
Nonlinearity in the Debt-Growth Nexus in the EU: Evidence from Dynamic Panel Threshold Regression

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Abstract

This study investigates the impact of public debt on economic growth in a panel of 27 EU economies over the period 2000–2022. As the preliminary analysis suggests a nonlinear relationship between these variables, the debt threshold analysis based on the dynamic panel threshold regression is employed. The results for the whole panel indicate that public debt supports growth below a threshold of 68.7%, but it has a detrimental impact on growth if it is above the threshold. The validity of the findings is confirmed by including the effects of crises, which also indicates that economic growth in countries with debt below the threshold was more resilient to crisis events. The robustness of the estimates is checked using the method of moments quantile regression. However, the analysis of subsamples based on a country's EMU membership and the indebtedness level reveals the variety of debt thresholds, which calls for different fiscal governance across countries to reduce the negative effects of debt on economic growth. Overall, the results emphasize the importance of adequate fiscal space to respond to economic disturbances.

Keywords: Public debt, economic growth, debt threshold, European Union countries, fiscal governance

JEL Classification: C23, F43, H63, O47

1. Introduction

Responsible public debt management represents an important factor in stable economic growth. High levels of public debt can lead to increased borrowing costs, as investors demand higher interest rates to compensate for the perceived risk of lending to heavily indebted governments (Chudik *et al.*, 2017; Law *et al.*, 2021). This can crowd out private investment, as both businesses and individuals face higher borrowing costs, reducing their capacity for growth and innovation. Moreover, large debt burdens can limit governments' ability to implement counter-cyclical fiscal policies in economic downturns, thus prolonging recessions and slowing down recovery efforts (Ostrihoň *et al.*, 2023).

The dramatic economic decline due to the COVID-19 pandemic triggered a steep rise in government debt around the globe. As stated by Kose *et al.* (2022), the global government debt reached 97% of the GDP in 2020 (a 13 percentage point increase), whereas the debt increase in advanced economies was even larger – by 16 percentage points, reaching 120% of the GDP. Emerging and developing economies faced a more moderate debt rise of about 9 percentage points and the debt level came to 63% of the GDP. As of the end of 2023, the EU's average government debt-to-GDP ratio stood at 81.7%, down from 83.4% the previous year. The ratio decreased from 90.8% to 88.6% within the euro area (Eurostat, 2024). Even though the debt levels tend to decrease (IMF, 2023), they are still unsustainable and call for structural and economic policy changes to prevent adverse economic consequences.

As in the time of the Global Financial Crisis of 2008 and the euro area sovereign debt crisis, the issue of empirically examining the relationship between debt and growth has regained attention of policymakers and academics. This resurgence is due to the significant challenge faced by the governments in maintaining public debt sustainability and fostering consistent economic growth over both the medium and long term, amidst rising inflation, low real interest rates, increasing public debt ratios and sluggish output growth (Shah *et al.*, 2024).

However, empirical evidence indicates that public debt does not always harm economic growth. If below a certain level, debt can support growth. Since the seminal paper by Reinhart and Rogoff (2010), a large body of empirical literature has investigated the public debt threshold effect on economic growth (Baum *et al.*, 2013; Bhimjee and Leão, 2020; Ibañez Martín *et al.*, 2024). Specifically, a threshold in the debt-growth relationship indicates that debt affects growth differently depending on whether it is below or above the threshold. There is also the possibility of an inverted U-shaped nexus, which emerges when debt supports growth if below the threshold and suppresses growth if above it. This is in line with the so-called debt overhang hypothesis (Krugman, 1988), which states that when a country's debt reaches a certain critical level, the an-

anticipated future tax burden required to service the debt can disincentivize private investment and consumption, leading to slower economic growth. In all these cases, the relationship between debt and growth is nonlinear, a phenomenon frequently documented in empirical studies (Zaghdoudi, 2020; Law *et al.*, 2021; Turan and Iyidogan, 2023).

Although European Union (EU) economies have frequently been the focus of political and academic debate when it comes to the problem of debt sustainability and sovereign debt crisis, there are unexpectedly few empirical studies addressing the issue of debt threshold effect on growth in these countries. The exceptions include, *inter alia*, the empirical studies of Checherita-Westphal and Rother (2012) and Baum *et al.* (2013) for 12 euro area countries, Mencinger *et al.* (2014) for 25 EU economies and Ostrihoň *et al.* (2023) for 28 EU countries. These studies have confirmed the presence of different debt threshold levels, spanning from about 54% for new EU member states (Mencinger *et al.* 2014), 67–70% for the euro area (Baum *et al.*, 2013) and the EU (Ostrihoň *et al.*, 2023), to 90–100% for euro area countries (Checherita-Westphal and Rother, 2012). The different debt threshold estimates across these studies are likely the result of the differences in econometric methods employed and periods observed, as well as the fact that public debt levels in EU countries vary significantly, reflecting diverse economic conditions and fiscal policies. Countries such as Estonia, Bulgaria and Luxembourg have maintained some of the lowest debt ratios, under 30%. In contrast, several countries, including Greece, Italy and France, have had debt levels exceeding 100% of their GDP, highlighting ongoing fiscal challenges. This variation underscores the differing economic landscapes and policy responses across the union.

The paper aims to expand the knowledge about the impact of public debt on economic growth in EU-27 economies and the presence of a debt threshold effect by employing the novel dynamic panel threshold regression (DPTR) approach proposed by Seo and Shin (2016) and Seo, Kim and Kim (2019). The previous empirical studies were mainly based on the DPTR method suggested by Hansen (1999) and Kremer *et al.* (2013). However, as stated by Seo and Shin (2016), a crucial assumption in all of these studies is that either regressors or the threshold variable or both are exogenous, which is not optimal as an econometric model should allow both threshold variable and regressors to be endogenous. Additionally, in the case of the debt-growth nexus, a reverse causality can emerge. For instance, in an economic slump, a reduction in economic growth commonly coincides with a rise in the debt-to-GDP ratio. Furthermore, the fact that the dynamics of economic growth should be considered implies that its lagged value should be used as a regressor. Therefore, in the present study, the model by Seo and Shin (2016) is chosen as an adequate econometric technique.

The paper contributes to the existing literature on the debt-growth relationship in the following ways. Firstly, it employs the relatively novel DPTR approach, which could improve knowledge about the impact of debt on growth by dealing with the potential endogeneity problem. Secondly, the study estimates the debt threshold and nonlinear impact of debt on growth, focusing on a panel of EU economies, which have not frequently been the focus of empirical research. The robustness of the results is checked by applying the novel method of moments quantile regression (MMQR) proposed by Machado and Santos Silva (2019), as an appropriate technique for dealing with heterogeneity and endogeneity while incorporating both asymmetric and nonlinear links. Thirdly, having in mind the heterogeneity of the EU economies in growth rates and public debt levels, this study makes an analysis of subpanels of EU economies based on the European Monetary Union (EMU) membership and the indebtedness levels. The finding of threshold effects across subpanels is particularly important for defining the policy recommendations regarding proper fiscal governance in the country sub-groups.

The paper is structured as follows. The second section presents a review of the empirical literature on the debt-growth relationship and the debt threshold effect. The third section describes the data and the econometric model. The estimation results and discussion, as well as a robustness check and an analysis of EU subsamples, are presented in the fourth section. Finally, the fifth section concludes with the main findings and policy recommendations.

2. Literature Review

A large body of empirical literature deals with the effects of public debt on economic growth. The main conclusion of the vast majority of such studies is that the debt negatively affects economic growth, in both the short and long run (Fetai *et al.*, 2020; Qureshi and Liaqat, 2020; Onofrei *et al.*, 2022; San and Chin, 2023). Studies that document a consistently positive impact of debt on growth are rare (*e.g.*, Chang and Chiang, 2012).

To be more selective, we will focus on the strand of empirical literature that tends to become the dominant view regarding the relationship between public debt and economic growth. This literature analyses nonlinearities and the presence of threshold effects in the debt-growth nexus. It is a promising field, as the majority of empirical studies support the fact-based stance that the impact of debt can vary significantly depending on whether it surpasses a certain threshold. Specifically, there is growing evidence of an inverted U-shaped relationship, where debt stimulates economic growth at low levels, while it hinders growth at high levels.

In their seminal paper on the threshold effect, Reinhart and Rogoff (2010) examined how public debt affected economic growth in 20 advanced economies from 1946 to 2009. They concluded that economic growth suffers when the debt-to-GDP ratio surpasses 90%. However, Hern-

don *et al.* (2014), among others, criticized Reinhart and Rogoff's findings, arguing that the 90% threshold lacks robustness and does not consistently harm long-term economic growth. They also identified methodological flaws in Reinhart and Rogoff's work and found that the impact of public debt on economic growth varies significantly across countries and time periods. These authors proposed a lower debt threshold of 30% that inhibits economic growth in advanced economies. Similarly, Chudik *et al.* (2013) emphasized the following problems in Reinhart and Rogoff's paper: strong homogeneity assumptions across countries, a lack of adequate treatment of dynamics and feedback effects between debt and GDP, and minimizing the effects of cross-sectional dependence and spillover effects across countries which become even more pronounced during economic crises.

The empirical studies that followed focused on analysing the presence of debt threshold effects by considering the elements that were lacking in Reinhart and Rogoff's paper. Baum *et al.* (2013) investigated the relationship between public debt and economic growth in 12 euro area countries and found that debt has a negative impact on growth only above a threshold of around 67%. Chudik *et al.* (2017) found that in a sample of 19 developed and 21 developing economies in the period 1965–2010, the debt threshold is between 60% and 80%, whereas the debt thresholds for the subsamples of developed and developing countries are around 80% and between 30% and 60%, respectively. Mencinger *et al.* (2014) conducted a study on the influence of public debt on economic growth within the EU spanning from 1980 to 2010. Utilizing a non-dynamic fixed-effect (FE) approach alongside a two-stage GMM model, they revealed that the debt threshold (above which a negative impact of debt on growth occurs) falls between 80 and 94% for the old member states and between 53 and 54% for the new member states. Bhimjee and Leão (2020) used the sovereign debt Laffer curve to investigate the nonlinear linkage between public debt and GDP in euro area economies in the period 1995–2016. They revealed the presence of a threshold effect in the majority of these economies, as well as that some of these countries already overreached their optimal threshold, which leads to a negative effect of debt on output growth. Fetai *et al.* (2020) employed various econometric techniques to examine the nexus between public debt and economic growth in the European transition countries in the period 1995–2017. They identified different threshold values for debt levels in Central Europe (81.60%), Eastern Europe (71.90%) and Western Balkan countries (58.20%). Zaghdoudi (2020) analysed the linkage between external debt and economic growth for middle and low-income countries in the period 2002–2016. He found evidence of a negative effect of external debt on growth when the debt surpasses the threshold level of 15.28%.

Ndoricimpa (2020) found different debt threshold values for 39 African countries in the period 1980–2012. The analysis based on the panel smooth transition regression method provided evidence of a debt threshold in the range of 58–63% for middle-income and resource-intensive

countries and a threshold in the range of 62–66% for the whole sample. Law *et al.* (2021) employed dynamic panel threshold regression using data from 71 developing countries and estimated a debt threshold value of 51.65%. Public debt harms growth if it is above the threshold, but has a statistically insignificant impact if it is below. They also found that higher institutional quality reduces the negative effect of debt on growth. San and Chin (2023) applied quantile regression to panel data for 97 countries in the period 2004–2018 and found that the negative effect of government debt on GDP per capita growth is more pronounced in economies with low growth rates (in lower quantiles), compared to upper and high-income economies. They concluded that policymakers in low-income countries should design proper fiscal policies to mitigate the negative effects of public debt and to provide support for sustainable economic growth. Turan and Iyidogan (2023) used the dynamic panel threshold regression method to investigate the effects of public debt on the growth rate, investment and domestic credit provided to the private sector in 53 developing countries in the period 1980–2019. They found no evidence of a negative impact of debt on the growth rate, as well as of a threshold in the impact of debt on private and total investment. On the other hand, they presented evidence for a threshold of 72.16% of the GDP in the effect of debt on public investment. Musa *et al.* (2024) examined the impact of public debt on economic growth in selected high-income economies, using quality of governance as one of the regressors and the moderating variable. By applying the method of moment quantile regression to panel data in the period 1990–2020, they revealed that debt stimulates economic growth in lower to upper-medium quantiles, but has no significant impact in high quantiles. They concluded that large public debt and restrictive regulation slow down economic growth rates in high-income countries. Similar findings were provided by Musa *et al.* (2022) for developing countries.

Ibañez Martín *et al.* (2024) investigated the presence of a threshold effect between debt and economic growth in 47 developing countries in the period 1970–2019. By employing the dynamic panel threshold regression model, they revealed, *inter alia*, that the critical value for external debt above which there is a negative impact on growth is 67.11%. When they included total debt as the threshold variable, they found no evidence of a threshold effect. Shah *et al.* (2024) estimated the threshold values of public debt in three groups of countries based on income. The analysis using dynamic panel threshold regression revealed differences in debt-to-GDP ratio thresholds for these groups: the estimated thresholds were 50.988%, 50.243% and 62.646% for developing countries, lower-middle-income economies and upper-middle economies, respectively. Beyond these thresholds, public debt negatively affects economic growth.

There are also empirical studies that did not find empirical evidence of a threshold effect in the debt-growth nexus. Qureshi and Liaqat (2020), for instance, employed a panel vector autoregression model to investigate the impact of external debt on economic growth in 123 economies. Although the authors revealed a negative effect of debt on growth across all income cat-

egories of countries, they failed to detect a common threshold effect in this relationship. Similar findings can be found in Turan and Yanikkaya (2021) for a large sample of developing countries.

Against this background, this paper investigates the presence of nonlinearity and estimates a debt threshold in a panel of 27 EU economies. Although a large body of literature has investigated threshold effects in a debt-growth relationship, significantly fewer studies have dealt with the dynamic properties of this linkage, especially for EU countries. The studies that employed econometric methodology which successfully copes with the presence of endogeneity and reverse causality are even fewer. Namely, the empirical studies presented in this section (*e.g.*, Law *et al.*, 2021; Turan and Iyidogan, 2023; Ibañez Martín *et al.*, 2024; Shah *et al.*, 2024) employed dynamic panel threshold regression proposed by Kremer *et al.* (2013). However, as stated by Seo and Shin (2016) and Seo, Kim and Kim (2019), the key assumption in this approach is that either regressors or the transition variable or both are exogenous. Therefore, the present study aims to fill the gap in the empirical literature by employing the DPTR approach developed by Seo and Shin (2016) to provide more valid estimates of the debt threshold in the panel of EU economies, but also in the subpanels, given the heterogeneity of these economies regarding the debt levels and growth rates.

3. Data and Methodology

3.1 Data and descriptive statistics

The present study analyses the impact of public debt on GDP per capita growth (GDP_{pcg}) in a panel of 27 EU economies in the period 2000–2022. Besides the gross domestic product per capita growth (GDP_{pcg}) as a dependent variable and the public debt-to-GDP ratio ($DEBT$) as the regressor, the estimated econometric model includes several control variables, which are explained in Table 1.

The choice of the control variables reflects their possible impact on the dependent variable in the model. Namely, GCF represents gross capital formation, as a measure of total investment in an economy. It increases production capacity and the potential for technological development, thus supporting economic growth. Trade openness (TO) measures how much an economy exchanges goods and services with the rest of the world, which is an important factor of economic growth. Inflation (INF) measures the annual change in the general price level and represents a commonly employed control variable in empirical studies (*e.g.*, Chudik *et al.*, 2013; Fukunaga *et al.*, 2021; Hilscher *et al.*, 2021).

Although population growth is a commonly included control variable in comparative economic studies (*e.g.*, Law *et al.*, 2021; Shah *et al.*, 2024), the present study employs the labour force participation rate (LFP), as it represents the share of labour force (sum of employed and

unemployed persons) in the country's total population. The rationale for this is the fact that *LFP* reflects the percentage of the country's population that could support economic growth, thus being more suitable for the present analysis.

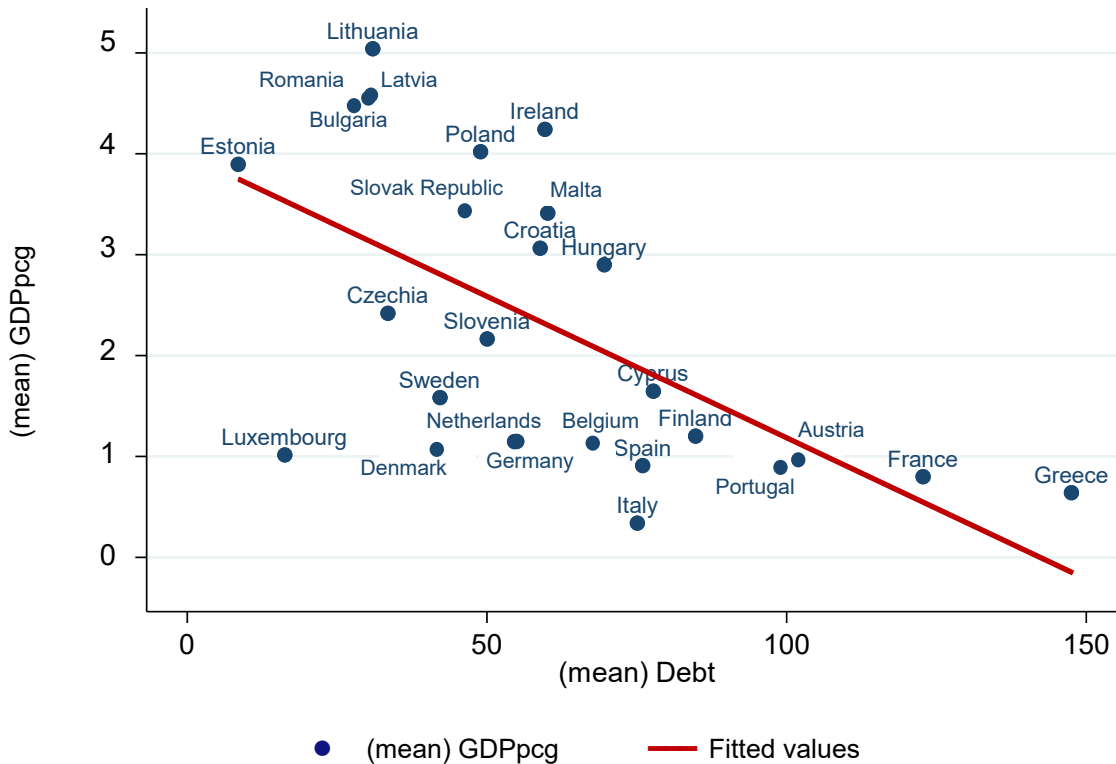
Table 1: Explanation of model variables

Variable	Explanation	Unit of measure	Source
<i>GDP_{pcg}</i>	Annual percentage growth rate of GDP per capita based on constant local currency. GDP per capita is gross domestic product divided by midyear population.	%	WB (2024)
<i>DEBT</i>	Total central government debt, as the entire stock of direct government fixed-term contractual obligations to others outstanding on a particular date.	% of GDP	WB (2024)
<i>GCF</i>	Gross capital formation, consisting of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories.	% of GDP	WB (2024)
<i>TO</i>	Trade openness, as the sum of exports and imports of goods and services measured as a share of gross domestic product.	% of GDP	WB (2024)
<i>INF</i>	Inflation rate (annual), measured by the consumer price index.	%, annual	WB (2024)
<i>INS</i>	Institutional quality; equal-weight aggregation of six aggregate indicators of the governance quality.	Scale from -2.5 to 2.5	Kaufmann and Kraay (2023)
<i>LFP</i>	Labour force participation rate, as the proportion of population aged 15 and older that is economically active.	% of total population	WB (2024)

Source: Author's own elaboration, WB (2024), and Kaufmann and Kraay (2023)

A visual representation of the relationship between average public debt levels and economic per capita growth rates is given by the scatter plot in Figure 1. The fitted values are represented by the straight line, which is negatively sloped, indicating the reverse nexus between debt and growth in EU economies. It is also confirmed by the Spearman rank coefficient value, which is negative and significant, as presented in Table A1. In other words, countries with lower debt levels tend to have higher growth rates, as already reported in the literature (*e.g.*, Ramos-Herrera and Sosvilla-Rivero, 2016). These economies are situated in the north-western part of the diagram. Economies with higher debt levels tend to grow at a slower pace (south-eastern part). There are also several economies with relatively low debt levels and low growth rates, such as Luxembourg, Denmark, Germany, Czechia, Slovenia and Sweden.

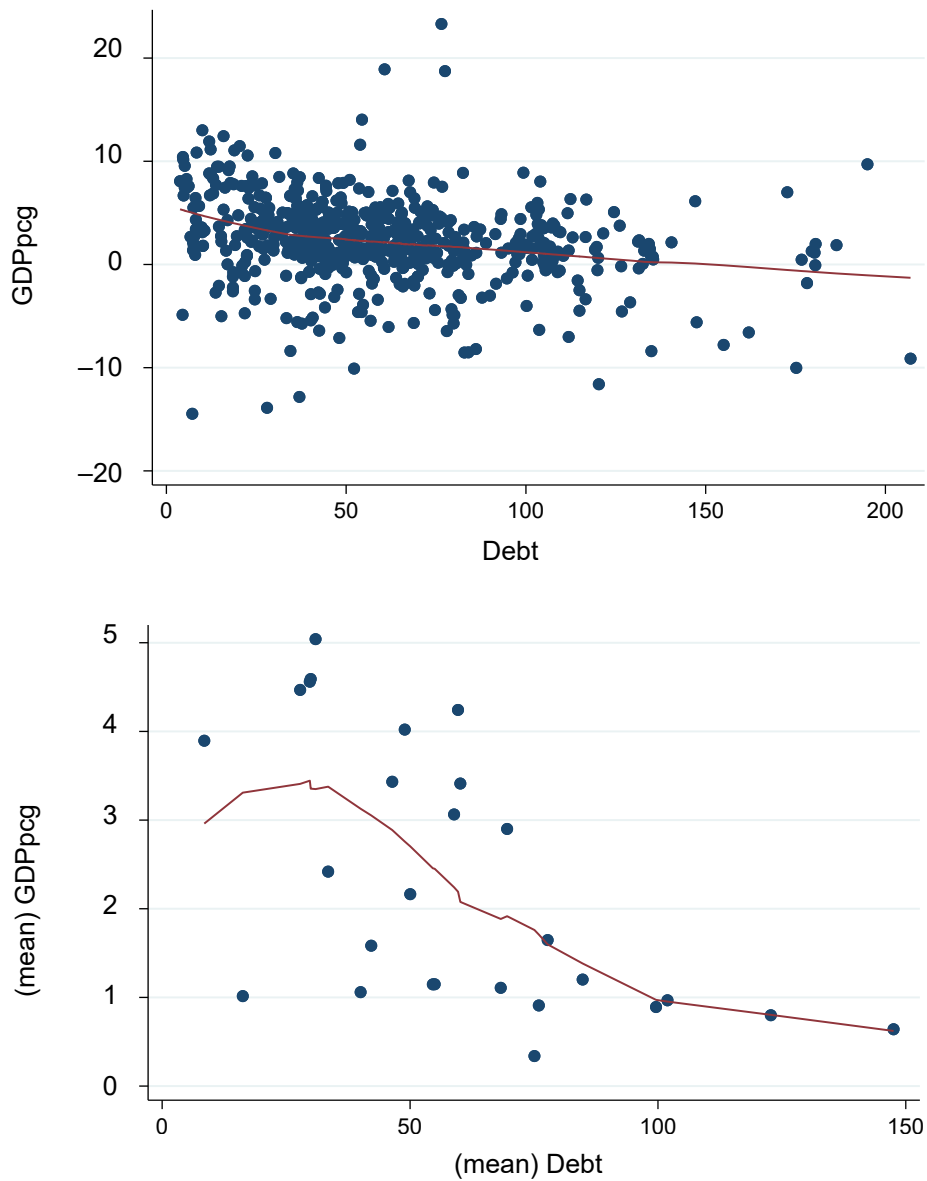
Figure 1: Scatter plot for mean values of *DEBT* and *GDP_{pcg}*



Source: Author's own elaboration

However, although the relationship between debt and growth is most likely negative, one should provide evidence of the potential threshold effect and nonlinearity. Therefore, prior to the econometric model estimation, it is useful to perform a preliminary analysis for the presence of nonlinearity and a threshold effect. This can be done by applying the locally weighted scatterplot smoothing (LOWESS) analysis for the GDP per capita growth rate on public debt (Figure 2). This technique does not make any assumption about the form of the linkage between the variables (Al Shammre *et al.*, 2023). The left-hand part of Figure 2 presents the effect of public debt on economic growth when all observations are presented, whereas the right-hand part includes only mean values of *GDP_{pcg}* and *DEBT* for each cross-section (country), following Law *et al.* (2021). It is apparent that the relationship between debt and growth is nonlinear, with a threshold effect that is particularly pronounced when the mean values are included. Even the sign of the relationship changes before and after the threshold, indicating that the threshold regression technique should be employed.

Figure 2: LOWESS smoothing of $DEBT$ on GDP_{pcg}



Source: Author's own elaboration

The descriptive statistics for the variables included in the model are presented in Table 2. One can conclude that the differences between the maximum and minimum values of the majority of variables are very large. The differences are particularly pronounced in the case of $DEBT$, TO and INF , but also for GDP_{pcg} . It is the result of the heterogeneity in the panel of EU economies, but also the fact that there were two serious economic crises in the observed period, leading to significant deterioration of the indicator values in some years.

Table 2: Descriptive statistics

<i>Variable</i>	Mean	Maximum	Minimum	Standard deviation	Observations
<i>GDP_{pcg}</i>	2.321	23.305	-14.464	4.046	621
<i>DEBT</i>	59.852	207.000	3.800	35.508	621
<i>GCF</i>	23.212	54.775	11.892	4.571	621
<i>TO</i>	121.598	393.141	45.419	64.670	621
<i>INF</i>	2.850	45.667	-4.478	3.691	621
<i>INS</i>	1.025	1.947	-0.162	0.497	621
<i>LFP</i>	57.849	66.620	47.818	4.570	621

Source: Author's own calculations

3.2 Econometric model

This study investigates the impact of public debt on the GDP per capita growth in EU economies, emphasizing the presence of a threshold effect and nonlinearity. To this end, we started with the following panel regression model:

$$GDPpcg_{it} = \alpha_i + \beta_1 DEBT_{it} + \beta_2 GCF_{it} + \beta_3 TO_{it} + \beta_4 INF_{it} + \beta_5 INS_{it} + \beta_6 LFP_{it} + \theta_t + \varepsilon_{it} \quad (1)$$

where GDP_{pcg} represents the GDP per capita growth rate, i denotes the country ($i = 1, \dots, N$), t represents the time ($t = 1, \dots, T$), α_i denotes an unobservable country-specific effect, θ_t is the time-specific effect, X is a vector of control variables (GCF , TO , INF , INS and LFP) and ε is an error term.

To capture the dynamic nature of the economic growth, *i.e.*, the fact that the previous values of the GDP are related to the current ones, the model should include the lagged values of the GDP per capita growth (GDP_{pcg-1}), so we get the following model:

$$GDPpcg_{it} = \alpha_i + \beta_0 GDPpcg_{it-1} + \beta_1 DEBT_{it} + \beta_2 GCF_{it} + \beta_3 TO_{it} + \beta_4 INF_{it} + \beta_5 INS_{it} + \beta_6 LFP_{it} + \theta_t + \varepsilon_{it} \quad (2)$$

In order to investigate the nonlinear (threshold) effects of public debt on economic growth, we implement the novel DPTR approach proposed by Seo and Shin (2016) and Seo, Kim and Kim (2019). This method extends the static panel threshold regression approach of Hansen (1999) and the GMM method of Kremer *et al.* (2013) by allowing endogenous regressors and threshold

variables. In other words, this approach successfully deals with potential endogeneity when there is a variable (*DEBT*, in our study) that acts not only as a threshold variable but also as an explanatory one. Furthermore, this is empirically relevant, since the dependent variable (economic growth per capita) could affect the public debt level (for instance, by changing tax revenue levels which, in turn, could change the government spending in the same direction). The approach by Seo and Shin (2016) is based on the general method of moments (GMM) estimator and it allows specific threshold value in the regressor (debt), thus differentiating between a lower and an upper regime. It can be presented as follows:

$$\begin{aligned}
 GDPpcg_{it} = & (\alpha_i + \beta_0 GDPpcg_{it-1} + \beta_1 DEBT_{it} + \beta_2 GCF_{it} + \beta_3 TO_{it} + \beta_4 INF_{it} + \beta_5 INS_{it} + \\
 & + \beta_6 LEP_{it}) I(DEBT_{it} \leq \gamma) + (\alpha_i + \delta_0 GDPpcg_{it-1} + \delta_1 DEBT_{it} + \delta_2 GCF_{it} + \delta_3 TO_{it} + \\
 & + \delta_4 INF_{it} + \delta_5 INS_{it} + \delta_6 LFP_{it}) + I(DEBT_{it} > \gamma) + \theta_t + \varepsilon_{it}
 \end{aligned} \quad (3)$$

where γ denotes the threshold value that will be estimated, I represents the indicator variable with the value of 1 if the condition in the parentheses is fulfilled and 0 otherwise, whereas β and δ are the coefficients for the lower and upper regime, respectively. The instrument variables include the lagged dependent variable, the exogenous variable and the other covariates. The variables were explained in Table 1 above.

Since this approach ensures that the estimates follow the normal distribution asymptotically, the standard Wald test for threshold existence can be applied. We perform the non-linearity test $supW = supW_n(\gamma)$ statistics for the null hypothesis $\beta - \delta = 0$, where $W_n(\gamma)$ is the standard Wald statistic for each fixed γ .

Considering that the observed period (2000–2022) witnessed two serious global economic crises (the global financial crisis of 2007 and the economic recession due to the COVID-19 pandemic), their impact on economic growth dynamics should also be analysed. Accordingly, we include a dummy variable for the crisis effect (*CRIS*), which takes the value of 1 for the years 2007–2010 and 2020–2022 and the value of 0 otherwise. While the model presented by Equation (3) is denoted as Model 1 in further analysis, the model that includes the crisis dummy as an additional control variable is referred to as Model 2.

To test the robustness of the obtained estimation results, a quantile regression is applied, as it can demonstrate the impact of public debt on economic growth in various quantiles. The lower quantiles consist of economies with lower economic growth rates, whereas the higher quantiles represent economies with higher rates. As shown in Figure 1 and Table A1 in the Appendix, economies with lower public debt levels tend to have higher economic per capita growth rates and *vice versa*, which is validated by the relatively strong and significant negative correlation.

Namely, the value of the Spearman rank correlation coefficient is -0.648 . Therefore, it is expected that economies with higher (lower) growth rates and lower (higher) debt levels will be situated in higher (lower) quantiles, and the impact of the debt on growth could be compared with the DPTR estimates. Since we deal with nonlinearity and a threshold effect, in this study we perform the novel method of moments quantile regression (MMQR) proposed by Machado and Santos Silva (2019). The MMQR has an advantage over other panel quantile regression methods when the model includes endogenous explanatory variables and when individual specific effects define the panel data. It is the most suitable technique for dealing with heterogeneity and endogeneity while incorporating both asymmetric and nonlinear links (Razzaq *et al.*, 2022). The general form of the MMQR method is as follows:

$$Q_y(t | X_{it}) = (a_i(\tau) + \rho_i q(\tau)) + X'_{it}\beta(\tau) + Z'_{it}\lambda(\tau) \quad (4)$$

where $a_i(\tau)$ is the quantile- τ fixed effect for the economies I , or the distributional effect (location effect), $\rho_i(\tau)$ is the scale effect, τ is the quantile, $Q_y(\tau|X_{it})$ represents the quantile of GDP_{peg} as the dependent variable, $X'_{it}\beta$ is the vector of the independent variables – *DEBT*, *GCF*, *TO*, *INF*, *INS* and *LFP*, and Z is the vector of known differentiable transformations of the components of X , with a probability of 1.

4. Results

4.1 Empirical estimates and discussion

Although the potential nonlinearity and threshold effect in the debt-growth nexus are demonstrated in Figure 1, a more formal test for its presence can be performed by investigating the slope homogeneity. If there is a threshold effect, the values of the slope coefficients will differ before and after the threshold. Table 3 reports the results of the Pesaran and Yamagata (2008) slope homogeneity test. The value of the test statistic (δ) is statistically significant and the null hypothesis of slope homogeneity is rejected. Accordingly, the slope coefficients in both models (Model 1 and Model 2) have different values, which supports the assumption of the threshold effect in the impact of debt on economic growth.

Table 3: Slope homogeneity test results

Indicator	Model 1		Model 2	
	Coefficient	Probability	Coefficient	Probability
Δ	2.268	0.023	2.743	0.006
$\tilde{\Delta}$	2.809	0.002	3.396	0.001

Note: Pesaran and Yamagata (2008) test using the *xthst* command in Stata.

Source: Author's own calculations

In order to check the stationarity of the variables, a unit root test was applied. However, prior to stationarity testing, the presence of cross-sectional dependence should be estimated. Table 4 reports the results of the CD test developed by Pesaran (2021). It is apparent that the null hypothesis of no cross-sectional dependence is strongly rejected at the 1% significance level. Therefore, since the variables are cross-sectionally dependent, a second-generation panel unit root test is performed (cross-sectional Im–Pesaran–Shin test – CIPS), (Pesaran, 2007). The lower part of Table 4 presents the test results indicating that all the variables are stationary at first difference. Accordingly, the further statistical inference based on the research methodology in the present study is valid, since it is based on the first-differenced GMM estimates of the DPTR model.

Table 4: Cross-sectional dependence (CD) and stationarity test results

	<i>GDPpcg</i>	<i>DEBT</i>	<i>GCF</i>	<i>TO</i>	<i>INF</i>	<i>INS</i>	<i>LFP</i>
Cross-sectional dependence test statistic	58.327***	40.399***	32.928***	71.147***	69.241***	9.387***	9.488***
CIPS unit root test results							
Level	−3.182***	−2.114*	−1.851	−1.701	−3.211***	−2.259**	−2.082*
First difference	−5.191***	−3.058***	−3.908***	−2.876***	−4.255***	−4.122***	−3.686***

Notes: ***, ** and * denote statistical significance at 10%, 5% and 1%, respectively.

Source: Author's own calculations

The empirical results of the DPTR model (Model 1) are presented in Table 5. The estimated value of the threshold variable (*DEBT*) is 68.7%. The debt as a regressor has a statistically significant positive impact on the dependent variable, which is GDP_{pcg} . More precisely, a 1% increase in public debt leads to a 0.526% increase in economic growth. In contrast, in the upper regime, the impact of public debt on economic growth is negative: a 1% increase in public debt leads to a 1.192% decrease in economic growth. In other words, in the panel of EU countries, government borrowing can support economic growth when public debt is below 68.7% of the GDP. In contrast, higher indebtedness in countries above the threshold leads to lower economic growth rates. Among the control variables, trade openness has a positive impact only in the upper regime, while inflation and institutions have a positive and negative impact on economic growth in the lower and upper regimes, respectively. It could indicate that in highly indebted countries, economic growth coincides with deterioration in the quality of governance and a pronounced negative effect of inflation due to a high level of public debt.

Table 5: Dynamic panel threshold regression estimates (threshold variable: *DEBT*) – Model 1

Variables	Model estimates	
	Lower regime ($y \leq 68.7$)	Upper regime ($y > 68.7$)
<i>GDP_{pcg}-1</i>	-0.704***	0.054
<i>DEBT</i>	0.526**	-1.192***
<i>GCF</i>	0.151	-0.684
<i>TO</i>	0.201	0.447***
<i>INF</i>	1.357*	-3.637***
<i>INS</i>	0.247*	-0.589***
<i>LFP</i>	0.085	0.368
Constant	-	82.767
Threshold estimate (γ)	68.7***	
95% conf. interval	[35.724, 101.603]	
Number of moment conditions	588	588
Observations	621	621
SupWald statistic (p -value)	47.176 (0.000)	

Notes: ***, ** and * denote statistical significance at 10%, 5% and 1%, respectively. The results are estimated using the *xthenreg* command in Stata, as proposed by Seo *et al.* (2019).

Source: Author's own calculations

To test the validity of the estimated threshold value, the results of Model 2 with a crisis dummy are reported in Table 6. The threshold estimate remains unaltered. In addition, the impact of debt on economic growth has the same signs in the lower and upper regimes, even though the negative effect of debt on growth is less pronounced (-0.819) than in Model 1. Trade openness has a positive and significant impact in both regimes, whereas inflation and institutions affect growth negatively in the upper regime. However, the most interesting finding from Model 2 is that crises have no statistically significant impact on economic growth in the lower regime. This indicates that economies with lower public debt levels are more resistant to economic disturbances, most likely due to the wider fiscal space that allows them to respond more effectively in a time of crisis. On the other hand, economies with higher indebtedness faced negative effects of crises. These results underline the importance of keeping the public debt level below the threshold in order to alleviate the negative effects of economic disturbances on economic growth.

These estimation results coincide with several previous empirical studies. For instance, Baum *et al.* (2013) found a negative impact of debt on growth above a threshold of around 67% for 12 euro area countries. Ibañez Martín *et al.* (2024) estimated a debt threshold of 67.11% in 47 developing countries. Ostrihoň *et al.* (2023) found a similar average debt threshold value of about 70% of the GDP for EU-28 economies in the period 1995–2014. Their estimates, similar to our findings from Models 1 and 2, were also characterized by relatively wide confidence intervals, leading these authors to suggest that policymakers differentiate the optimal level of public debt for countries in the EU depending on the threshold level.

In addition, similar results for the effect of control variables on growth can be found in empirical literature: a negative impact of inflation (Equiza-Goñi, 2016; Fukunaga *et al.*, 2021; Hilscher *et al.*, 2021) and a positive impact of gross capital formation and trade openness on growth (Mohsin *et al.*, 2021; Konatar *et al.*, 2022; Kacou *et al.*, 2022). In contrast, although there are studies indicating a negative relationship between governance quality and growth (*e.g.*, Alimi and Dhiab, 2023), empirical studies commonly support a positive impact of institutions of economic growth (Kim *et al.*, 2017; Kemoe and Lartey, 2022; Barra and Ruggiero, 2023), which is not the case in this study. Possible reasons could be the choice of the estimation method and the institutional quality indicator.

Table 6: Dynamic panel threshold regression estimates (threshold variable: *DEBT*) – Model 2

Variables	Model estimates	
	Lower regime ($\gamma \leq 68.7$)	Upper regime ($\gamma > 68.7$)
<i>GDP</i> _{pcg-1}	-0.802***	0.105
<i>DEBT</i>	0.515**	-0.819***
<i>GCF</i>	0.482	0.838
<i>TO</i>	0.175***	0.158**
<i>INF</i>	0.915*	-1.849***
<i>INS</i>	0.157	-0.252**
<i>LFP</i>	0.094	0.165*
Constant	-	45.531
CRIS	2.361	-10.156***
Threshold estimate	68.7**	
95% conf. interval	[10.734, 126.593]	
Number of moment conditions	588	588
Observations	621	621
SupWald statistic (p-value)	47.176 (0.000)	

Notes: ***, ** and * denote statistical significance at 10%, 5% and 1%, respectively.

Source: Author's own calculations

4.2 Robustness analysis

To check the validity of the empirical results obtained, the MMQR method is applied. As stated before, the negative value of the Spearman correlation coefficient between *DEBT* and *GDP*_{pcg} (Table A1 in the Appendix) indicates that EU economies with higher (lower) debt levels tend to have lower (higher) per capita growth rates. Considering the DPTR analysis results, one can expect that

the impact of debt on growth will be less pronounced in higher quantiles, where economies with higher growth rates and lower public debt levels are situated (below the threshold, *i.e.*, in the lower regime). Indeed, as the results presented in Table 7 demonstrate, the negative impact of debt on economic growth is stronger in the lower quantiles and gradually declines towards the higher quantiles, which is also apparent from the quantile regression plot presented in Figure 3. This could be taken as a validation of the estimated results of Model 1 and Model 2 since the negative impact of debt on economic growth is more pronounced in the upper regime (which corresponds to the lower quantiles). This finding coincides, among others, with that of San and Chin (2023), who stated that the negative effect of government debt on GDP per capita growth is more pronounced in economies with low growth rates.

Table 7: Method of moments quantile regression (MMQR) estimates

Variable	Location	Scale	q10	q25	q50	q75	q90
<i>DEBT</i>	−0.014***	0.001	−0.021**	−0.016**	−0.013**	−0.009*	−0.007
<i>GCF</i>	0.269***	0.007	0.258***	0.265***	0.269***	0.275***	0.279***
<i>TO</i>	0.006**	0.005**	−0.002	0.003	0.006**	0.009***	0.013***
<i>INF</i>	−0.178***	0.039	−0.243**	−0.204**	−0.173***	−0.145**	−0.122
<i>INS</i>	−0.018***	−0.011***	0.001	−0.011**	−0.019***	−0.027***	−0.033***
<i>LFP</i>	−0.021	0.058*	−0.115	−0.058	−0.013	0.029	0.063
<i>CRIS</i>	−2.234***	2.071***	−5.379***	−3.961***	−2.237***	−0.501	0.855
Constant	−0.149	−0.881	1.295	0.418	−0.258	−0.887	−1.408
Observations	621	621	621	621	621	621	621

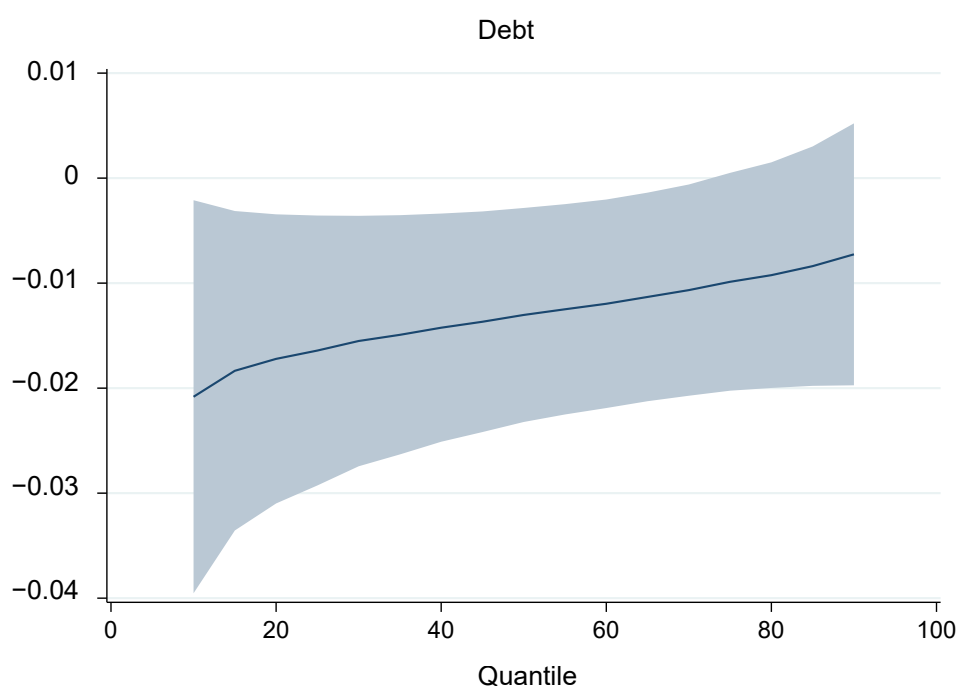
Note: ***, ** and * denote statistical significance at 10%, 5% and 1%, respectively.

Source: Author's own calculations

As regards the control variables, the impact of GCF on growth is positive and significant in all the quantiles, which was not the case in the DPTR model. The importance of trade openness in supporting growth increases towards the higher quantiles, which is aligned with the findings from Model 1. The effect of inflation on growth is also confirmed as it is stronger in the lower quantiles. Yet, the impact of institutional quality on economic growth is not validated through the quantile regression. Namely, in the higher quantiles, institutional quality has a more pronounced negative effect on growth, which is in contrast with the results of Models 1 and 2. This re-

sult corroborates the findings of Alimi and Dhiab (2023), which showed that improvement in governance quality negatively affects economic growth in developing economies, mainly supporting the views provided earlier by Andrews (2013). Finally, the effect of crises on economic growth from the DPTR model is confirmed. As reported in Table 6, the crises negatively affect growth in the upper regime, which corresponds with the results of the quantile regression: in the lower quantiles, the negative impact of crises is much stronger than in the higher ones. Furthermore, in the last two quantiles included (q75 and q90), the impact of crises is not significant. These results validate that the DPTR estimates are robust.

Figure 3: Quantile regression plot for impact of $DEBT$ on GDP_{pcg}



Source: Author's own elaboration

4.3 Analysis of subsamples

Bearing in mind the heterogeneity between EU economies, as well as the wide confidence intervals in Models 1 and 2, there is a necessity for investigating debt thresholds in subsamples (subpanels) of EU countries. We estimated debt threshold levels for two subsamples. The first one is based on the European Monetary Union (EMU) membership. As suggested by Belke *et al.* (2017), we divided the whole sample into three panels: core EMU countries, non-core EMU countries and non-EMU countries (Table A1). On the other hand, following Reinhart and Rogoff (2010) and

Shah *et al.* (2024), we took into account the average debt levels. We divided the whole sample into four panels, consisting of countries with a low public debt ratio ($\leq 30\%$ of GDP), a medium-low public debt ratio (30–60% of GDP), a medium-high public debt ratio (60–90% of GDP) and a high public debt ratio (above 90% of GDP) (Table A2). The estimation results are reported in Table 8. We focus on the debt threshold levels and the debt coefficients, which measure the impact of debt on economic growth below the debt threshold (lower regime) and above the debt threshold (upper regime).

As expected, the estimation results suggest the presence of different debt threshold values across the subpanels. The highest debt thresholds are in the panel of economies with a high public debt ratio (104.3%) and in the panel of non-core EMU countries (72.5%). However, the analysis based on the subsamples does not support an inverted U-shape relationship between public debt and economic growth, as the debt in almost all the cases negatively affects growth in both the lower and upper regimes. The exception is the panel of non-EMU economies, for which the results indicate a positive impact of debt on growth below the relatively low threshold of 12.4%. This could be explained by the fact that these economies, albeit not directly obliged to follow the directions of the Stability and Growth Pact (SGP), actually have relatively low public debt levels (41.7% on average) while growing relatively fast (average growth rate of about 3% in the observed period). Even though the inverted U-shape linkage is not confirmed, the debt-growth nexus is still nonlinear, *i.e.*, there is a debt threshold effect in the subpanels.

The most pronounced negative impact of debt on growth is present in the group of economies with a medium-high public debt ratio (60–90%) above the debt threshold of 53.3%. Namely, a 1% increase in public debt leads to a 0.155% decrease in the economic growth rate. Below the threshold, this impact is much less pronounced, which is also the case for all the other panels. The average debt level in the core EMU panel is 81.2%, yet more negative effects of debt on growth are present above the threshold of 58.2%, which roughly corresponds to the limit defined by the SGP. This indicates that the core EMU countries should reduce their debt levels, as a 1% decrease in debt when above the threshold leads to a 0.129% increase in growth. Similarly, non-core EMU economies with public debt above the 72.5% debt threshold (Cyprus, Greece, Italy, Portugal and Spain) should strive to reduce debt levels, as a 1% decrease in debt leads to a 0.101% increase in the growth rate.

Table 8: Estimation results for subsamples of EU economies

Country sub-panels (EMU membership)	Observations	Debt threshold value [confidence interval]	Lower regime	Upper regime
Core EMU	138	58.2*** [57.0, 59.0]	-0.089***	-0.129***
Non-core EMU	322	72.5*** [68.1, 73.7]	-0.045**	-0.101***
Non-EMU	161	12.4* [11.9, 13.0]	0.464***	0.025
Country sub-panels (average debt level)		Debt threshold value [confidence interval]	Lower regime	Upper regime
≤30%	115	41.8 [41.6, 42.4]	-0.037	-0.116**
30–60%	253	58.8** [57.4, 60.6]	-0.066***	-0.126***
60–90%	161	53.3* [51.9, 54.0]	-0.059**	-0.155***
>90%	92	104.3* [103.9, 104.8]	-0.031	-0.054*

Notes: GDP_{pcg} is the dependent variable; ***, ** and * denote statistical significance at 10%, 5% and 1%, respectively.

Source: Author's own calculations

Overall, the results indicate heterogeneity of the debt threshold levels across the EU economies, while supporting the policy recommendation about debt reduction in order to be more sustainable. This is in line with the conclusion of Martin *et al.* (2021), who stated that the European fiscal framework should mainly be concerned with debt sustainability, whereas the appropriate fiscal trajectory is fundamentally heterogeneous among member countries. In addition, as stated by Heimberger (2023), one should be cautious when prescribing “one-size-fits-all” fiscal policy in dealing with higher public debt levels.

5. Conclusions

The empirical analysis in this study provides evidence for an inverted U-shape relationship between public debt and economic growth in a panel of EU-27 economies. Public debt supports growth if below the estimated debt threshold of 68.7% of the GDP. In other words, moderate levels of public debt can be beneficial if used to finance activities that can boost long-term economic growth, such as productive investments in infrastructure, education and technology. In contrast, once the debt reaches the threshold, the costs associated with the high debt levels start to outweigh the benefits, most likely due to higher borrowing costs, which reduce the capacity for growth and innovation, and the unavoidable austerity measures.

Given the heterogeneity of the EU economies in terms of growth rates and public debt levels, an analysis of subsamples was also performed. The findings indicate different debt threshold values for country groups based on EMU membership and indebtedness level. The highest debt thresholds were estimated for economies with a high public debt ratio (104.3% of the GDP) – Greece, Portugal, France and Austria, and for countries that do not belong to the core EMU economies (72.5%). The lowest debt threshold was estimated for non-EMU economies: 12.4%, below which a positive effect of public debt on growth is estimated. Since the debt levels negatively affect the growth rates in all the country groups except the non-EMU countries, the inverted U-shape debt-growth relationship is not confirmed for country sub-samples. This indicates that the governments in all the country groups should strive to reduce their public debt to sustainable levels by implementing adequate fiscal governance measures.

Overall, managing public debt effectively is crucial for fostering economic resilience and sustainable growth within the EU. While borrowing can be beneficial for financing growth-enhancing investments, EU economies must avoid excessive debt accumulation that could trigger a debt overhang, thereby stifling long-term economic growth. Effective fiscal governance should involve implementation of policies and frameworks that promote responsible fiscal management, transparency and accountability, such as further implementation of fiscal rules and frameworks such as the Stability and Growth Pact; debt management strategies, which should be transparent and prudent to enhance investor confidence and reduce borrowing costs; structural reforms (of labour markets, pension systems and public administration), which can enhance efficiency, increase productivity and expand the tax base; fiscal governance based on a strong institutional framework, which includes fiscal councils; and effective coordination between fiscal and monetary policies, which is particularly important in the EU given the shared monetary policy under the European Central Bank and the diverse fiscal policies of member states. Implementing all the aforesaid could ensure managing public debt prudently, with debt levels remaining within a range that supports economic stability and growth of EU economies, rather than becoming a drag on future prosperity.

However, the present study has some limitations that should be acknowledged. Although panel analysis has its advantages, it cannot provide debt threshold estimates for each country, which is particularly important in designing specific fiscal policy measures. In addition, the observed period covers the years of the pandemic crisis, with uncommon effects on debt and growth dynamics. Although a crisis dummy is used to capture these effects, one should be aware that this event can affect the debt threshold estimates. Furthermore, as the present study and the analysis of empirical literature showed, a uniform public debt-to-GDP threshold beyond which growth slows cannot be identified, as the threshold estimates are sensitive to the selected time span and econometric methodology.

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Appendixes

Table A1: List of EU countries and country groups based on EMU membership

Country group	Country	Average debt (2000–2022)	Average GDP per capita growth rate
Core EMU economies	Austria	101.926	0.968
	Belgium	68.296	1.108
	Finland	84.817	1.201
	France	122.774	0.799
	Germany	54.970	1.149
	Netherlands	54.600	1.147
	Group average	81.231	1.062
Non-core EMU economies	Croatia	58.883	3.064
	Cyprus	77.761	1.647
	Estonia	8.496	3.895
	Greece	147.526	0.641
	Ireland	59.674	4.242
	Italy	75.091	0.339
	Latvia	29.965	4.590
	Lithuania	30.948	5.041
	Luxembourg	16.270	1.015
	Malta	60.143	3.412
	Portugal	99.617	0.892
	Slovakia	46.409	3.432
	Slovenia	50.039	2.165
	Spain	75.978	0.910
	Group average	59.771	2.521
Non-EMU economies	Bulgaria	27.835	4.468
	Czechia	33.478	2.419
	Denmark	40.030	1.059
	Hungary	69.578	2.900
	Poland	48.930	4.021
	Romania	29.787	4.561
	Sweden	42.170	1.583
	Group average	41.687	3.001
Spearman's rho rank correlation coefficient		−0.648***	

Source: Authors' own calculations, based on the WB (2024)

Table A2: EU economies' subsamples based on level of indebtedness

Average public debt (% of GDP)	Countries
≤30%	Bulgaria, Estonia, Latvia, Luxembourg, Romania
30–60%	Croatia, Ireland, Lithuania, Slovakia, Slovenia, Germany, Netherlands, Czechia, Denmark, Poland, Sweden
60–90%	Belgium, Cyprus, Finland, Hungary, Italy, Malta, Spain
>90%	Austria, France, Greece, Portugal

Source: Authors' own calculations

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