

## Article

# Fiscal Sustainability in the European Countries: A Panel ARDL Approach and a Dynamic Panel Threshold Model

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**Abstract:** We analyze the fiscal sustainability hypothesis for a panel of 20 European Union countries from 2000 to 2019. In particular, we employ new econometric methodologies that, to the best of our knowledge, are applied for the first time to the study of sovereign fiscal policy sustainability in these economies. Specifically, we estimate the panel ARDL technique, distinguishing between short- and long-run coefficients because the order of integration of our variables is not the same. Moreover, a panel threshold model with endogeneity is considered to investigate whether, departing from a particular threshold, there is different behavior between the government primary balance and public debt, both taken as a ratio of potential GDP. Finally, the panel Granger causality test is implemented to determine the direction of causality or the existence of bidirectional causality.

**Keywords:** fiscal sustainability; panel ARDL; panel threshold model with endogeneity; panel Granger causality

**JEL Classification:** E62; H63; C23; C24

## 1. Introduction

Since the global financial crisis, many developed and developing economies have experienced significant increases in their public debt. Simultaneously, governments have suffered a crucial loosening of fiscal policy (i.e., they have registered some difficulties in order to stabilize sovereign debt via revenues and expenditures).

If this situation persists over years, it can lead to macroeconomic instability and obstacles to financial capacity. According to Canagarajah et al. [1], longer periods of fiscal unsustainability can lead to a fiscal crisis much sooner than fiscal planners expect. The existence of persistent budgetary imbalances would necessarily lead to economic adjustments that allow a return to the path of sustainability (Afonso and Jalles [2]).

A fiscal policy can be considered sustainable when it does not violate the solvency constraint or when the government's intertemporal budget constraint (IBC) holds. It is well known that when the public debt is too high, the monetary authority is not able to control inflation. This concept is further developed by the Fiscal Theory of the Price Level (FTPL). The FTPL highlights that the IBC can be fulfilled through two channels.

According to the Ricardian or “monetary dominant” (MD) regime, the monetary authority fixes the price level and the fiscal authority should be adjusted, which implies that a government primary budget surplus is needed in order to guarantee fiscal solvency. In this scenario, the budget surplus

path is considered as endogenous. On the contrary, there is another perspective in which the budget surplus is exogenous, and an endogenous adjustment of price levels is crucial for accomplishing solvency. This is the so-called fiscal dominant (FD) regime.

Looking at the empirical studies, there is no consensus due to different specifications of the transversality condition, the sample period, and the econometric methodology (Quintos [3]; Payne [4]; Bajo-Rubio et al. [5]; Afonso and Jalles [2]; Afonso and Jalles [6]; Paniagua et al. [7]; Feld et al. [8]; among others).

Motivated by this issue, this study tries to provide additional empirical evidence and analysis of long-term fiscal solvency. Our purpose is to shed light on this topic using two techniques that, to best of our knowledge, have not been implemented with regard to this issue. First, we apply the panel autoregressive distributed lag (ARDL) because one of the strengths of dynamic models is that they allow different orders of integration of series, or when they are  $I(0)$  or  $I(1)$  or a mixture of them. Second, we also examine potential nonlinearity in the debt-primary balance relationship, considering a very recent panel threshold model proposed by Seo and Shin [9] that takes into account endogeneity. Finally, we compute the panel Granger causality tests based on Dumitrescu and Hurlin [10].

The paper is organized as follows: The next section provides a very brief literature review. Section 3 explains in detail how to compute fiscal sustainability. Section 4 focuses on the data. The econometric methodology is developed in Section 5, and the empirical results are exposed in Section 6, followed by conclusions in Section 7.

## 2. Literature Review

In order to analyze whether the government primary balance reacts to lagged public debt, the most general framework used is based on Bohn's [11] approach. In particular, he points out that if the primary balance is able to react systematically to changes in the sovereign debt, it can be claimed that fiscal policy is sustainable. By contrast, in the scenario in which there is a negative relationship between these variables, debt would become unsustainable.

According to Keynes [12], a sustainable fiscal policy is achieved when government satisfies its budget constraint. In particular, an economy can be endangered when the government debt to GDP ratio reaches an excessive value. In other words, a sustainable fiscal policy is defined as a situation in which sovereign revenues are capable of continuing to finance costs related to the new issuance of public debt. In an unsustainable scenario, the government would be forced to increase taxes or decrease its expenditures.

It is well known that a necessary condition for fiscal policy sustainability is that the first difference of the government debt should be integrated of order zero (i.e., it is stationary). Another major analytical procedure is to ensure the cointegration between government expenditures and government revenues. These are the main customary means of checking the sustainability of public finances.

On the one hand, according to the backward-looking approach proposed by Bohn [11], it should be necessary to study the cointegration relationship between a lagged level of debt and primary surplus. This is the so-called monetary dominance. On the other hand, there is also the forward-looking approach proposed by Canzoneri et al. [13], in which another way to analyze fiscal sustainability is when a higher primary surplus today can produce a decrease in the future level. This perspective is the so-called fiscal dominance.

According to the empirical literature, Bohn [11] showed that US fiscal policy was sustainable during the period 1916–1995. The same conclusion was achieved by Semmler et al. [14], who examined some eurozone countries. They found that these economies had sustainable paths during the period 1960–2003.

Bohn [15] highlighted the invalidity of the rejections of fiscal sustainability using the unit root and cointegration tests since the IBC would be satisfied because, in an infinite sample, any order of integration of public debt would be consistent with no Ponzi game condition. This criticism led this author to propose an alternative way to verify IBC compliance. Specifically, he focused on the

impact of the debt-GDP ratio on the primary surplus-GDP ratio. Once the variables are expressed as a percentage of the GDP, a positive response can confirm expected fiscal sustainability.

A new concept was introduced by Ghosh et al. [16]: the idea of fiscal fatigue. This happens when public debt achieves some threshold and departs from this threshold value the primary balance does not adjust to debt. According to Flood and Marion [17], it is possible that once countries surpass a particular debt limit, they would face market access problems. Fatás and Mihov [18] did not detect evidence of fiscal fatigue when analyzing some eurozone countries; however, one of the deficiencies of their results is that they did not include the crisis period in their empirical work.

By implementing panel unit root tests and panel cointegration analysis with structural breaks on the EU-15, Afonso and Rault [19] did not rule out fiscal sustainability as a problem for certain individual economies. However, when considering all the countries in the panel as a whole and making robustness estimations (they consider different robust techniques such as Pedroni [20,21], Banerjee and Carrion-i-Silvestre [22] and the test proposed by Westerlund and Edgerton [23]) in different sub-periods, they found that public finances were sustainable. Using panel unit root test, in the presence of cross-section dependence, Brady and Magazzino [24,25] obtained evidence in favor of the solvency condition for the EMU-19 countries in the period 1970–2016.

Magazzino et al. [26] studied the sustainability of fiscal policy in a panel framework for the G-7 countries in the period 1980–2015 and found a clear cointegrating relationship between government debt and primary deficit.

By analyzing 19 countries during a longer period (1880–2009) and allowing for multiple structural breaks, Afonso and Jalles [27] could not reject the hypothesis of longer-run fiscal sustainability (expected for Japan and Spain).

Authors such as Ahmed and Rogers [28], Hatemi-J [29] or Bohn [30] offered more empirical evidence in favor of fiscal sustainability for advanced industrial economies with long time series. However, when evaluating the recurrent explosive behavior, Phillips et al. [31] found that even in periods of unsustainable (explosive) dynamics of public debt in the short term (United Kingdom, United States, or Sweden in this study), it is possible to say that they are compatible with long-run fiscal sustainability. This means that unsustainable paths can be achieved because of adverse shocks or political events; nonetheless, active fiscal policies are able to adjust to restore sustainability.

Bajo-Rubio et al. [32] identified a cointegration nexus between expenditures and revenues. Besides, these authors, in a more recent study (Bajo-Rubio et al. [33]), investigated the way in which this fiscal sustainability was achieved by analyzing the interactions between fiscal and monetary policies. In particular, they found that Spain was characterized by fiscal dominance during the period 1850–2000.

In the same vein, the solvency condition is satisfied for 19 European Monetary Union (EMU) countries because government debt is stationary, which guarantees the effectiveness of the austerity policies (Gordon and Cosimo [25]).

In contrast, Papadopoulos and Sidiropoulos [34] found that some European countries are in danger to miss the target of limiting public debt which is a precondition for EMU entry. Besides, applying panel data techniques and analyzing four budget balance definitions, Mahdavi and Westerlund [35] tested the fiscal sustainability hypothesis for 47 state-local governments in the US. They identified “strong” sustainability for the full sample and subsamples when special funds and federal grants were covered in the balances. Nevertheless, excluding these items, a weak sustainability was detected for the full sample and some subsamples.

In the same line, Paniagua et al. [7] estimated the time-varying fiscal reaction function for eleven eurozone countries. In spite of providing the first perception of the sustainability of fiscal policy, the adjustment mechanism applied to the rapid accumulation of debt has failed in recent years. Moreover, they identified heterogeneity among EMU countries in order to deal with their sovereign revenues and expenditures. Furthermore, Lee et al. [36], detected fiscal solvency in non-eurozone economies due to the significantly positive marginal responses; nonetheless, the long-run policy rule of the eurozone countries is not solvent for most of the regional groups.

In a more recent study, Feld et al. [8] applied Bohn's [30] extended fiscal sustainability test to 16 German states between 1950 and 2015. They found that policymakers have reacted by increasing budget surpluses to face higher levels of public debt since 1991. Nevertheless, controlling for cross-sectional dependence and incorporating heterogeneous slopes, they do not observe a significant positive reaction to higher levels of public debt. For this reason, they warn that these unsustainable public finances at the sub-federal level may jeopardize the overall fiscal sustainability of the Bund.

### 3. Fiscal Sustainability

According to Bohn's [15] recommendation, which we explained earlier, the government's intertemporal budget constraint expressed in GDP percentage is:

$$D_t = \sum_{j=0}^{\infty} \left( \frac{1+g}{1+r} \right)^{j+1} E_t GPB_{t+j+1} + \lim_{j \rightarrow \infty} \left( \frac{1+g}{1+r} \right)^{j+1} E_t D_{t+j+1} \quad (1)$$

where  $D_t$  and  $GPB_t$  represent the public debt and the government primary balance as percentages of GDP, respectively. In addition,  $g$  and  $r$  reflect the growth rate for real GDP and the real interest rate, respectively.  $E_t$  is the expectation operator conditional on the information available at time  $t$ . Therefore, assuming these last parameters as constant, the transversality (no Ponzi games) condition can be postulated as:

$$\lim_{j \rightarrow \infty} \left( \frac{1+g}{1+r} \right)^{j+1} E_t D_{t+j+1} = 0 \quad (2)$$

For this reason, we would claim that the government's fiscal policy is solvent when the expected future budget surpluses, measured as present value, coincide with its outstanding public debt.

Quintos [3] distinguishes between "weak" and "strong" sustainability. He assumes that public debt can be I(1) or I(2). Concretely, he considers that when  $\Delta D_{it}$  is I(0), fiscal sustainability is strong. This scenario is consistent with the idea that deficits cannot be persistent in the long run. On the contrary, he postulates that the government's fiscal policy can be sustainable even if  $\Delta D_{it}$  is I(1), meaning that its revenues do not compensate for its expenditures, which triggers concerns regarding marketing its debt. Hence, the fiscal policy rule is weakly sustainable.

This study focuses on the following policy rule proposed by Bohn [11]:

$$GPB^*_{it} = \alpha_i + \beta D^*_{i,t-1} + \epsilon_{i,t} \quad (3)$$

in which  $GPB^*_{it}$  is the government primary balance as a percentage of the potential GDP (Beqiraj et al. [37]) and  $D^*_{i,t-1}$  is the (lagged) debt-potential GDP ratio. The marginal response of the primary balance to debt is captured by  $\beta$ . Bohn [11] showed that if  $\beta$  is positive, this means that higher levels of public debt would lead to an increase in the primary surplus, which in turn produces a reduction in debt, implying that sovereign debt is stabilized in the long term as long as such a policy rule is sustained in the future.

### 4. Data

This study uses annual time series for 20 European Union countries during the 2000 to 2019 period. In particular, we have considered the following countries: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden and the United Kingdom. Following Beqiraj et al. [37] and Bohn [15], we consider our variables as a percentage of potential GDP. In particular, we use the cyclically adjusted general government primary balance as a percentage of potential GDP and the gross public debt, according to the Maastricht criterion, to potential GDP, extracted from the OECD statistics.

## 5. Econometric Methodology

### 5.1. Panel Unit Root Tests

Before conducting the cointegration analysis, the applied time series should be examined by unit root tests. We implement the most relevant panel unit root tests to identify the order of integration of each variable. In particular, we apply the Levin-Lin-Chu (LLC, [38]), Harris-Tzavalis (HT, [39]), Breitung [40], Im-Pesaran-Shin [41], and Fisher-type (Choi, [42]) tests. These tests are characterized by having a null hypothesis in which all the panels contain a unit root. The same autoregressive parameter is assumed for all panels in LLC, HT, and in Breitung, rather than the other tests which allow the panel to be specific. We carry out each test with variables both in levels and in first differences.

### 5.2. Panel Cointegration Tests

Once the panel unit root has been determined, the issue arises whether it is possible to establish a long-run equilibrium relationship between these variables. For this purpose, the traditional panel cointegration tests can be applied: Kao [43], Pedroni [20,21], and Westerlund [44]. Nevertheless, in cases in which both variables do not coincide with the same order of integration, another technique is required.

### 5.3. Dynamic Panel Model ARDL

On the one hand, according to Loayza and Ranciere [45], the usual standard static panel models such as pooled OLS, fixed effects, or random effects do not offer the possibility of distinguishing between the short- and long-run relationships among variables. Besides, Campos and Kinoshita [46] claim that the parameters can be biased when some regressors are endogenous, as we will see in our particular sample. On the other hand, focusing on the dynamic panel models, the GMM-difference estimator introduced by Arellano and Bond [47] and the GMM-system estimator by Arellano and Bover [48] are very useful when the sample is characterized by a large number of countries relative to the time period, which is not our case. Moreover, the GMM is more focused on the short-run dynamics.

Henceforth, taking into account these shortcomings, the panel autoregressive distributed lag (ARDL) technique seems a very successful method for overcoming these drawbacks. In fact, one of the main advantages is that, based on Pesaran and Shin [49], this methodology can be applied when variables present different orders of integration, or when they are  $I(0)$  or  $I(1)$  or a mixture of them.

Based on the error-correction model, it is possible to introduce the dynamic panel regression applying the ARDL ( $p, q$ ) as follows:

$$\Delta GPB^*_{it} = \sum_{j=1}^{p-1} \gamma_j^i \Delta GPB^*_{i,t-j} + \sum_{j=0}^{q-1} \delta_j^i \Delta D^*_{i,t-j} + \varphi^i [GPB^*_{i,t-1} - \{\beta_0^i + \beta_1^i D^*_{i,t-1}\}] + \epsilon_{i,t} \quad (4)$$

where  $p$  and  $q$  are the lags of the dependent and independent variables, respectively.  $GPB^*_{it}$  is the government primary balance as a ratio of potential GDP and  $D^*_{it}$  is the debt-potential GDP ratio. In particular,  $\gamma$  represents the short-term parameters of the lagged dependent variable;  $\delta$  refers also to the short-run coefficients but of the lagged explanatory variables, which in our case is debt.  $\varphi$  reflects the speed of adjustment to the long-run equilibrium.  $\beta$  indicates the impact of debt in the long run.

It can be estimated using three alternative estimators: the Mean Group (MG) estimator, the Pooled Mean Group (PMG) estimator, and the Dynamic Fixed Effects (DFE) estimator. The PMG introduced by Pesaran et al. [50] considers the long-term slope parameters homogeneous across countries, but the short-run coefficients are heterogeneous. The MG proposed by Pesaran and Smith [51], allows country-specificity in the short and long terms. Specifically, this procedure estimates individual regressions for each country and after that, unweighted means are computed. The DFE is very similar to PMG, but it additionally restricts not only the long-run coefficients but also the short-run to being equal across countries.

In order to distinguish between the PMG, MG, and DFE, we apply the Hausman test to check whether there are significant differences among these estimators. It is well known that PMG and MG are both consistent; nevertheless, PMG is more efficient under the assumption of long-term homogeneity. Therefore, we test the null hypothesis that the difference between PMG and MG is not significant and, in addition, between PMG and DFE to identify which is the most appropriate.

#### 5.4. Panel Threshold Model

In this section, we study the possibility of examining nonlinearity in the debt-primary balance nexus. To determine the existence of a sharp discrete shift, apart from the relationship between both variables being different, we apply a very recent panel threshold estimator considering endogeneity that was developed by Seo and Shin [9].

The panel threshold model proposed by Hansen [52] is able to determine the asymmetrical effect of the exogenous variable, whether the threshold variable is below or above a particular value. However, this model is static, and it requires exogeneity among the covariates. For this reason, we implement an extended dynamic panel model considering an endogenous threshold that was introduced by Seo and Shin [9].

In particular, the general specification proposed by Seo and Shin [9] can be expressed as follows:

$$y_{it} = x'_{it}\beta + (1, x'_{it})\delta 1\{q_{it} > \gamma\} + \epsilon_{i,t}, \quad i = 1, \dots, n; t = 1, \dots, T \quad (5)$$

where  $q_{it}$  refers to the threshold variable,  $1\{\cdot\}$  is an indicator function, and  $x_{it}$  is the vector of time-varying regressors that can include lagged dependent variables, and  $\gamma$  is the threshold parameter. The error term is composed of the idiosyncratic random disturbance and the individual fixed effect ( $\epsilon_{i,t} = v_{it} + \alpha_i$ ), in which  $v_{it}$  is assumed to be a martingale difference sequence.

In our particular case, it can be derived as:

$$GPB^*_{it} = \beta D^*_{it} + \delta 1\{D^*_{it} > \gamma\} + \epsilon_{i,t}, \quad i = 1, \dots, n; t = 1, \dots, T \quad (6)$$

where the public debt is considered as our threshold variable, and  $\gamma$  is the threshold value to be estimated, with the purpose of analyzing whether a different behavior exists above or below this threshold parameter. Following Seo and Shin [9], the unknown parameters are estimated by the First-Difference Generalized Method of Moments (FD-GMM) method (see Seo and Shin [9] for more details).

Due to that, it is well known that the fixed effects estimators of the autoregressive parameters are biased downward, and we apply the first-difference transformation to deal with the correlation between regressors and individual effects, as proposed by Seo and Shin [9].

One of the main advantages of this procedure is its ability to model simultaneously unobserved individual heterogeneity across countries and the nonlinear asymmetrical dynamics. Besides, this methodology is also able to overcome the problem of the correlation of explanatory variables with individual effects as mentioned by Nickell [53], since they use the first-difference transformation proposed by Arellano and Bond [47].

To be more specific, assuming  $\theta = (\beta', \delta', \gamma)'$ , the  $l$ -dimensional column vector used by these authors related to the sample moment conditions are:

$$\bar{g}_n(\theta) = \frac{1}{n} \sum_{i=1}^n g_i(\theta) \quad (7)$$



where:

$$g_i(\theta) = \begin{pmatrix} z_{i0}(\Delta y_{i0} - \beta' \Delta x_{i0} - \delta' X'_{i0} 1_{i0}(\gamma)) \\ \vdots \\ z_{iT}(\Delta y_{iT} - \beta' \Delta x_{iT} - \delta' X'_{iT} 1_{iT}(\gamma)) \end{pmatrix} \quad (8)$$

in which  $\{z_{it}\}_{t=t_0}^T$  captures the instrumental variables since these authors allow that the threshold variable is endogenous ( $E(D_{it}^* \Delta \epsilon_{it}) \neq 0$ ). Therefore, the GMM estimator of  $\theta$  is given by:

$$\hat{\theta} = \underset{\theta \in \Theta}{\operatorname{argmin}} \bar{J}_n(\theta) \quad (9)$$

where  $\bar{J}_n(\theta) = \bar{g}_n(\theta)' W_n \bar{g}_n(\theta)$ , in which  $W_n$  is a positive definite matrix such that  $W_n \xrightarrow{p} \Omega^{-1}$ .

According to Seo and Shin [9], since the objective function  $\bar{J}_n(\theta)$  is not continuous in  $\gamma$ , the grid search algorithm for a fixed threshold parameter is practical. First, let us define:

$$\bar{g}_{1n} = \frac{1}{n} \sum_{i=1}^n g_{1i} \text{ and } \bar{g}_{2n}(\gamma) = \frac{1}{n} \sum_{i=1}^n g_{2i}(\gamma) \quad (10)$$

where:

$$g_{1i} = \begin{pmatrix} z_{i0} \Delta y_{i0} \\ \vdots \\ z_{iT} \Delta y_{iT} \end{pmatrix} \text{ and } g_{2i}(\gamma) = \begin{pmatrix} z_{i0}(\Delta x_{i0}, 1_{i0}(\gamma)' X_{i0}) \\ \vdots \\ z_{iT}(\Delta x_{iT}, 1_{iT}(\gamma)' X_{iT}) \end{pmatrix} \quad (11)$$

Therefore, the GMM estimator, given a particular value of threshold parameter, would be as follows:

$$(\hat{\beta}(\gamma)', \hat{\delta}(\gamma)')' = (\bar{g}_{2n}(\gamma)' W_n \bar{g}_{2n}(\gamma))^{-1} \bar{g}_{2n}(\gamma)' W_n \bar{g}_{1n} \quad (12)$$

It is possible to achieve the GMM estimator of  $\theta$  by:

$$\hat{\gamma} = \underset{\gamma \in \Gamma}{\operatorname{argmin}} \hat{J}_n(\gamma) ; (\hat{\beta}', \hat{\delta}')' = (\hat{\beta}(\hat{\gamma})', \hat{\delta}(\hat{\gamma})')' \quad (13)$$

### 5.5. Panel Granger Causality Based on the Dumitrescu and Hurlin Test

Another interesting issue is the causal relationship between our variables. Based on the concept proposed by Granger [54] on time series, Dumitrescu and Hurlin [10] developed an extension to identify causality among variables in a panel data scenario. Based on these authors, we can analyze the panel Granger causality in our model as follows (testing the causality running from debt to the primary balance is the other way around, in particular, as follows):

$$GPB_{it}^* = \alpha_i + \delta_{i,1} GPB_{i,t-1}^* + \dots + \delta_{i,p} GPB_{i,t-p}^* + \beta_{i,1} D_{i,t-1}^* + \dots + \beta_{i,p} D_{i,t-p}^* + \epsilon_{i,t} \quad (14)$$

where  $GPB_{it}^*$  and  $D_{i,t}^*$  are stationary variables for country  $i$  in period  $t$  (in this regression, we work with the first difference of debt because stationarity is a requirement).

The purpose with this specific test is to assess whether the past values of debt are crucial for explaining the behavior of the present values of the primary balance. For this purpose, they consider the following null hypothesis in which the absence of causality for all countries is considered:

$$H_0 : \beta_{i,1} = \dots = \beta_{i,p} = 0 \quad \forall i = 1, \dots, N \quad (15)$$

Moreover, in the alternative hypothesis, they allow causality for some countries but not necessarily for all, as can be seen:

$$H_1 : \beta_{i,1} = \dots = \beta_{i,P} = 0 \quad \forall i = 1, \dots, N_1 \quad (16)$$

$$\beta_{i,1} \neq 0 \text{ or } \dots \beta_{i,P} \neq 0 \quad \forall i = N_1 + 1, \dots, N \quad (17)$$

The procedure is as follows: We run the  $N$  individual regressions for (4); second, we compute the F-tests of the  $P$  linear hypothesis ( $\beta_{i,1} = \dots = \beta_{i,P} = 0$ ) in order to achieve the individual Wald statistic ( $W_i$ ). Then, the next step is to obtain the average Wald statistic ( $\bar{W}$ ) from the individual Wald statistic ( $W_i$ ):

$$\bar{W} = \frac{1}{N} \sum_{i=1}^N W_i \quad (18)$$

Additionally, it has been established that when some circumstances such as  $W_i$  are independently and identically distributed across countries, the standardized statistic  $\bar{Z}$  follows a standard normal distribution when  $T \rightarrow \infty$  and  $N \rightarrow \infty$ :

$$\bar{Z} = \sqrt{\frac{N}{2P}} (\bar{W} - P) \xrightarrow{d} N(0, 1) \quad (19)$$

## 6. Empirical Results

Table 1 reports the corresponding main descriptive statistics of the main variables in our analysis. The mean for  $GPB^*$  is 0.0199%, with a standard deviation of 3.1178. The minimum and maximum are −26.12% and 9.67%, respectively. On the contrary, the mean and the standard deviation for  $D^*$  are 62.5013% and 33.5015, respectively. Its associated minimum is 4.11% and its maximum is 161.52%.

**Table 1.** Descriptive statistics.

Variables	Mean	Standard Deviation	Minimum	Maximum
$GPB_{it}^*$	0.0199	3.1178	−26.1224	9.6710
$D_{it}^*$	62.5013	33.5015	4.1089	161.5196

### 6.1. Panel Unit Roots and Cointegration

Table 2 shows the results of panel unit root tests. As can be seen, there is an absolute consensus with respect to the debt-potential GDP ratio because for all tests we have performed, we do not have any statistical significance evidence to reject the null hypothesis, regardless of whether the model includes trend or not.

We can clearly conclude that this variable is non-stationary. It means that the solvency condition is not satisfied for these economies. Once we apply the first difference to this explanatory variable, we check its stationarity, obtaining as a result that it is integrated of order one, i.e.,  $I(1)$ . However, our dependent variable (government primary balance to potential GDP ratio) can be treated as stationary, i.e.,  $I(0)$ , when considering all panel unit root tests except for the Fisher-type (Choi, [42]) and LLC with trend. According to these results, we cannot apply the conventional panel cointegration tests—Kao [43]; Pedroni [20,21]; or Westerlund [44]—because our variables do not present the same order of integration. For this reason, we follow the panel ARDL procedure.

### 6.2. Dynamic Panel Model ARDL

Table 3 shows the results of panel ARDL, considering the PMG, MG, and DFE estimations. In addition, we offer the Hausman test to clarify which is the best method to achieve consistency and efficiency. As can be observed, regardless of the method used, there is a positive and significant impact on the government primary balance in the short run. By contrast, a negative but not significant link



is identified by the MG and DFE for the long run, while the PMG detects a significantly negative relationship between debt and the primary balance.

**Table 2.** Panel unit roots results.

Test Statistic	Level		First Difference	
	$GPB_{it}^*$	$D_{it}^*$	$GPB_{it}^*$	$D_{it}^*$
<b>LLC</b>				
Level	−4.0103 (0.0000)	−1.1071 (0.1341)	−7.0918 (0.0000)	−0.6650 (0.2530)
Trend	−0.3828 (0.3509)	3.7154 (0.9999)	−1.6044 (0.0543)	0.8669 (0.8070)
<b>HT</b>				
Level	0.6532 (0.0000)	0.9415 (0.9946)	−0.1604 (0.0000)	0.3673 (0.0000)
Trend	0.5217 (0.0018)	0.8516 (1.0000)	−0.1517 (0.0000)	0.4340 (0.0000)
<b>Breitung</b>				
Level	−2.0190 (0.0217)	2.7364 (0.9969)	−7.1988 (0.0000)	−5.6116 (0.0000)
Trend	−1.6181 (0.0528)	3.4744 (0.9997)	−8.0350 (0.0000)	−4.2621 (0.0000)
<b>IPS</b>				
Level	−2.2929 (0.0109)	4.0753 (1.0000)	−10.1891 (0.0000)	−5.7766 (0.0000)
Trend	−4.4133 (0.0000)	0.8070 (0.7902)	−10.3413 (0.0000)	−6.7719 (0.0000)
<b>Fisher</b>				
Level	0.3314 (0.3702)	−1.2282 (0.8903)	6.6234 (0.0000)	2.8745 (0.0020)
Trend	−1.3271 (0.9078)	−1.1494 (0.8748)	2.6824 (0.0037)	0.3923 (0.3474)

Numbers in parenthesis are *p*-values.

**Table 3.** Panel ARDL results.

	Pooled Mean Group		Mean Group		Dynamic Fixed Effects	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
<b>Long-run coefficients</b>						
$D_{it}^*$	−0.0452 ***	0.0153	−3.2686	3.7413	−0.0474	0.0331
<b>Error-correction coefficient</b>	0.3735 ***	0.066	0.4990 ***	0.0997	0.3896 ***	0.1221
$\Delta D_{it}^*$	0.1075 ***	0.0360	0.1522 ***	0.0548	0.1411 ***	0.0561
Intercept	−0.9750 ***	0.1559	−1.0241	0.9097	−1.3162	0.8421
Observations	380		380		380	
Hausman Test			0.53 <sup>(i)</sup> (0.4664)		0.98 <sup>(ii)</sup> (0.3234)	

Note: \*\*\* indicate significance at 1%. <sup>(i)</sup> Under the null hypothesis, PMG is more efficient estimation than MG.

<sup>(ii)</sup> PMG is more efficient estimation than DFE under the null hypothesis.

Once we apply the Hausman test, as can be seen, we cannot reject the null hypothesis of the homogeneity restriction related to the debt-potential GDP ratio in the long term. This highlights that

the PMG is more efficient than the MG. Furthermore, comparing the PMG with the DFE, the null hypothesis is not rejected, meaning that the PMG is recommended since it is efficient. It is very clear that we can conclude that the PMG is the most efficient estimator and, for this reason, we focus our interpretation on this estimator. Henceforth, according to the PMG, there is a sustainable relationship between these variables in the short term; nonetheless, this situation is not sustainable anymore in the long run. In other words, governments react to changes in public debt by adjusting the primary fiscal balance in the short run; however, governments do not react positively to a shock of debt in the long run, meaning that debt becomes unsustainable. In accordance with Bajo-Rubio et al. [33], our results indicate the prevalence of monetary dominance with respect to fiscal dominance in the short term because our debt's coefficient is significantly positive. This result is a sufficient condition for solvency, which reflects that governments are able to satisfy their present-value budget constraints. By contrast, fiscal dominance prevailed over monetary dominance in the long run.

### 6.3. Panel Threshold Model

First of all, in Table 4, we show the endogeneity test for the debt variable in which the null hypothesis claims that the specified endogenous regressor can be treated as exogenous. Clearly, we reject this null hypothesis, supporting the idea that debt is an endogenous variable. For this reason, it is more suitable to apply the panel threshold model considering endogeneity (Seo and Shin [9]). The estimation results for the dynamic threshold model of the government primary balance is shown in Table 4. Using the debt-potential GDP ratio as the transition variable, the threshold value is estimated at 93.01%, with 20.5% of observations falling into the high-debt regime. This threshold is statistically significant at the 1% level and the 95% confidence interval is [88.8106, 97.2114]. We can conclude that below the threshold value, there is a significantly positive impact of debt on the primary balance, meaning sustainability. Nevertheless, a significantly negative relationship between these variables is detected above 93% of the debt-potential GDP ratio. Moreover, the higher marginal effect above the threshold can be seen. In other words, when the public debt is below the estimated threshold value (93.01%), the government is able to clearly compensate for its expenditures with higher revenues. But when public debt surpasses this threshold, the government's primary balance deteriorates, given the high level of debt. This result suggests that public debt above this threshold value erodes fiscal sustainability.

**Table 4.** Results of debt-potential GDP ratio threshold and its impact on general government primary balance.

	Considering Endogeneity
Threshold estimates ( $\hat{\gamma}$ )	93.0110
Significance of threshold $p$ -value	0.0000
95% Confidence interval	[88.8106, 97.2114]
<b>Impact of debt on government primary balance:</b>	
$\hat{\beta}_1$	0.0372 *** (0.0138)
$\hat{\beta}_2$	−0.2928 *** (0.0180)
N	400
Endogeneity test of $D_{it}^*$	130.83 [0.0000]
Endogeneity test of instruments	0.00 [1.0000]

Notes: In the ordinary brackets below the parameter estimates are the corresponding  $z$ -statistics, computed using White [55]'s heteroskedasticity-robust standard errors. In the square brackets below the specification tests are the associated  $p$ -values. \*\*\* indicate significance at 1% respectively.

#### 6.4. Panel Granger Causality Based on the Dumitrescu and Hurlin Test

Table 5 offers the results from the Dumitrescu and Hurlin [10] panel Wald statistic, the Z-bar statistic, and their associated probability values. It can be observed that the null hypothesis (debt does not Granger cause the government primary balance) is clearly rejected regardless of the information criteria used.

**Table 5.** Dumitrescu and Hurlin [10] panel causality test in heterogeneous panels.

<b>H0: Debt Does not Granger Cause Primary Balance</b>			
	AIC (k = 4)	HQIC (k = 4)	BIC (k = 1)
W-Stat.	9.3137	9.3137	2.1764
Z bar-Stat.	8.4016	8.4016	3.7202
Prob.	0.0000	0.0000	0.0002
<b>H0: Primary Balance Does Not Granger Cause Debt</b>			
	AIC (k = 4)	HQIC (k = 4)	BIC (k = 1)
W-Stat.	9.2148	9.2448	2.3127
Z bar-Stat.	8.2454	8.2454	4.1511
Prob.	0.0000	0.0000	0.0000

The same conclusion is reached once we check the null hypothesis that the primary balance does not Granger cause debt (we show the results of all statistics considering the optimal lags, which are 4, 4, and 1 for AIC, HQIC, and BIC, respectively). Therefore, a bidirectional causality (also called feedback) relationship is detected across debt-potential GDP ratio and government primary balance.

## 7. Conclusions

This paper analyses the fiscal sustainability of 20 European Union countries in the 2000–2019 period by using a new double approach: the panel autoregressive distributed lag (ARDL) and the dynamic panel threshold model proposed by Seo and Shin [9], given the endogeneity of public debt.

The results of panel unit root tests indicate that the variables (debt-potential GDP ratio and the government primary balance to potential GDP ratio) do not have the same order of integration. The null of non-stationarity is not rejected for debt and is rejected for the primary balance, which is determined by following a panel ARDL procedure instead of a conventional panel cointegration one.

The usual standard static panel models, such as pooled OLS, fixed effects, or random effects, do not offer the possibility of distinguishing between the short- and long-run relationships among variables. Besides, the GMM is more focused on the short-run dynamics. Therefore, the panel ARDL technique seems a very successful method for overcoming these drawbacks. Moreover, one of the main strengths is that this methodology can be applied when the order of integration is different among variables, which is our case. In particular, we implement three alternative estimators: the Mean Group (MG) estimator, the Pooled Mean Group (PMG) estimator, and the Dynamic Fixed Effects (DFE) estimator.

Regardless of the method used, there is a positive and significant impact on the government primary balance in the short run. After applying the Hausman test, it can be observed that the PMG is the best estimator, given its consistency and efficiency. According to the PMG, our results offer empirical evidence of fiscal sustainability for European Union countries in the short term; however, this situation is not sustainable anymore in the long run. Moreover, the estimations point out the prevalence of monetary dominance in the short term, as the debt to GDP ratio presents significant positive coefficient estimates and fiscal dominance in the long run.

In order to investigate the possibility of nonlinearity in the debt-primary balance nexus, we applied an extended dynamic panel model considering an endogenous threshold introduced by Seo and Shin [9] to determine whether a different pattern is detected when considering two alternative regimes.

In general, the results point to below-the-threshold values (93.01%), and there is a significant and positive impact of debt on the primary balance that is compatible with the sustainability concept. Nevertheless, levels of public debt above the estimated threshold value indicate a statistically significant negative impact on the government primary balance, meaning that government does not fulfill the intertemporal budget constraint. Therefore, our results highlight that above the threshold value, fiscal sustainability does not hold in the long term.

Finally, Dumitrescu and Hurlin [10] developed an extension to identify causality among variables in a panel data scenario. It is an extension of the Granger causality test in which causality for some countries is assumed, but not necessarily for all of them. According to our results, a bi-directional causality relationship (with a feedback mechanism) is found both between debt and the government primary balance.

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