substantially higher than the EA mean in 1995, however it was generally on a downward trend until 2007, which by mid-2003 its value had fallen below the EA average, remain until today. After 2007, the debt trend and fluctuations were quite similar to the EA mean movements.

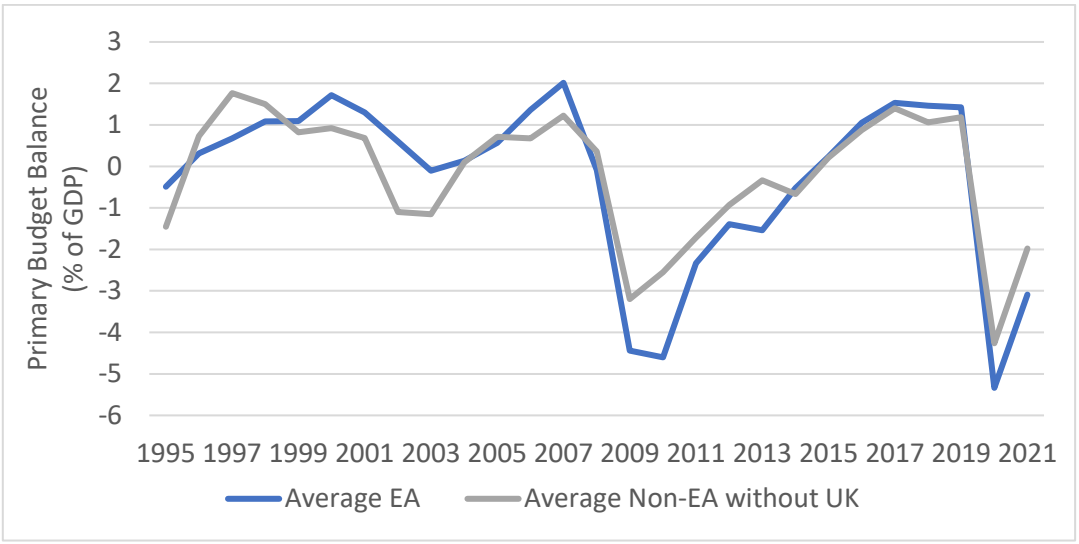
Figure 1: Debt-to-GDP ratio



Source: AMECO database.

Finally, prior to the subprime crisis, the average primary balance, was mostly positive for the EA and Non-EA countries, with some fluctuations. With the beginning of the 2007 crisis, the primary budget balance significantly declined and the balance for all nation groups went negative between 2008 and later 2014 and between 2019 until 2021 (Figure 2).

Figure 2: Primary Budget Balance (% of GDP)



Source: AMECO database.

4.2 RESULTS

4.2.1 UNIT ROOT TESTS

Appendix Table A13 reports unit root tests for each variable in each panel. Generally, and using a 5% level of significance as a reference, we can verify that both tests report an agreement in their results for the variables primary budget balance, output gap and R-G, in other words, with a few exceptions, almost all variables confirm their stationarity in both tests for each panel. However, for inflation and debt these results mostly present a disagreement, i.e., in the IPS test stationarity is demonstrated, while in the LLC test the variables are non-stationary in almost panels. Therefore, as explained in section 3.1, the LLC test will receive greater attention when analysing these two variables.

Moving to a more in-depth study, it can be seen that both the primary budget balance and the output gap reveal stationarity over the entire sample period in all panels at a 5% significance level. In other words, because these variables reject the null hypothesis, they lack a unit root and hence do not need to apply any differentiation to the model variables. However, on the other hand, it is evident that the tests for inflation in all panels deny the presence of stationarity at 10% and 5% significance level too, which means that a differentiation will have to be applied to the model variable. Additionally, regarding R-G, it can be inferred that there is no stationary only in the Non-EA panels, and, finally, the tests provide evidence that the debt variable is non-stationary exclusively in the EA panel. Although the debt variable displayed non-stationarity in the EA panel, it was found that when a differentiation was applied to the variable, the coefficient went negative, providing results that were unexpected and incongruent with reality, when considered the study's object. Thus, it was concluded that the variable should not be differentiated, but rather deferring it one period in order to remain to prevent potential issues with biased and misleading results and, at the same time, make sense with reality.

4.2.2 FISCAL REACTION FUNCTIONS

Our baseline specification estimates (fiscal reaction function (5)) of the EA and Non-EA without UK panels are presented in Tables 1 and 2, using multiple estimation techniques, allowing for testing the robustness of results, as already mentioned. Before proceeding with the table analysis, it is important to aware the reader that it was decided not to report the GMM outcomes because they were equal to the 2SLS findings.

Table 1: Estimations for Primary Budget Balance, Non-EA without UK

Dependent Variable	**Primary Budget Balance as a share of GDP**			
Regressor/estimation	OLS		2SLS	
	Coefficient	P-value	Coefficient	P-value
C	-4,631043 (1,120800)	0,0001	-8,184685 (2,018858)	0,0001
PB (-1)	0,626873 (0,061874)	0,0000	0,411943 (0,134396)	0,0026
DEBT (-1)	0,066997 (0,017097)	0,0001	0,103692 (0,027496)	0,0002
GAP (-1)	-2,198626 (1,084563)	0,0445	-4,956617 (1,795160)	0,0065
D(INFL)	0,052700 (0,053417)	0,3255	0,257984 (0,115266)	0,0268
D(RG)	-0,139652 (0,027421)	0,0000	-0,028031 (0,064210)	0,6631
RULES	-0,245060 (0,231568)	0,2917	-0,012373 (0,386076)	0,9745
EU	1,192306 (0,545015)	0,0303	2,672754 (0,879388)	0,0028
Observations	160		158	
R-squared	0,722717		0,645177	

Note: Standard errors in brackets.

Table 2: Estimations for Primary Budget Balance, EA

Dependent Variable	**Primary Budget Balance as a share of GDP**			
Regressor/estimation	OLS		2SLS	
	Coefficient	P-value	Coefficient	P-value
C	-2,158072 (0,624309)	0,0006	-3,347021 (0,839220)	0,0001
PB (-1)	0,622656 (0,036489)	0,0000	0,526939 (0,093443)	0,0000
DEBT (-1)	0,033934 (0,008067)	0,0000	0,046516 (0,010242)	0,0000
GAP (-1)	-1,183919 (0,804696)	0,1419	-0,865949 (1,231915)	0,4825
D(INFL)	0,122296 (0,073707)	0,0978	-0,229602 (0,261658)	0,3807
RG	-0,140561 (0,021746)	0,0000	-0,268127 (0,102652)	0,0093
RULES	-0,449472 (0,214776)	0,0369	-0,959629 (0,382904)	0,0126
EA	-0,563251 (0,386395)	0,1456	-0,041772 (0,580331)	0,9427
Observations	463		443	
R-squared	0,580449		0,550232	

Note: Standard errors in brackets.

Through Table 1 and 2 we can noticed that in general both regressions provide evidence for a positive and statistically significant parameter ρ that captures the fiscal reaction behavior, which means (in line with Bohn's definition and criterion of fiscal sustainability) that this systematic reaction by the governments might be interpreted as indication for overall sustainable fiscal policies. As previously stated, this positive outcome was already expected because it is a group analysis and not an individual investigation of each country.

Conducting a more detailed description, the result for Non-EA countries without UK suggest that, throughout the course of the study period, these European countries responded by raising their primary budget balance in terms of GDP by approximately 0.104 percentage points for every 1 percentage point (pp) increase in the lagged debt-to-GDP ratio, after controlling for other relevant factors (see 2SLS results in Table 1). Alternatively, the outcome of the regression applied to the Eurozone countries, reveals that this group of nations reacted to a 1 pp. rise in the lagged debt in terms of GDP by improve their primary budget balance by 0,046 percentage points, after controlling for other important variables (see Table 2). Although both coefficients are positive and statistically significant, it is fundamental to highlight the different intensity of the reaction of countries that have embraced the euro to be lower than the nations that have not adopted the single currency. Given that euro area countries are subject to stricter budgetary restrictions and have a larger average debt, this result may be explained by the fact that the most indebted nations have a stronger need to make fiscal adjustments in order to ensure the sustainability of public finances. The amount of adjustment of revenues to government expenditures is inversely correlated with the debt-to-GDP ratio. Therefore, governments are less able to absorb larger levels of public spending when the debt-to-GDP ratio is higher. This is in part because there is a fiscal limit that taxpayers are willing to accept (Afonso *et al*., 2024).

Regarding the remaining panels, it is interesting to analyse that when the UK is included in the group of non-eurozone nations, the reaction to a 1% shock in the lagged debt-to-GDP ratio becomes smaller (0.060753 pp). From another perspective, when calculated the coefficient for a sample that included all of the countries considered in this study (both with and without UK), we found it to be low, similar to the value for the eurozone, due to the increased weight/presence of countries with the single currency in the calculations (Appendix Tables A14-A16).

Although the debt variable plays an important role for determining fiscal sustainability, there are other equally important factors. R-G is another statistically significant variable in the EA panel. When there is a shock of 1% in the difference between interest rate and economic growth in this set of nations, the primary budget balance falls by approximately 0,268

percentage points. In this case, a negative impact represents a deterioration in fiscal sustainability, that is, an increase of the differential, decreases the responsiveness of the primary budget balance to changes in the public debt in terms of GDP, limiting fiscal authorities' ability to implement fiscal changes. In relation to the remaining panels, the estimates of the response coefficients have the same negative reaction, ranging from -0.028031 to -0.163174 (see Appendix Tables A14-A16).

The output gap appears to be statistically significant and negative in almost panels in this investigation, namely: Non-EA with and without UK, and Both with and without UK. Where a 1% shock in the output gap had a negative reaction of approximately 4,96 percentage points in the primary budget balance, more specifically in the Non-EA without UK panel (see Table 1). In other words, the output gap contributes to decrease fiscal sustainability by negatively influencing the responsiveness of the primary budget balance. This outcome may be explained by the fact that when the output gap is negative, government expenditures rise, revenues fall, and there is more dependence on discretionary fiscal policies to stabilize economic activity, reducing public savings.

Finally, we have the inflation variable, which shows to be similar, statistically significant, and positive for both Non-EA groups of countries (Table 1 and Appendix Table A14). Naturally, inflation increases the level of public expenditure in a way to compensate for its negative impact on society, which affects public accounts and restricts fiscal space even when it lowers the actual values of the stock of government debt and results in higher tax collections. Inflation has a beneficial short-term effect, but a long-term persistence of a high inflation rate damage the economy and deteriorate the public accounts.

After this analysis, as already mentioned, it was thought pertinent to question whether the soundness of fiscal policies has altered because of euro membership and the fiscal behaviour of Euro Area nations. Therefore, an extension of the model was carried out by adding the interaction of the variables with the EA dummy, exclusively for the panel of Eurozone countries (fiscal reaction function (6)), where the interaction term debt*EA is the relevant coefficient that we are looking for.

As a result, Table 3 reveals that when the debt variable interacts with the dummy, the coefficient is negative, i.e., after joining Eurozone, the countries' reaction to a 1% debt-to-GDP shock in the primary budget balance is less pronounced than previously to the entry (-0.0626 percentage points). The findings of this experiment are in line with the conclusions of Weichenrieder and Zimmer (2014) and seen to support the popular view/belief that, despite governments' attempts to secure EMU membership, the fiscal rules of EMU did not sufficiently

promote a high degree of fiscal prudence after countries were admitted to the single currency. Although this may support prevailing assumptions, according to Weichenrieder and Zimmer (2014), there may be some reservations regarding how reliable this outcome is. The inclusion of the crisis years, 2009-2011, is one concern for this doubt, which may have a significant impact on the results due to massive deficits.

Table 3: Estimations for Primary Budget Balance, EA (Dummy interaction)

Dependent Variable	**Primary Budget Balance as a share of GDP**			
Regressor/estimation	OLS		2SLS	
	Coefficient	P-value	Coefficient	P-value
C	-3,729658 (0,742750)	0,0000	-5,772447 (1,001505)	0,0000
PB (-1)	0,566813 (0,035667)	0,0000	0,485635 (0,070120)	0,0000
DEBT (-1)	0,073444 (0,010372)	0,0000	0,108508 (0,014699)	0,0000
GAP (-1)	-0,376060 (0,888879)	0,6725	0,088180 (1,409557)	0,9501
D(INFL)	-0,008587 (0,076789)	0,9110	-0,207659 (0,169431)	0,2210
RG	-0,090796 (0,026958)	0,0008	-0,269217 (0,086614)	0,0020
RULES	0,067407 (0,234830)	0,7742	-0,099636 (0,343408)	0,7719
EA	-0,703255 (0,810848)	0,3863	0,833708 (1,138819)	0,4645
DEBT*EA	-0,034654 (0,008918)	0,0001	-0,062600 (0,013726)	0,0000
GAP*EA	-5,058409 (1,563990)	0,0013	-5,032308 (2,452893)	0,0408
INFL*EA	0,562133 (0123098)	0,0000	0,701478 (0,175265)	0,0001
RG*EA	-0,075545 (0,036540)	0,0393	0,106448 (0,078887)	0,1780
Observations	463		443	
R-squared	0,638129		0,610292	

Note: Standard errors in brackets.

5. CONCLUSIONS

We have provided an assessment of an issue that is current and frequently questioned by Eurozone countries when discussing government debt and fiscal policies, owing the necessity to maintain the euro a strong currency and the convergence of these nations' economies. Therefore, in this work, the reaction of nations groups to debt levels was assessed in order to determine whether there was any difference in the sustainability of public finances in the Eurozone group and the group of countries that chose not to embrace the single currency. For 5 panel's data sets of European countries, we used annual data between 1990 and 2021, a

period that covers the GFC, the European sovereign debt crisis and the beginning of COVID-19 health crisis.

Our analysis finds that, although to a limited extent in some instances, all the country panels are shown to favourably adjust their fiscal policy to growing levels of government debt. This positive response has different levels of intensity among the diverse panels. For the Eurozone country-group there is a smaller response, 0.046 percentage points (pp), to an increase in the debt ratio than in the case of the Eurozone group of countries, where the response is around 0.1036 pp, to an increase in the debt-to-GDP ratio, after controlling for other relevant factors. Overall, most of the panel's variability results obtained are in line with the general non-country specific fiscal reaction functions literature.

Moreover, based on the model's extension analysis, we may conclude that there was a decrease in fiscal prudence when the countries joined the monetary union and adhered to the single currency. By being part of a monetary union, member states face a significant limitation in their ability to develop national and independent economic policies, with only more freedom in the formulation and implementation of fiscal policies. Given that countries are no longer able to use monetary policy to address issues with public debt and competitiveness, joining a currency union may potentially demand lower debt levels (Weichenrieder and Zimmer, 2014).

In the future, achieving fiscal sustainability may become more complicated due to the rising age-related payments and to the anticipated trend drop in potential growth caused by population ageing. For governments to be able to have fiscal sustainability, additional public resources must be carefully used and funded. Taxes that are clear, fair, and transparent and that do not unintentionally harm the incentives to save, invest, work, and build wealth must be used to pay for financial support for public expenditure (on healthcare, pensions, infrastructure, etc.). Public debt, which redistributes the cost of funding public spending over time (across generations and between different stakeholders within a generation), plays a crucial role in meeting many of today´s financial challenges as fairness and efficiency have intertemporal and intergenerational dimensions as well.

Following this line of thought, some pertinent factors could be further investigated to determine the impact that ageing population increase may have on fiscal sustainability with the aim of studying whether the application of fiscal policies and social policies together is efficient or not and what impact this can have on the sustainability of public accounts, under the comparison between the Non-EA countries and the EA nations.

REFERENCES

Afonso, A., Alves, J., & Coelho, J. C. (2024). Determinants of the degree of fiscal sustainability. *International Journal of Finance and Economics*, 178, 100486.

Afonso, A., Coelho, J. C. (2024). Fiscal Sustainability, Fiscal Reactions, Pitfalls and Determinants. *Applied Economics*, forthcoming.

Afonso, A., Jalles, J. T. (2011). Appraising fiscal reaction functions. *Economics Bulletin*, 31(4), 3320-3330

Afonso, A., & Rault, C. (2010). What do we really know about fiscal sustainability in the EU? A panel data diagnostic. *Review of World Economics, 145*, 731-755.

Afonso, A. (2008). Ricardian fiscal regimes in the European Union. *Empirica, 35*(3), 313-334.

Afonso, A. (2000). *Fiscal policy sustainability: some unpleasant European evidence, Department of Economics, ISEG-UTL* (No. 12). Working Paper.

Baldi, G., & Staehr, K. (2016). The European debt crisis and fiscal reactions in Europe 2000–2014. *International Economics and Economic Policy*, *13*, 297-317.

Barbieri, L. (2009). Panel unit root tests under cross-sectional dependence: An overview. *Journal of Statistics: Advances in Theory and Applications*, *1*(2), 117-158.

Bernoth, K., Hughes, A. J., & Lewis, J. (2008). Did fiscal policy makers know what they were doing? Reassessing fiscal policy with real time data. CEPR Discussion Papers 6758, C.E.P.R. Discussion Papers.

Berti, K., Colesnic, E., Desponts, C., Pamies, S., & Sail, E. (2016). *Fiscal reaction functions for European Union countries* (No. 028). Directorate General Economic and Financial Affairs (DG ECFIN), European Commission.

Bohn, H. (1998). The behavior of US public debt and deficits. *the Quarterly Journal of Economics*, *113*(3), 949-963.

Bohn, H. (2007). Are stationarity and cointegration restrictions really necessary for the intertemporal budget constraint?. *Journal of Monetary Economics*, *54*(7), 1837-1847.

Bond, S.: Dynamic Panel Data Models: A guide to Micro Data Methods and Practice. CEMMAP Working Paper 09/02. The institute for Fiscal Studies, Department of Economics, UCL, April 2002.

Bravo, A. B. S., & Silvestre, A. L. (2002). Intertemporal sustainability of fiscal policies: some tests for European countries. *European Journal of Political Economy*, *18*(3), 517-528.

Camarero, M., Castillo, J., Picazo-Tadeo, A. J., & Tamarit, C. (2013). Eco-efficiency and convergence in OECD countries. *Environmental and Resource Economics*, *55*(1), 87-106.

Checherita-Westphal, C., & Žďárek, V. (2017). Fiscal reaction function and fiscal fatigue: evidence for the euro area (No. 2036). ECB Working Paper.

Chen, P. F. (2016). US fiscal sustainability and the causality relationship between government expenditures and revenues: a new approach based on quantile cointegration. *Fiscal Studies*, *37*(2), 301-320.

Daniel, B. C., & Shiamptanis, C. (2013). Pushing the limit? Fiscal policy in the European Monetary Union. *Journal of Economic Dynamics and Control*, *37*(11), 2307-2321.

Darvas, Z. (2010). The impact of the crisis on budget policy in Central and Eastern Europe. *OECD Journal on Budgeting*, *10*(1), 1-42.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Sssociation*, *74*(366a), 427-431.

Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 1057-1072.

Fincke, B., & Greiner, A. (2012). How to assess debt sustainability? Some theory and empirical evidence for selected euro area countries. *Applied Economics*, *44*(28), 3717-3724.

Galí, J., & Perotti, R. (2003). Fiscal policy and monetary integration in Europe. *Economic Policy*, *18*(37), 533-572.

Ghosh, A. R., Ostry, J. D., & Qureshi, M. S. (2013). Fiscal space and sovereign risk pricing in a currency union. *Journal of International Money and Finance*, *34*, 131-163.

Greiner, A., Koeller, U., & Semmler, W. (2007). Debt sustainability in the European Monetary Union: Theory and empirical evidence for selected countries. *Oxford Economic Papers*, *59*(2), 194-218.

Hamilton, J. D. and M. A. Flavin (1986), "On the Limitations of Government Borrowing: A Framework for Empirical Testing", *The American Economic Review*, Vol. 76, Issue 4, pp. 808-819

Hakkio, C. S., & Rush, M. (1991). Is the budget deficit "too large?". *Economic Inquiry*, *29*(3), 429-445.

Ilzetzki, E., & Végh, C. A. (2008). *Procyclical fiscal policy in developing countries: Truth or fiction?* (No. w14191). National Bureau of Economic Research.

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1), 53-74.

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics*, *108*(1), 1-24.

Mendoza, E. G., & Ostry, J. D. (2008). International evidence on fiscal solvency: Is fiscal policy "responsible"?. *Journal of Monetary Economics*, *55*(6), 1081-1093.

Nickell, S. (1981). Biases in dynamic models with fixed effects. *Econometrica:*, 1417-1426.

Payne, J. E. (1997). International evidence on the sustainability of budget deficits. *Applied Economics Letters*, *4*(12), 775-779.

Quintos, C. E. (1995). Sustainability of the deficit process with structural shifts. *Journal of Business & Economic Statistics*, *13*(4), 409-417.

Trehan, B., & Walsh, C. E. (1991). Testing intertemporal budget constraints: Theory and applications to US federal budget and current account deficits. *Journal of Money, Credit and Banking*, *23*(2), 206-223.

Weichenrieder, A. J., & Zimmer, J. (2014). Euro membership and fiscal reaction functions. *International Tax and Public Finance*, *21*, 598-613.

Wooldridge, J. M. (2015). *Introductory econometrics: A modern approach*. Cengage learning.

APPENDIX

Table A1: Fiscal Reaction Function - Summary of Literature

Authors	Countries	Data Frequency	Period	Tests Performed	Main results
Hamilton and Flavin (1986)	US	Annual	1962 - 1984	Deficit and public debt stationarity	Sustainable
Treahan and Walsh (1991)	US	Annual	1890 - 1983	Deficit stationarity	Sustainable
Hakkio and Rush (1991)	US	Quarterly	1950Q2 – 1988Q4	Public revenues and expenditures cointegration	Does not verify sustainability
Quintos (1995)	US	Quarterly	1947Q2 – 1992Q3	Public revenues and expenditures cointegration	Sustainability until 1980, no afterwards
Payne (1997)	G7 countries	Annual	1949 - 1994	Public revenues and expenditures cointegration	Sustainability for DE
Artis and Marcelino (1998)	EU countries	Annual	1963 - 1994	Stationarity tests (public debt)	Sustainability for UK, NL, and AT
Bohn (1998)	US	Annual	1916 - 1995	Relationship between primary surpluses and debt ratio	Positive reaction of primary surplus to (initial) debt ratio. Ricardian regime
Bravo and Silvestre (2002)	EU countries	Annual	1970 - 1997	Stationarity and cointegration tests of total public expenditures and revenues as ratios of GDP	Sustainability for DE, AT, UK, NL and FI
Galí and Perotti (2003)	EU - 11 and OECD – 5 countries	Annual	1980 - 2002	Cyclically adjusted primary deficit and general government primary deficit divided by potential output	Cyclically primary deficits decrease with increase in debt. Ricardian regime
Bohn (2007)	US	Annual	1792 - 2003	Relationship between primary surpluses and debt ratio	Sustainable
Afonso and Jelles (2011)	OECD 18 countries	Annual	1970 - 2010	Panel data analysis and a panel VAR	Signals of a Ricardian fiscal regime
Fincke and Greiner (2012)	AT, FR, DE, IT, NL, and PT	Annual	Mid 70´s – 2005/2006	Time – series analysis and non – linear function (time – varying coefficients)	Debt coefficient from 0,1 for FR to 0,15 for DE

Medeiros (2012)	EU countries	Quarterly	1976/1990 – 2009/2011	Panel data analysis (level and first difference), linear and non-linear function (polynomial function)	Debt coefficient equal to 0,08; results confirm the existence of fiscal fatigue above a debt ratio of around 90% to 100% of GDP
Mauro *et al* (2013)	55 countries (advanced and emerging economies)	Annual	1800 - 2011	Time-series analysis and panel data analysis, linear and non-linear functions	Debt coefficient equal to 0,02 over all panel and period 1950 – 2011;
Ghosh *et al* (2013)	23 advanced economies (including euro area)	Annual	1970/1985 - 2007	Panel - data analysis, non-linear function (polynomial function)	Show signs of fiscal fatigue
Camarero *et al.* (2013)	23 OEDC countries	Annual	1970 - 2012	Cointegration tests	Sustainability for AT, PT, JP, NZ, NL, ES
Weichwnrieder and Zimmer (2014)	17 EA countries	Annual	1970 – 2008/2011	Panel – data analysis, linear and non-linear function	Debt coefficient reduced but still positive since EMU; results sensitive to the exclusion of one country and the exclusion of crisis
Checherita-Westphal and Žďárek, (2015)	18 EA countries	Annual	1970 - 2013	Panel – data analysis, linear and non-linear function (polynomial function)	Debt coefficient equal to 0,05; increased debt coefficient since EMU and since the crisis; weak signs of fiscal fatigue
Baldi and Staehr (2015)	27 EU countries	Quarterly	2000/2009 – 2008/2014	Panel-data analysis, linear function	Debt coefficient equal to 0,05 before the crisis and 0,1 since the crisis
Chen (2016)	US	Quarterly	1960Q2 – 2010Q3	Quantile cointegration	Quantile – dependent cointegration relationships between government expenditures and revenues
Afonso and Jalles (2017)	11 EA countries	Quarterly	1999Q1 – 2013Q4	Time series analysis and time – varying coefficients	Evidence of fiscal sustainability for FR, DE, NL, and BE
Afonso and Coelho (2024)	19 EA	Annual	1995 - 2020	Panel cointegration and time – varying coefficients	Evidence of a Ricardian fiscal regime
Afonso *et al* (2024)	22 OECD	Annual	1950 - 2019	Panel data and quantile regressions	Sustainability and a cross-relationship between the fiscal sustainability coefficients

Source: Some of the studies mentioned above and others, own adaptation. Abbreviations: AT: Austria. BE: Belgium. ES: Spain. DE: Germany. FI: Finland. FR: France. IT: Italy. JP: Japan. PT: Portugal. NL: Netherlands. NZ: New Zealand. UK: United Kingdom. US: United States. EA: Euro Area. EU: European Union.

Table A2: Countries Description

Groups	Countries
EA	AT, BE, CY, EE, FI, FR, DE, EL, IE, IT, LV, LT, LU, MT, NL, PT, SK, SI, ES
Non-EA with UK	BG, HR, CZ, DK, HU, PL, RO, SE, UK
Non-EA without UK	BG, HR, CZ, DK, HU, PL, RO, SE
Both with UK	AT, BE, BG, HR, CY, CZ, DK, EE, FI, FR, DE, EL, HU, IE, IT, LV, LT, LU, MT, NL, PL, PT, RO, SK, SI, ES, SE, UK
Both without UK	AT, BE, BG, HR, CY, CZ, DK, EE, FI, FR, DE, EL, HU, IE, IT, LV, LT, LU, MT, NL, PL, PT, RO, SK, SI, ES, SE

Note: The country codes are the official EU abbreviations.

Table A3: Variables Description

Variable	Definition	Source
PB	Primary government balance as a percentage of GDP	AMECO
GAP	The difference between effective and potential gross domestic product at constant market prices, as a percentage of potential output	Author's calculations based on AMECO data
INFL	Inflation rate	Author's calculations based on AMECO data
RG	The difference between interest rate and economic growth	Author's calculations based on AMECO data
DEBT	Government debt as a percentage of GDP	Author's calculations based on AMECO data
RULES	Fiscal rules index	European Commission (2023)
EU	Dummy that takes the value 1 if the country belongs to EU, and 0 otherwise	Own definition
EA	Dummy that takes the value 1 if the country belongs to EA, and 0 otherwise	Own definition

Table A4: Correlation Matrix, EA

	PB	GAP	INFL	RG	DEBT	RULES	EU	EA
PB	1							
GAP	-0,127632	1						
INFL	0,070743	-0,281540	1					
RG	-0,295986	-0,139754	-0,171336	1				
DEBT	-0,099331	0,275607	-0,3325251	0,305088	1			
RULES	0,008050	0,486309	-0,339494	-0,184192	0,151961	1		
EU	0,084977	0,515710	-0,221618	-0,064669	0,232620	0,215403	1	
EA	-0,041986	0,635110	-0,363377	-0,013769	0,309367	0,423504	0,457172	1

Source: Calculations trough EViews

Table A5: Correlation Matrix, Non-EA without UK

	PB	GAP	INFL	RG	DEBT	RULES	EU
PB	1						
GAP	-0,140385	1					
INFL	-0,272688	-0,267529	1				
RG	-0,182120	-0,092027	0,071791	1			
DEBT	-0,049991	0,042243	0,281504	0,283237	1		
RULES	0,085077	0,421907	-0,241135	-0,222557	-0,168997	1	
EU	0,141091	0,570135	-0,490585	-0,015743	-0,159269	0,311798	1

Source: Calculations trough EViews

Table A6: Correlation Matrix, Non-EA with UK

	PB	GAP	INFL	RG	DEBT	RULES	EU
PB	1						
GAP	-0,160841	1					
INFL	-0,249115	-0,240632	1				
RG	-0,185506	-0,109792	0,059549	1			
DEBT	-0,120717	0,073453	0,259609	0,266356	1		
RULES	0,089850	0,353223	-0,252207	-0,200882	-0,156407	1	
EU	0,114539	0,533439	-0,496763	-0,001479	-0,138260	0,325264	1

Source: Calculations trough EViews

Table A7: Correlation Matrix, Both without UK

	PB	GAP	INFL	RG	DEBT	RULES	EU	EA
PB	1							
GAP	-0,130562	1						
INFL	-0,043246	-0,241349	1					
RG	-0,273244	-0,134744	-0,100024	1				
DEBT	-0,086391	0,201350	-0,186316	0,307747	1			
RULES	0,023596	0,477217	-0,253376	-0,198992	0,055341	1		
EU	0,099270	0,507069	-0,358253	-0,040379	0,157468	0,219090	1	
EA	-0,022696	0,356248	-0,319447	0,033824	0,366321	0,178712	0,347344	1

Source: Calculations trough EViews

Table A8: Correlation Matrix, Both with UK

	PB	GAP	INFL	RG	DEBT	RULES	EU	EA
PB	1							
GAP	-0,137162	1						
INFL	-0,044280	-0,237322	1					
RG	-0,271454	-0,136623	-0,100038	1				
DEBT	-0,093340	0,208363	-0,183057	0,303281	1			
RULES	0,022688	0,456990	-0,252257	-0,193933	0,044842	1		
EU	0,094350	0,501456	-0,358496	-0,038854	0,154587	0,223566	1	
EA	-0,010879	0,355085	-0,308688	0,028555	0,364318	0,143878	0,331350	1

Source: Calculations trough EViews

Table A9: Descriptive Statistics, EA

Variable	Obs.	Mean	Std. Dev.	Maximum	Minimum
PB	475	-0,161053	3,542660	9,600000	-29,30000
GAP	475	-0,162556	0,216899	0,188612	-1,185185
INFL	475	2,117105	1,922959	15,37484	-4,459861
RG	475	-0,619948	6,663331	35,25714	-33,60267
DEBT	475	67,21912	37,27967	206,2878	3,658537
RULES	475	0,200400	0,977807	2,760000	-1,020000
EU	475	0,928421	0,258061	1,000000	0,000000
EA	475	0,730526	0,444154	1,000000	0,000000

Source: Calculations trough EViews

Table A10: Descriptive Statistics, Non-EA without UK

Variable	Obs.	Mean	Std. Dev.	Maximum	Minimum
PB	168	-0,233333	2,998955	7,000000	-8,000000
GAP	168	-0,115055	0,211946	0,245324	-1,113856
INFL	168	3,191691	3,257685	18,81720	-1,500000
RG	168	-1,587059	5,140477	13,77938	-19,10291
DEBT	168	48,63641	22,89162	115,5172	11,95678
RULES	168	0,542321	0,950840	2,820000	-1,020000
EU	168	0,845238	0,362759	1,000000	0,000000
EA	168	0,000000	0,000000	0,000000	0,000000

Source: Calculations trough EViews

Table A11: Descriptive Statistics, Non-EA with UK

Variable	Obs.	Mean	Std. Dev.	Maximum	Minimum
PB	187	-0,355615	3,038128	7,000000	-8.200000
GAP	187	-0,123438	0,206343	0,245324	-1,113856
INFL	187	3,072056	3,117503	18,81720	-1,500000
RG	187	-1,416596	4,931946	13,77938	-19,10291
DEBT	187	49,33268	22,72858	115,5172	11,95678
RULES	187	0,612246	0,942366	2,820000	-1,020000
EU	187	0,860963	0,346914	1,000000	0,000000
EA	187	0,000000	0,000000	0,000000	0,000000

Source: Calculations trough EViews

Table A12: Descriptive Statistics, Both without UK

Variable	Obs.	Mean	Std. Dev.	Maximum	Minimum
PB	643	-0,179938	3,406863	9,600000	-29,30000
GAP	643	-0,150145	0,216461	0,245324	-1,185185
INFL	643	2,397868	2,390383	18,81720	-4,459861
RG	643	-0,872630	6,311558	35,25714	-33,60267
DEBT	643	62,36392	35,05938	206,2878	3,658537
RULES	643	0,289736	0,981676	2,820000	-1,020000
EU	643	0,906687	0,291096	1,000000	0,000000
EA	643	0,539658	0,539658	1,000000	0,000000

Source: Calculations trough EViews

Table A13: Panel Unit Root Tests Results

Series	Sample	Common Unit Root (LLC)			Individual Unit Root (IPS)		
		Statistic	**P-value**	**N**	**Statistic**	**P-value**	**N**
Primary Budget Balance	**EA**	-3,79775	0,0001	535	-5,22264	0,0000	535
	Non-EA with UK	-2,28736	0,0111	235	-3,21373	0,0007	235
	Non-EA without UK	-2,13674	0,0163	204	-2,97602	0,0015	204
	Both with UK	-4,52414	0,0000	770	-6,12334	0,0000	770
	Both without UK	-4,35175	0,0000	739	-5,99980	0,0000	739
Output Gap	**EA**	-14,1959	0,0000	816	-8,53258	0,0000	816
	Non-EA with UK	-5,05207	0,0000	304	-4,71892	0,0000	304
	Non-EA without UK	-3,74448	0,0001	254	-2,79521	0,0026	254
	Both with UK	-14,1443	0,0000	1120	-9,69454	0,0000	1120
	Both without UK	-13,5783	0,0000	1070	-8,65216	0,0000	1070
Inflation	**EA**	-1,06645	0,1431	974	-5,29474	0,0000	974
	Non-EA with UK	-1,25529	0,1047	357	-2,99056	0,0014	357
	Non-EA without UK	-1,08328	0,1393	297	-2,86102	0,0021	297
	Both with UK	-1,59290	0,0556	1331	-6,05189	0,0000	1331
	Both without UK	-1,36489	0,0861	1271	-5,99342	0,0000	1271
R-G	**EA**	-4,00535	0,0000	723	-7,34663	0,0000	723
	Non-EA with UK	-1,15394	0,1243	284	-2,11882	0,0171	284
	Non-EA without UK	-0,91628	0,1798	225	-1,70847	0,0438	225
	Both with UK	-4,29400	0,0000	1007	-7,21967	0,0000	1007
	Both without UK	-3,98166	0,0000	948	-7,04705	0,0000	948
Debt	**EA**	-1,09049	0,1377	539	0,78866	0,7848	539
	Non-EA with UK	-3,76877	0,0001	221	-1,43667	0,0754	221
	Non-EA without UK	-4,13441	0,0000	197	-1,91922	0,0275	197
	Both with UK	-3,03452	0,0012	760	-0,17412	0,4309	760
	Both without UK	-3,17119	0,0008	736	-0,39422	0,3467	736

Source: Calculations trough EViews

Notes: LLC – Levin, Lin and Chu. IPS – Im, Persaran and Shi.

Table A14: Estimations for Primary Budget Balance, Non-EA with UK

Dependent Variable	**Primary Budget Balance as a share of GDP**			
Regressor/estimation	OLS		2SLS	
	Coefficient	P-value	Coefficient	P-value
C	-4,029254 (1,029550)	0,0001	-6,473750 (1,646722)	0,0001
PB (-1)	0,684864 (0,057378)	0,0000	0,545828 (0,105748)	0,0000
DEBT (-1)	0,044248 (0,013680)	0,0015	0,060753 (0,017842)	0,0008
GAP (-1)	-3,088325 (1,067414)	0,0043	-5,113684 (1,734582)	0,0037
D(INFL)	0,065590 (0,054074)	0,2269	0,261828 (0,110665)	0,0192
D(RG)	-0,150364 (0,027290)	0,0000	-0,092825 (0,054561)	0,0908
RULES	-0,044142 (0,223552)	0,8437	-0,024129 (0,387915)	0,9595
EU	1,380341 (0,552922)	0,0135	2,870841 (0,855188)	0,0010
Observations	178		175	
R-squared	0,718695		0,670287	

Source: Calculations trough EViews
Note: Standard errors in brackets.

Table A15: Estimations for Primary Budget Balance, Both without UK

Dependent Variable	**Primary Budget Balance as a share of GDP**			
Regressor/estimation	OLS		2SLS	
	Coefficient	P-value	Coefficient	P-value
C	-3,427912 (0,590152)	0,0000	-4,713911 (0,769575)	0,0000
PB (-1)	0,596213 (0,030493)	0,0000	0,525029 (0,076293)	0,0000
DEBT (-1)	0,033763 (0,006442)	0,0000	0,037935 (0,007565)	0,0000
GAP (-1)	-2,057055 (0,695244)	0,0032	-2,888558 (1,13640)	0,0109
D(INFL)	0,067665 (0,047642)	0,1560	0,037570 (0,157803)	0,8119
RG	-0,137973 (0,017250)	0,0000	-0,163174 (0,081299)	0,0452
RULES	-0,351139 (0,159879)	0,0285	-0,515009 (0,281412)	0,0678
EU	1,334576 (0,412696)	0,0013	2,218164 (0,636424)	0,0005
EA	-0,672084 (0,325983)	0,0397	-0,468670 (0,434658)	0,2814
Observations	629		605	
R-squared	0,601021		0,600402	

Source: Calculations trough EViews
Note: Standard errors in brackets.

Table A16: Estimations for Primary Budget Balance, Both with UK

Dependent Variable	**Primary Budget Balance as a share of GDP**			
Regressor/estimation	OLS		2SLS	
	Coefficient	P-value	Coefficient	P-value
C	-3,434944 (0,585089)	0,0000	-5,053786 (0,766359)	0,0000
PB (-1)	0,600869 (0,030136)	0,0000	0,553480 (0,068279)	0,0000
DEBT (-1)	0,030177 (0,006203)	0,0000	0,0400344 (0,007357)	0,0000
GAP (-1)	-2,495419 (0,675473)	0,0002	-3,245180 (1,046947)	0,0020
D(INFL)	0,075635 (0,047297)	0,1103	0,055711 (0,153332)	0,7165
RG	-0,133640 (0,017073)	0,0000	-0,150547 (0,077344)	0,0521
RULES	-0,229467 (0,153419)	0,1353	-0,473816 (0,268209)	0,0778
EU	1,436681 (0,409638)	0,0005	2,258953 (0,621910)	0,0003
EA	-0,653861 (0,324608)	0,0444	-0,341055 (0,443973)	0,4427
Observations	647		618	
R-squared	0,603858		0,605807	

Source: Calculations trough EViews

Note: Standard errors in brackets.